U.S. Department of Transportation

Air Quality Impacts of Intercity Freight

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Volume I: Guidebook

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Notice

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Preface

The efficient movement of goods between and within cities and metropolitan areas has major implications for not only for the economy, but on the use and performance of the transportation system. Traffic congestion and air quality are two important impacts that result from this activity. And while "intercity freight" is most often thought of in terms of long-distance shipments by rail, large combination trucks, barge, and to an increasing extent, air cargo, the activities that occur at the ends of the trip may actually be the source of some of the major impacts. To accomplish the connection between shipper and mode, or between modes and terminals, considerable activity must occur within the local transportation system, often on crowded highways and during prime travel hours. The constraints posed by inefficient intermodal connections, operation and management of intermodal facilities, barriers and bottlenecks in the highway network, help contribute to the congestion and freight/passenger vehicle conflicts that result.

States and metropolitan planning organizations traditionally have not directed active planning or project efforts at the freight sector. This is due to both a limited understanding of freight transportation characteristics and issues, and the presumption that the key decisions for freight rest in the private sector. However, the importance of freight transportation to economic development, emphasis on freight and intermodal transportation under ISTEA, and concerns about traffic congestion and troublesome air pollution problems, have greatly raised the level of interest in freight transportation. Also, there is growing acceptance and awareness that actions which address congestion and air quality problems may also address issues of service efficiency and cost to the transportation industry and shippers as well.

In response to these concerns, this report has been developed to provide assistance to planners and decision makers -- public and private -- to improve the understanding of freight transportation, economic and air quality relationships, and to provide some helpful tools for identifying and testing improvement strategies. The focus of the report is on truck and rail/intermodal transportation, and it offers guidance and procedures in assessing the impacts of shifts in the industry and overall traffic levels, capacity enhancements, changes in operational or management practices, policy or pricing initiatives, or changes in vehicle technologies or fuels. To underscore its importance and need, this study and report have been sponsored jointly by the Federal Highway and Federal Rail Administrations of the U.S. Department of Transportation and the U.S. Environmental Protection Agency.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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1.0 Introduction

1.1 Purpose and Use of Report

The movement of goods within, between and through metropolitan areas or intercity corridors has important implications for transportation system performance and air quality. Often recognized by its modes of conveyance, freight transportation includes trucks, railroads, waterway and ocean-going vessels, and to an increasing extent air cargo. Petroleum pipelines are also considered to be a component of the surface freight transportation system. It is a highly complex and interconnected system, with many specialized elements, industry segments and modes that compete but must also cooperate in order to function. The form of the freight service varies with the characteristics and needs of the respective market, and hence, a different family of modes and services exists in long distance, or "intercity", vs. local environments. For the purposes of this study, the focus has been restricted to intercity rail and truck in those circumstances and configurations where the two modes can or do compete for similar commodity traffic.

An important set of concerns accompany the intercity freight market. Technically, "intercity freight" characterizes shipments which have one or more of the trip ends "outside" the given geographic region. If the region is a metropolitan area, this means that local transportation system or policy actions do not entirely determine the nature of the travel activity, since there are important factors outside the area which determine the volume of this traffic, its mode, and key aspects of its operation. Metropolitan areas which are "freight centers", either because of heavy industrial activity or because they serve as a strategic port or hub in the nation's transportation infrastructure, find that freight activity has a major effect on traffic conditions, congestion levels, and system capacity or maintenance needs, as well as air quality. Intercity freight shipments often require transfer from mode to mode, or terminal to terminal, *within* a metropolitan area. This intermediate handling can give rise to intense transportation activity within respective metropolitan area portions. Moreover, since port and terminal facilities are often located in the oldest, most densely developed, and congested portions of a metropolitan area, traffic congestion and air quality impacts are intensified in these areas.

The major types of concerns that arise with respect to intercity freight include:

- Competing demand for highway capacity, particularly during prime/peak travel hours, between truck and private automobile/commercial users, resulting in congestion, reduced mobility, and higher accident rates.
- Contribution to emissions inventories in air quality nonattainment areas: In particular, since most intercity freight is moved in vehicles which are diesel-powered, these modes become important sources of nitrogen oxides (NOx), sulfur dioxide (SO_2) and particulate matter. Of particular concern is the pending change in the NAAQS

standard for particulate matter, from PM-10 to PM-2.5. The smaller, 2.5-micron particulate standard emphasizes fine particulates, which are also formed from a secondary reaction of NOx and SO_2 emissions in the atmosphere.

- Special demands raised by heavy truck movements on infrastructure needs and wear rates, and associated questions about safety and noise impacts, contributions to congestion, and issues about equitable cost sharing.
- Freight activity undeniably has an impact on the flow of other traffic, and hence the level of emissions that this non-freight traffic generates. These "secondary emissions" are the additional emissions that result from congestion, erratic flow, or elongated trip paths induced by conflicts between freight and other transportation users on the highway and at rail/highway at-grade crossings.

Identifying alternatives or solutions to these types of problems or concerns is impeded by a lack of understanding of the operation and character of the freight sector and a shortage of analytic tools, data, and guidance to identify and assess potential solutions. Forecasting truck activity, and its response to investment or policy actions, is one of the weakest elements in most regional transportation planning processes, and when the focus is shifted to *intercity freight*, these difficulties only increase.

This report is the product of a study that has examined the operation and characteristics of the intercity freight transportation sector in some detail. The objectives have been to:

- **Emissions:** Identify those aspects of the intercity freight industry that represent opportunities for improving efficiency and lowering emissions.
- **Strategies:** Identifying promising and realistic strategies for affecting those characteristics that generate high emissions which also represent attractive economic opportunities to the freight industry and shippers.
- **Tools:** Develop practical analytic tools and guidance to help state and local transportation and environmental agencies identify, screen and evaluate these options in ways that illustrate their air quality and other benefits and costs.

Following these objectives, this report is intended to be a resource to planners and decisionmakers who are addressing freight-related policy or planning issues which have air quality as a direct or indirect concern. Examples of situations where the report and its guidance would be relevant include:

- **Emissions:** Development of State Implementation Plan (SIP) updates, to either maintain NAAQS standards, or to identify measures to meet new standards, particularly in relation to NOx or PM-2.5.
- **Conformity:** Determining whether an action would aid or detract from achieving conformity of a region's long-range plan and its short-range Transportation Improvement Program (TIP) with the SIP.
- **Freight Enhancements:** To enhance the efficiency and competitiveness of a region's freight system, while also gaining emissions benefits.

- **Public-Private Cooperation:** To enumerate an array of infrastructure, technological, institutional or economic options with sufficient detail on their benefits and costs to enable meaningful dialogue and negotiation between industry and public sector toward mutually satisfactory solutions.

The report provides its guidance at two levels:

- **Education:** It provides an overview of the structure and operation of the intercity freight industry, with sufficient detail on the different sectors, market and service characteristics, and technological factors relating to emissions to provide a foundation for the planner/analyst to correctly identify freight problems and solutions.
- **Analysis:** It provides a step-by-step methodology for assessing freight problems, selecting strategies, and performing an evaluation of their transportation and air quality impacts.

This methodology is presented in the form of worksheets, tables and instructions, accompanied by test applications of the methodology on some real-life case study problems. Major Summaries and Reviews on other key freight and emissions studies, modeling tools and data sources are provided in a separate appendix volume.

1.2 Background

This study has been sponsored by three Federal agencies, reflecting an important collaboration of interests in seeing a need for the type of information and technical aids which are found in this report. They include:

- The **Federal Railroad Administration** of the US Department of Transportation (US DOT), which has a keen interest in identifying opportunities for effective use of rail, and particularly rail intermodal service in appropriate markets, where it can achieve economic efficiency with emissions savings.
- The **Federal Highway Administration** of the US DOT, which sees benefits in congestion relief, intermodalism, and emissions reductions through the improved management of intercity freight.
- The **US Environmental Protection Agency**, which has an interest in the emissions related to freight sources, and in attainment of National Ambient Air Quality Standards.

In order to meet these three sets of objectives, all three sponsors are agreed in the need for improved guidance and analysis tools for identifying and spurring the implementation of solutions in this market sector whose importance has frequently been overlooked.

An extensive research project has preceded the development of this report and its methodology, the stated objective of which has been to ***strengthen the linkage between transportation economics and air quality, and to identify ways to improve intermodal connections that contribute to improved transportation efficiency and environmental*** *quality.* The study's methodology was expected to provide users with the following capabilities:

1. To be able to identify the emissions produced by trucks and rail-intermodal service when engaged in intercity freight service in nonattainment areas.
2. To be able to evaluate the environmental and economic implications of potential emission reduction strategies.
3. To be able to identify and advance promising, innovative strategies in cooperation with the freight industry.

The research effort was designed to draw upon and make maximum use of existing analytic tools and data, rather than to develop an entirely new set of analytic tools with separate data requirements. The goal was to furnish a "toolbox" of practical procedures and information to planners and others involved with intercity freight issues to increase their capability and comfort level in dealing with this topic. The two primary research methods therefore were (1) an extensive research review and synthesis, and (2) an empirical element involving the use of an expert advisory panel and a set of case studies.

The work scope for the project included the following tasks:

Task 1: Literature Review: A comprehensive literature review was performed which identified, reviewed and evaluated an extensive array of freight planning and emissions studies, both domestic and international, for insights as to models, data, approaches, strategies, and findings.

Task 2: Review Air Quality Issues: Freight-related issues, travel and emissions impacts, improvement strategies, and analytic needs and capabilities were primarily assessed through the identification of a set of "case study" sites. Three sites were chosen based on important freight functions and challenges in meeting National Ambient Air Quality Standards.

Task 3: Identify Strategies and Develop Procedure to Analyze Impacts: Based on the findings of Tasks 1 and 2, the study developed a procedure for identifying appropriate freight strategies and evaluating their travel and emissions impacts. The procedure was developed in conjunction with the case study sites, and tested on some illustrative, typical examples.

Task 4: Implementation Guidelines: To accompany the methodology, the study was to develop guidelines and criteria for selecting projects and moving them toward implementation, including identification of implementation impediments and examples of successfully implemented strategies.

Task 5: Final Report: A final product was desired that both summarized the key findings of the research, as well as serving as a help document (in effect, a workbook or guidance manual) to allow users to become familiar with important intercity freight issues and also to provide them with analytical capability to identify, assess and initiate the implementation of effective strategies.

1.3 Advisory Panel

To add insight and credibility to the research effort, a panel of planning and freight industry professionals was assembled. This group of 12 individuals represented railroads, trucking companies, state Departments of Transportation, air quality agencies, and several Metropolitan Planning Organizations (MPOs). The group has served as a review body for the products of the research effort. It was convened early in the project to articulate issues pertaining to freight operations and air quality, industry practices and problems, legal and regulatory requirements, impediments to intermodalism, competition aspects, public-private dialogue and collaboration, and planning and data needs and requirements. Specific deficiencies and problems related to freight were identified, and strategies suggested which offered potential for improvement. Key issues raised and recommendations derived from this meeting are presented in Chapter 2.

1.4 Content and Organization of the Report

The report is structured in the following manner:

Chapter 2: Overview of Freight Issues and Analysis Needs

This chapter presents a general overview and introduction to freight transportation to those who are unfamiliar with some of the operating characteristics or terminology. Information contained in this overview include discussions of:

- The different freight markets, modes and services.
- The nature of freight intermodal service, and impediments to greater efficiency and use.
- The nature of freight transportation demand, industry structure and service levels as being heavily driven by the marketplace and the needs of shippers.
- Freight system problems and deficiencies, and strategies which have been used or suggested for their resolution.
- Emissions characteristics of freight transportation modes, and factors that contribute to emissions rates.
- Regulatory requirements imposed by states or on states and MPOs to meet emissions and air quality standards, and freight concerns in relation to those requirements.
- The needs of planning organizations for tools and guidance to be able to respond to either planning or regulatory issues and procedures.

Chapter 3: Synthesis of Findings from Literature Review

This chapter presents a summary of key studies, models and databases that were identified in the research review of prior or ongoing work in relation to freight planning or emissions. It includes:

- An overview of freight forecasting models and a description and comparison of some of the most important models.
- An introduction to and review of the data sources available for use in the analysis of freight.
- A discussion of the major factors that influence emissions rates, and the development of emissions factors for intercity freight.
- Overview of studies which have attempted to model or analyze freight emissions.
- A discussion of the methods currently used for computation of freight emissions and their deficiencies in relation to identified needs

Chapter 4: Analysis Methodology:

This is perhaps the most important chapter in the report. It introduces a methodology which has been developed for the analysis of intercity freight travel and emissions impacts, under current conditions in response to various strategies, actions or even external events. The Chapter is divided into the following information groups:

- It presents a framework for envisioning freight transportation activity, through a hierarchy of events beginning with overall *freight demand* (commodity volume and direction), *modal distribution* (including line-haul intercity and intermodal transfer and drayage), and then the *trip-specific parameters* of route, time of day, VMT, load, speed, etc. which directly determine emissions rates. This hierarchy is used as a mechanism to show where various types of strategies, actions or events would have impact, as a guide in where to direct the analysis.
- It provides a linkage between freight-related problems or deficiencies and groups of strategies, along with a guide for assessing which strategies are most appropriate for which problems, and where to direct the emphasis in analysis.
- Finally, it unveils a methodology that is able to facilitate analysis of a wide range of possible actions. This step-wise procedure is introduced first in summary, and then in complete detail. Worksheet forms have been designed to direct this analysis, and numerous look-up tables and calculating routines are offered to help the user through an often-complex analysis. Special procedures are provided for aligning analysis techniques with particular steps in the analysis, based on the needs of the given strategy, the requirements of the analysis itself, and of course, local capabilities.

Chapter 5: Case Study Applications and Strategy Assessments

This Chapter describes the case study element of the project. It introduces the three sites which were selected as case study examples, and provides a profile of their freight, transportation, and emissions conditions. It then describes the application of the study methodology to the analysis of a number of typical problems in different settings, and strategies applied as possible solutions. Sensitivity tests indicate how emissions are affected by changes in key variables, either outside or inside the "system".

Appendix A: Supplemental Resources and References

This Appendix is a significant resource and reference guide for those users who desire more information on models or the relationships behind the models. It presents additional documentation of many of the key studies, and also a bibliography to aid in searching out additional information.

Appendix B: Detailed Case Study Profiles

This Appendix presents detailed summaries of conditions at each of the three case study sites. It covers, for each site:

- The principal features and characteristics of the freight system.
- The area's air quality attainment status and progress toward attainment of standards.
- An attempt to estimate the contribution of intercity freight modes to the regional emissions inventory.
- Major current or future deficiencies or problems in the freight system, and plans or programs to address them.
- A review of the analytic capability of the site, compared with the needs being faced in responding to planning or regulatory requirements.

Appendix C: Advisory Panel

This Appendix provides a summary of ideas and needs supplied by members of the Advisory Panel at its June 1995 meeting, which had a major impact on the design of the project approach.

2.0 Overview of Intercity Freight Transportation System Characteristics, Issues and Analysis Needs

2.1 Introduction

This chapter provides an overview of characteristics, concerns and issues related to intercity freight, such as may be important to states, MPOs, air quality agencies, or even the freight industry. It is intended to serve as a basic introduction to planners or analysts who are relatively new to or unfamiliar with freight transportation and related emissions issues. For those who are experienced, it serves as a basis for establishing common terminology and assumptions in conjunction with the methods which are introduced later in Chapter 4. It also serves as an outline for the types of issues, strategies, and planning requirements that have been the focus of the research and the resulting methodology.

A number of sources have been used in compiling this information. In addition to findings from the research reviews and the experience of the study team in the subject area, issues, problems, improvement strategies and analytic needs have been derived from the inputs of the Project Advisory Panel and from the three case study examples.

Chapter 2 provides overview discussion of the following topics:

- Issues that face transportation and planning agencies in relation to intercity freight.
- Factors which affect freight transportation performance or problems.
- Strategies or actions to manage or improve freight operations and emissions.
- Analytic capabilities and needs of agencies in addressing freight issues.

2.2 Issues Related to Intercity Freight

While its involvement in and impact on the overall transportation system is generally quite evident, intercity freight transportation activity is typically not accorded the same level of attention or focus by public transportation or planning agencies as passenger transportation . This secondary priority may be due to the following factors:

- Relationships that are not well understood by many transportation planners, in comparison to passenger transportation.
- Absence of responsive analytic tools and data to address key issues or actions.
- A general sense of decision-making authority that rests in the private/business sector and which is not readily influenced by public actions.

These limitations notwithstanding, intercity freight operations raise important issues and concerns to planners and decisionmakers, as described in the following sections.

2.2.1. Transportation System Performance and Efficiency

No one questions the importance of efficient goods movement as a mainstay of our economy and standard of living, yet at the same time it is clear that freight activity and passenger and commercial activity place different and often competing demands on our transportation systems. Trucks on the highway system consume more space and capacity per vehicle than their light-duty vehicle counterparts, require more time to accelerate or decelerate in traffic, and also require different geometric allowances for turns and clearances. Local trucks, whether they be involved in local delivery or in intermodal transfer, tend to be in greatest number during the main business hours of the day, which happens to coincide with commuter and other passenger and commercial peak travel movements. Large combination trucks, such as are used in region-to-region goods movement, vie with mixed traffic on expressways or arterials, at most any time of day, contributing to congestion and frequently also to higher accident rates, as the two very different scales of transportation vehicles attempt to share crowded facilities. Heavy trucks also contribute to higher rates of pavement and bridge wear, accelerating the need for repair, replacement or expansion.

Federal, state and local officials are increasingly recognizing these concerns and taking active steps to treat them. The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) linked Federal transportation funding to a set of new requirements designed to exact the most efficient near and long-term utilization from transportation system investments. Treating the transportation system as a multimodal framework, ISTEA directed the initiation of Management Systems to develop tracking and decisionmaking capabilities at the state and metropolitan levels to better manage these system components. Two management system elements specifically caused greater attention to freight issues:

- **Congestion Management System (CMS):** States were directed to develop a systematic process for obtaining information on transportation system performance and alternative strategies to alleviate congestion and enhance the mobility of people and goods. The CMS was to include methods to monitor and evaluate performance, identify alternative actions, assess and implement cost-effective actions, and evaluate the effectiveness of those actions.

- **Intermodal Management System (IMS):** States were directed to develop a systematic process for identifying key linkages between one or more modes of transportation, both passenger and freight, where the performance of one mode will affect the performance of the other, and define, evaluate, implement and monitor strategies for improving the effectiveness of these modal interactions.

These two planning requirements clearly raised overall interest in freight and intermodal transportation activity, impacts, and identification of improvement strategies among state and regional planning agencies. While compliance with the formal requirement for all of the ISTEA Management Systems except the CMS was reduced to a voluntary level by an act of Congress in the Fall of 1995, many states and MPOs have continued their efforts with the management systems, recognizing the importance of managing these elements.

In this light, it becomes evident that there are disconnects and inefficiencies in the transportation system with regard to goods movement, and particularly intercity goods movement. Intermodal terminals are sometimes difficult to access and use, based on their design or location Ports are often physically separated from rail terminals, and two railroads exchanging intermodal trailers or containers may not be physically connected. Each of these conditions leads to inter-terminal transfer by truck, frequently in the most concentrated and congested portion of the regional transportation system. Physical constraints in the highway system, plus concentration of these intermodal movements into the peak time periods, cause a mixing of these traffic streams and difficult planning and management issues for public agencies. These are critical planning and design issues that force an active role in freight planning and public-private sector dialogue and cooperation.

In addition to the ISTEA management systems' influence on freight planning priorities, the statewide and MPO planning process requirements introduced by ISTEA, and the National Highway System (NHS) Connectors, have also been important stimuli in raising the level of attention now devoted to freight transportation issues.

2.2.2. Air Quality

The Clean Air Act Amendments of 1990 (CAAA) require states to submit revisions to their State Implementation Plans (SIPs) detailing the strategies they will employ to bring their air quality into compliance with National Ambient Air Quality Standards (NAAQS) established by the EPA. Separate standards for Ozone, Carbon Monoxide (CO), and Particulate Matter (PM) showed a large number of metropolitan areas and regions in non-compliance in 1990, requiring the respective jurisdictions to take action and identify measures that would reduce emissions and improve air quality. An important aspect of these 1990 Amendments was a formal connection to the provisions of ISTEA, requiring transportation actions to be consistent with the objective of reduced emissions. Specifically, the "Conformity" provision within the CAAA requires that annual Transportation Improvement Programs (an area's list of projects programmed for funding and implementation, or a TIP) would conform to the NAAQS attainment schedule set forth in the SIP. That is, MPOs and states were required to formally demonstrate that their transportation programs would not lead to emissions levels that would cause a departure from the attainment schedule.

Required submissions under the 1990 CAAA included: a 1990 base year emissions inventory; a 15% volatile organic compounds (VOC) reduction plan, indicating how VOC emissions would be reduced 15% below levels in the 1990 inventory by 1996; and a continuing [attainment] demonstration plan, indicating how the area would achieve each of its standards by a specified target year, which varied with the type of pollutant and the severity of current conditions. Most nonattainment areas were able to demonstrate that they would *conform* to the NAAQS in their initial plans mainly through continuing improvements in vehicle technology, clean fuels, and for some areas, an enhanced inspection and maintenance program.

As nonattainment areas now are focused on maintaining the NAAQS over the long-term, or achieving standards on specific pollutants, the following concerns are raised:

- As vehicle miles of travel continue to increase at a rate of 2 to 3% per year, VOC emissions – as one of the major contributors to ozone – could increase in the future (reversing a long, downward trend) unless technological improvements keep pace.

- In some areas, long-term maintenance or attainment of ozone standards will also be impeded by levels of NOx (oxides of nitrogen) emissions, the pollutant that mixes with VOCs to produce atmospheric ozone. Nitric Oxide (NO) forms during high-temperature combustion processes, such as occurs in diesel engines. Nitrogen dioxide (NO_2) forms when NO further reacts in the atmosphere. Not only are the *absolute* levels of reduction of VOCs and NOx important in achieving ozone standards, but achieving a *balance* in their respective concentrations is critical.

- Particulate Matter is rapidly becoming the next major air pollution problem, particularly in the western states. PM, which describes any material that exists as a solid or liquid in the atmosphere, produces particles of the size that lodge in the lungs; health costs associated with air pollution are most clearly related to mortality from PM sources. While most PM of the particulate size of 10 microns or larger (PM-10) comes directly from natural sources, such as road dust, or smokestacks, transportation is also an important source. Transportation PM may either come directly from the tailpipe as "soot", or indirectly as a result of atmospheric condensation and precipitation of gaseous emissions (especially NOx and SO_2) as fine particulates. This secondary PM pollution results in much finer particles which are less than 10 microns. A pending change in the NAAQS for PM from 10 microns to 2.5 microns (PM-2.5) raises considerable interest in the PM contributions of mobile sources, and particularly diesel-powered vehicles.

Because the movement of intercity freight is primarily by means of large, heavy-duty diesel-powered vehicles, the contribution of intercity freight modes and operations is an important factor in an area's long-range attainment efforts.

2.2.3. Other Impacts

There is a range of other issues that command attention to intercity freight by the broader transportation planning process. These include:

- Concerns about freight transportation demands contributing to infrastructure capacity, maintenance, or replacement needs.

- Concerns about freight's role in transportation safety and accidents.
- Noise and other environmental impacts
- Importance of sustained mobility and high-quality service in regional/national economic competitiveness and productivity.

Each of these issues and concerns have important implications regarding the role and performance of intercity freight operations.

2.3 Basic Freight Transportation Concepts

In order to better understand how intercity freight transportation affects a given region, it is helpful to become familiar with some basic concepts that economists and transportation planners use to describe goods movement and the choice of freight transportation modes.

At the most disaggregate level, there are individual ***shipments***. These shipments consist of a specific ***commodity*** that is being shipped and the ***quantity*** of that commodity that is being shipped. When examining the choice of transportation ***mode*** for this shipment, the commodity characteristics are an important consideration. For example, certain commodities are shipped in bulk, the products have a relatively long shelf life, and the transport time is not that critical to the buyer. Products such as coal and grain are typical of these commodities. These commodities are more likely to be shipped by rail or barge than by truck, and they are unlikely to be very sensitive to the difference in cost between modes. In contrast, some commodities are either of high unit value or have a short shelf life. For these commodities, rapid and reliable shipments are required, and higher shipping rates are accepted. Truck and air are the dominant modes for these commodity shipments. And, of course, there are a number of commodities for which the modes compete. The packaging of certain commodities into containers or trailers allows their shipment to occur either by rail or truck, generally requiring efficient ***intermodal*** coordination. Shipment of containers or trailers-on-flat-car allows efficient long-haul transport of these goods by rail, generally for distances of 600 miles or more, but with strategic distribution at terminal ends by truck to final users. Thus, in describing goods movement, the commodity and the typical size of shipment are both important variables.

Each shipment also has an ***origin*** and a ***destination***. Knowledge of origins and destinations is important when looking at mode use for individual shipments because it determines the availability and suitability of modal options (longer haul shipments are more likely to travel by rail than by truck). Other modal characteristics which determine the choice of freight transportation mode include shipping rates, transit time between origins and destinations, reliability, and on-time arrival.

■ 2.4 Overview of Intercity Freight Transportation Industry

The principal actors in the movement of intercity freight are the railroads, the trucking industry, waterways, petroleum pipelines, and to a qualified but important extent, air cargo. The share of activity across these carriers is illustrated in Table 2.1, in terms of the percentage of Total Tonnage, Ton Miles, and Revenues in 1995, compared with the respective performance in 1985 (for Tons or Ton-Miles) and 1980 (for Revenues).

Table 2.1. Intercity Freight Ton-Miles, Tonnage, and Revenues by Mode[1]

	Ton Miles		Tonnage		Revenue	
	1985	**1995**	**1985**	**1995**	**1980**	**1995**
Rail	36.4%	40.6%	27.5%	25.8%	13.0%	7.8%
Truck	24.8	27.2	37.8	45.5	72.7	78.9
Oil Pipeline	22.9	17.7	18.0	15.1	3.5	1.9
Waterways	15.6	14.1	16.6	13.3	7.3	5.0
Air/Misc.	0.3	0.4	0.1	0.1	3.5	6.4
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100%**

The data show rail as the leader in ***ton-miles*** carried, the traditional measure of freight activity. Its 40.6% share of intercity ton miles substantially exceeds that of trucking (27.2%), oil pipeline (17.7%), and waterways (14.1%), with the ton-mile share of air cargo being negligible. This 40.6% share also reflects an increase from its 36.4% share in 1985, and only rail and trucking accomplished increases in share over this period. In respect to tonnage carried and percent of revenues earned, however, the picture is much more skewed toward trucking. Trucks carried 45.5% of intercity freight ***tonnage*** in 1995, compared to only 25.8% for rail, 15.1% for oil pipeline, and 13.3% for waterways (with the tonnage carried by air cargo again being negligible). Moreover, trucking was the only mode to increase tonnage between 1985 and 1995 (37.8% to 45.5%), whereas all other modes lost share, including rail which declined from 27.5% to 25.8%. Perhaps most telling in terms of activity share is the distribution of ***revenues***: trucking accounted for 78.9% of industry revenues in 1995, compared to only 7.8% for rail, 1.9% for oil pipeline, and 5% for waterways. Air cargo, while not carrying substantial tonnage, nevertheless accounted for 6.4% of all revenues in 1995, almost equal to rail's share.

These statistics do a fairly good job of portraying the role of the various intercity freight modes, and the underlying economic trends that are shaping that role. While the level of demand for freight transportation has continued to increase over the past 10 to 15 years, that demand has grown more slowly than the GNP,[2] due in part to a continuing shift of the US economy away from basic manufacturing and industry toward more of an

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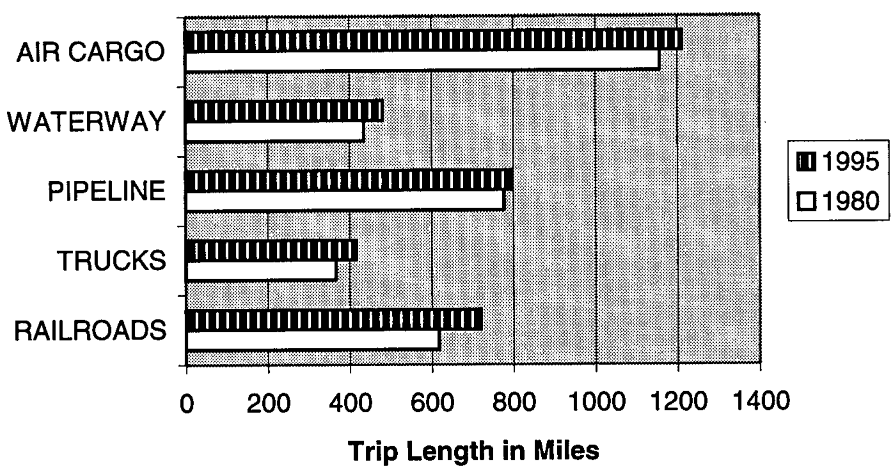
[1] Roslyn Wilson, *Transportation in America,* Fourteenth Edition (Westport, Connecticut: The Eno Foundation for Transportation, Inc. 1996).

[2] The nation's freight transportation bill as a portion of GNP has fallen fairly steadily from 19.8% in 1980 to 15.9% in 1995. *1996 National Transportation Statistics.* Bureau of Transportation Statistics, US DOT. Table 79.

emphasis on services and high technology products. Expanding industries have shown less of a reliance on materials to produce their goods, which suggests a declining need for movement of bulk goods, a trend which has clearly had an impact on rail and waterborne traffic. Major trends have been toward smaller manufacturing facilities, which favor smaller, more frequent shipments, where on-time arrivals are as important (or more important) than shipping cost. In addition, as national production continues to disperse away from concentrated industrial centers, the overall effect on freight demand is for smaller shipments of higher-value products to smaller facilities in more remote locations.[3]

These trends help explain the balance of shares and the shift of activity across modes over time. Since rail, oil pipelines and waterways have traditionally been the carriers of high-bulk, low-unit-value commodities over medium-to-long distances, their market shares have gradually shifted over to truck, which carries both bulk and high-value commodities in short-to-medium haul markets or where time and flexibility are very important, and air cargo, which serves high-value, time-sensitive commodity markets. Figure 2.1 profiles the average length of haul for the major freight modes, and Table 2.2 profiles the major commodities which are carried by each mode.

Figure 2.1: Average Trip Length for Shipments by Primary Freight Mode, 1980 vs. 1995[4]



The data in Figure 2.1 illustrate that the average length of haul for commodities is longest by air cargo, at about 1200 miles, followed by pipeline (crude oil) at about 800 miles and rail at about 700 miles, with waterway and truck being similar in the range of 400 to 500 miles. This is reflected in the types of commodities being carried, as shown in Table 2.2. Table 2.2 presents data which illustrate the relationships in the types of commodities that are carried by the major intercity modes. The table is in three parts: Part 1 lists total tonnage carried in 1994; Part 2 then shows the share of a given commodity group that is

[3] *National Transportation Strategic Planning Study,* US Department of Transportation, 1990.

[4] *Transportation in America 1996.* Eno Foundation, p.71.

Table 2.2. Commodity Shares by Mode

1994 Freight Volume by Commodity Type (In Million Short Tons)

Commodity Shipped	Truck	Rail	Intermodal	Air	Water	Pipeline	Total
Agricultural & Food Products	1205.2	234.9	10.5	0.4	95.0	-	1546.0
Ores & Minerals	1562.0	209.8	-	-	190.0	-	1961.8
Clay, Concrete, Stone, Glass	683.1	49.6	1.1	-	13.2	-	747.0
Forestry, Wood, Paper Products	737.3	110.1	5.2	0.3	22.1	-	875.0
Chemicals & Allied Products	309.3	141.3	3.3	0.1	70.9	-	524.9
Coal & Petroleum Products	407.7	727.9	0.4	-	484.3	785.4	2405.7
Crude Petroleum & Natural Gas	-	3.0	-	-	136.4	890.2	1029.6
Textiles & Apparel	29.7	-	1.0	0.2	0.5	-	31.4
Manufactured Goods	21.3	0.3	0.8	-	2.8	-	25.2
Primary Metal Products	112.4	55.7	0.5	0.1	10.1	-	178.8
Fabricated Metal Products	71.6	0.2	0.5	0.1	4.2	-	76.6
Machinery & Electrical Equip.	58.0	1.1	1.4	0.8	1.9	-	63.2
Transportation Equipment	43.9	34.6	2.7	0.3	0.6	-	82.1
Instruments, Small Package	19.9	-	1.0	3.5	0.1	-	24.5
Waste or Scrap Metal	143.9	38.0	4.1	-	24.8	-	210.8
Other	49.5	7.9	95.4	0.8	0.7	-	154.3
Total	5454.8	1614.4	127.9	6.6	1057.6	1675.6	9937

1994 Percentage of Commodity Tons Shipped by Mode

Commodity Shipped	Truck	Rail	Intermodal	Air	Water	Pipeline	Total
Agricultural & Food Products	78.0%	15.2%	0.7%	0.0%	6.1%	0.0%	100%
Ores & Minerals	79.6%	10.7%	0.0%	0.0%	9.7%	0.0%	100%
Clay, Concrete, Stone, Glass	91.4%	6.6%	0.1%	0.0%	1.8%	0.0%	100%
Forestry, Wood, Paper Products	84.3%	12.6%	0.6%	0.0%	2.5%	0.0%	100%
Chemicals & Allied Products	58.9%	26.9%	0.6%	0.0%	13.5%	0.0%	100%
Coal & Petroleum Products	16.9%	30.3%	0.0%	0.0%	20.1%	32.6%	100%
Crude Petroleum & Natural Gas	0.0%	0.3%	0.0%	0.0%	13.2%	86.5%	100%
Textiles & Apparel	94.6%	0.0%	3.2%	0.6%	1.6%	0.0%	100%
Manufactured Goods	84.5%	1.2%	3.2%	0.0%	11.1%	0.0%	100%
Primary Metal Products	62.9%	31.2%	0.3%	0.1%	5.6%	0.0%	100%
Fabricated Metal Products	93.5%	0.3%	0.7%	0.1%	5.5%	0.0%	100%
Machinery & Electrical Equip.	91.8%	1.7%	2.2%	1.3%	3.0%	0.0%	100%
Transportation Equipment	53.5%	42.1%	3.3%	0.4%	0.7%	0.0%	100%
Instruments, Small Package	81.2%	0.0%	4.1%	14.3%	0.4%	0.0%	100%
Waste or Scrap Metal	68.3%	18.0%	1.9%	0.0%	11.8%	0.0%	100%
Other	32.1%	5.1%	61.8%	0.5%	0.5%	0.0%	100%
Total	54.9%	16.2%	1.3%	0.1%	10.6%	16.9%	100.0%

1994 Percentage of Modal Shipments by Commodity (tons)

Commodity Shipped	Truck	Rail	Intermodal	Air	Water	Pipeline	Total
Agricultural & Food Products	22.1%	14.6%	8.2%	6.1%	9.0%	0.0%	15.6%
Ores & Minerals	28.6%	13.0%	0.0%	0.0%	18.0%	0.0%	19.7%
Clay, Concrete, Stone, Glass	12.5%	3.1%	0.9%	0.0%	1.2%	0.0%	7.5%
Forestry, Wood, Paper Products	13.5%	6.8%	4.1%	4.5%	2.1%	0.0%	8.8%
Chemicals & Allied Products	5.7%	8.8%	2.6%	1.5%	6.7%	0.0%	5.3%
Coal & Petroleum Products	7.5%	45.1%	0.3%	0.0%	45.8%	46.9%	24.2%
Crude Petroleum & Natural Gas	0.0%	0.2%	0.0%	0.0%	12.9%	53.1%	10.4%
Textiles & Apparel	0.5%	0.0%	0.8%	3.0%	0.0%	0.0%	0.3%
Manufactured Goods	0.4%	0.0%	0.6%	0.0%	0.3%	0.0%	0.3%
Primary Metal Products	2.1%	3.5%	0.4%	1.5%	1.0%	0.0%	1.8%
Fabricated Metal Products	1.3%	0.0%	0.4%	1.5%	0.4%	0.0%	0.8%
Machinery & Electrical Equip.	1.1%	0.1%	1.1%	12.1%	0.2%	0.0%	0.6%
Transportation Equipment	0.8%	2.1%	2.1%	4.5%	0.1%	0.0%	0.8%
Instruments, Small Package	0.4%	0.0%	0.8%	53.0%	0.0%	0.0%	0.2%
Waste or Scrap Metal	2.6%	2.4%	3.2%	0.0%	2.3%	0.0%	2.1%
Other	0.9%	0.5%	74.6%	12.1%	0.1%	0.0%	1.6%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: DRI/McGraw-Hill. US Freight Transportation Forecast...to 2004.

carried by each mode, and Part 3, conversely, shows the distribution of commodity traffic carried by the given mode. What the data show fairly clearly are:

- That intercity truck accounts for the majority of tons carried, with 54.9% of all tons carried, with 16.2% carried by rail, 16.9% by pipeline, 10.6% by water, 1.3% by intermodal, and only 0.1% by air. A similar distribution of activity by *revenue* would show a very different picture, with truck and air accounting for the greatest share among the modes, whereas a distribution by *ton-miles* would show rail as the dominant mode.

- The most substantial commodities carried by truck, *on a tonnage basis*, are Agricultural and Food Products (22.1%), Ores & Minerals (28.6%), Forestry, Wood and Paper Products (13.5%), and Clay, Concrete, Stone and Glass (12.5%).

- The most substantial commodities carried by rail are Coal and Petroleum Products (45.1%), Agricultural and Food Products (14.6%), Ores and Minerals (13.0%), and Chemicals and Allied Products (8.8%).

- Although rail is commonly regarded as the dominant carrier of heavy, bulk commodities, the statistics show that 78% of all Agricultural & Food Products, 79.6% of all Ores & Minerals, 91.4% of all Clay, Concrete, Stone & Glass materials, 62.9% of all Primary Metal Products, 93.5% of all Fabricated Metal Products, and 68.3% of all Waste and Scrap Metal are hauled by truck on a *tonnage* basis (A *ton-mile* comparison might be expected to shift some, but not all, of this activity share to rail).

- The Intermodal category of freight mode is defined as "transportation shipments involving more than one mode, e.g., rail/truck, truck/air, or rail/water"[5]. This may include much of the containerized (container or trailer) shipments of un-typed/miscellaneous cargo carried by truck or rail.

While these historical "stereotypes" of particular modes being associated with particular commodity markets, lengths of haul, service patterns and rates may still describe the majority of modal operations, there are an increasing number of circumstances where the modes more nearly ***compete*** with service. Focusing particularly on rail and truck in this comparison, intermodal containerized (COFC) or trailer-on-flat-car (TOFC) services have provided shippers of higher value goods over medium-to-long distances with an alternative to truck for all or at least a portion of the trip. Rail intermodal service has increased dramatically over the last two decades. The volume of containers or trailers shipped by rail intermodal service has grown from 3.1 million units in 1980 to 8.1 million in 1995.[6] This increase is due largely to the introduction in 1984 of specialized railcars with depressed platforms that carry containers stacked two high (termed "double-stack" service). Such double-stack trains now account for approximately 40% of all domestic intermodal capacity, and 80% of all container moves . It seems apparent that the potential for this class of service has not nearly peaked. Containerized rail shipments have become

[5] *American Trucking Trends: 1996 Edition.* American Trucking Association, Washington DC.

[6] *Railroad Facts: 1996 Edition.* Association of American Railroads, Washington DC (p. 26). The 8.1 million units in 1995 included 4.6 million containers and 3.5 million trailers.

quite common in the movement of freight from markets in the Far East which reach the U.S. through West Coast ports. Roughly 130 double-stack trains now depart from west coast ports weekly, transporting import goods on an expedited schedule inland, and then carrying domestic and export traffic westbound on the return trip.[7] Double-stack trains movements are defining a "land-bridge" that connects the population centers of the eastern U.S. with these Asian-Pacific markets. Recent, ongoing shifts in production activity in Asia are also beginning to make the Suez Canal and East Coast ports attractive for such traffic, and may add to this growing level of containerized freight movement. The efficiency and productivity potential of these intermodal services is becoming increasingly attractive to the railroads and trucking companies, and to public officials as a means to stretch transportation system capacity and to manage environmental impacts.

2.4.1 Characteristics of the Rail Industry

Railroads have been a mainstay of the nation's transportation system since early in its beginnings, opening vast reaches of the middle and western United States to settlement and economic development, and supplying industry and consumers with raw materials and manufactured goods. As the shape of the country, its economy, and its infrastructure have changed over time, the railroad industry has also undergone many changes. A shift in the post-WW II economy from heavy industry to specialty products and services across a broader geographic landscape has meant a loss in share of the freight market to the railroads. However, these changes have also induced important shifts in the structure of the industry and the types of services it offers.

Unlike those freight carriers which use public highways, airports/airspace, or waterways, the rail industry is unique in owning its facilities, and having sole responsibility for their upkeep, replacement, or expansion. This situation has had important and flexibility impacts on the rail industry's ability to shift with the times, compounded by extensive regulations on their rates, services, and service regions. The Rail Revitalization and Regulatory Reform Act of 1976 and the Staggers Rail Act of 1980 contributed substantially to the restructuring of the US rail industry by removing many long-standing regulatory controls on rates and services. Since this time, the industry has seen numerous reorganizations, mergers, and reconfiguration of routes and service areas, as well as the services and rates themselves. Today, nearly 70% of rail freight is transported under contracts voluntarily negotiated between railroad and shipper. The rail freight industry continues to operate on a comparatively modest profit margin, though its ongoing re-engineering of product and services has continued to increase productivity and return on investment, as the industry continues to redefine and reposition itself to best serve the markets of today and tomorrow.

The Surface Transportation Board (STB), the successor agency to the Interstate Commerce Commission, is the federal agency responsible for the economic regulation of the rail industry. The STB classifies railroads in relation to level of operating revenue, adjusting this annually for inflation. In 1994, Class I railroads were defined as properties with operating revenues of $255.9 million or more; Class II railroads had revenues of $20.5

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[7] *US Industrial Outlook: 1994.* US Department of Commerce/International Trade Association, January 1994.

million or more; and Class III railroads had revenues of less than $20.5 million. Since 1979, only Class I railroads are still required to report financial and operating information to the STB. Perhaps a more functional classification system is the one used by the Association of American Railroads (AAR), which categorizes non-Class I railroads as either Regional or Local, where Regional are line-haul railroads with at least 350 miles of road and/or earning revenue of at least $40 million. Local railroads are line-haul operations whose characteristics fall below the Regional criteria, and also include switching and terminal railroads[8].

There are 10[9] Class I railroads currently in service; they are:

Eastern:	CSX Transportation Consolidated Rail Corporation (Conrail) Grand Trunk Western/Canadian National (CN) Illinois Central Railroad Co. Norfolk Southern Corporation (NS)
Western:	Burlington Northern Santa Fe (BNSF) Kansas City Southern Railway Co. Soo Line/Canadian Pacific Railway (CP) Southern Pacific Transportation Company Union Pacific Railroad Co.

While they comprise only 2% of the number of railroads in the country, the Class I railroads account for 73% of the industry's mileage, 89% of its employment, and 91% of its freight revenue. As shown in the table below, Class I railroads generated $31.4 billion in freight revenues in 1995[10], compared to about $1.5 billion for the 30 Regional railroads and $1.4 billion for the estimated 500 Local railroads. The national Class I rail network is show in in Figure 2.2.

Railroad	Number	Road Miles Operated	Employees	Freight Revenue (000)
Class I`	11	125,072	185,782	$31,355,593
Regional	30	18,815	10,647	1,549,627
Local	500	26,546	13,269	1,436,811
Total	541	170,433	209,698	$34,342,031

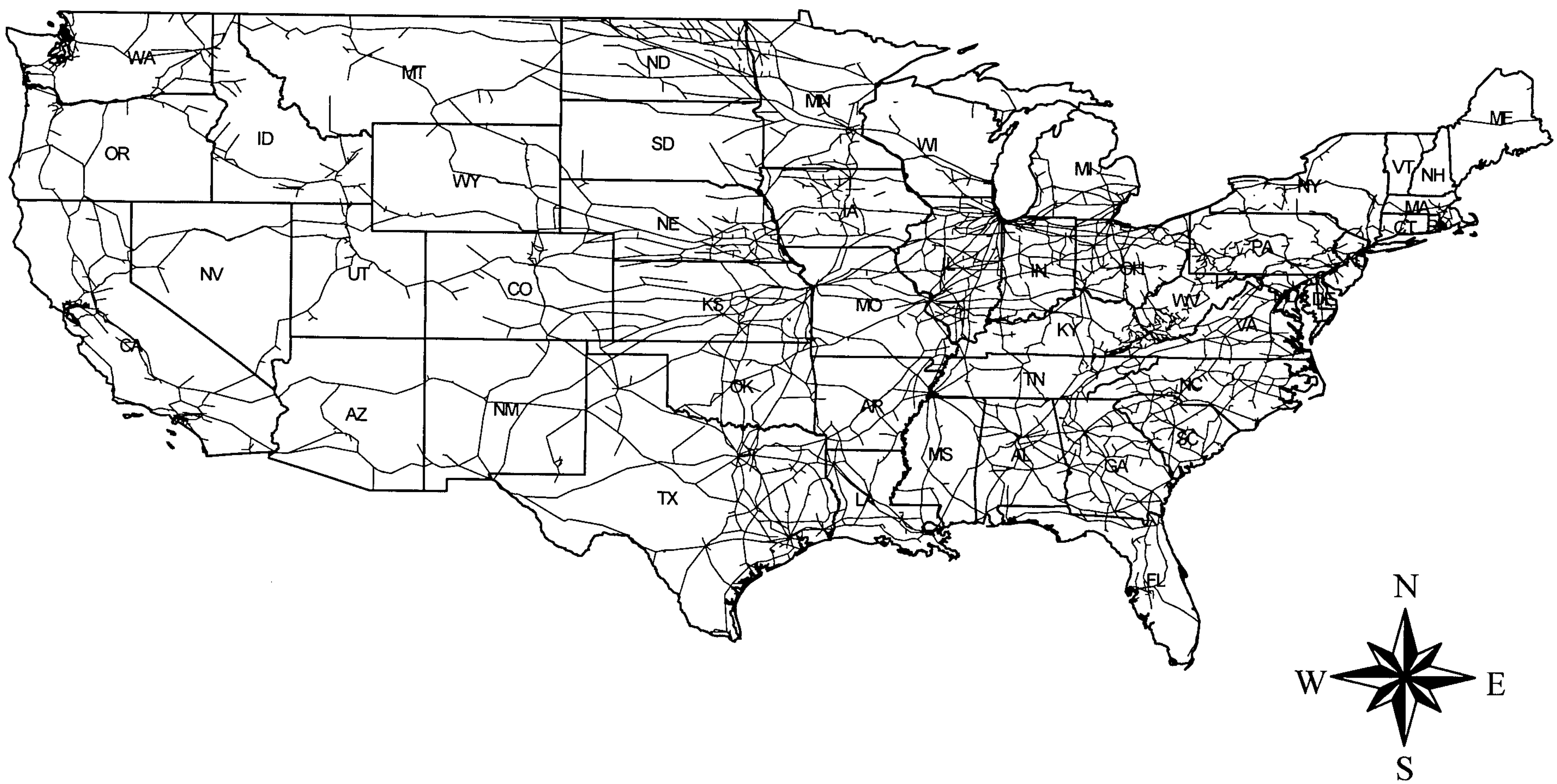
Source: *Railroad Facts: 1996*. Association of American Railroads, Washington, DC

[8] *Railroad Facts: 1996*. Association of American Railroads, Washington DC.

[9] The Burlington Northern and the Santa Fe merged in September of 1995, but reported separately to the STB for 1995. Hence, 11 Class I railroads are reported for 1995 though there are now officially 10 Class I roads. The STB-approved merger of the Union Pacific and Southern Pacific in 1996, reduced the number to 9.

[10] Total Class I operating revenue of $32.3 billion in 1995 was comprised of $31.4 billion in freight revenue, $89 million in passenger revenue, and $835 million in all other revenue.

Figure 2.2 Current Class I Rail Network



Source: National Transportation Atlas Data Bases; Bureau of Transportation Statistics; 1995

The miles of road and track owned by Class I railroads have been declining steadily over the past few decades. Many former Class I miles have been sold to smaller, lower-cost Regional and Local ("short-line") operators, with the result that non-Class I railroads now operate almost 45,000 miles of road, up from 9,500 from 1970. A smaller number of miles that could not be operated profitably, even by non-Class I railroads, have been abandoned. Trends in the Class I portion of the industry between 1960 and 1995 are reflected in the tables below:

Year	Track Miles	Locomotives in Service	Freight Cars in Service
1960	340,800	29,000	2.0 million
1970	319,100	27,100	1.8 million
1980	270,600	28,100	1.7 million
1990	200,100	18,800	1.2 million
1995	180,400	18,800	1.2 million

Source: AAR Railroad Facts (pp. 44,48,50)

These data illustrate the steady downsizing of facilities and equipment that has accompanied the industry's restructuring, as measured in terms of track miles, locomotives and freight cars in service. More powerful locomotives, larger capacity freight cars, and improved signalization have enabled this restructuring to occur in parallel with an increase in overall activity levels, as shown below:

Year	Tons Originated (billions)	Ton-Miles Originated (billions)	Length of Haul (miles)	Carloads Originated (millions)	Trailers and Containers (millions)	Freight Revenues (billion $)
1960	1.2	572	461	27.9	—	$8.0
1970	1.5	764	515	27.0	2.4	10.9
1980	1.5	918	616	22.2	3.1	26.3
1990	1.4	1,034	726	21.4	6.2	27.5
1995	1.5	1,306	843	23.7	8.1	31.4

Source: AAR Railroad Facts, (pp. 28, 26, 36, 24, 26,13)

The picture for the Class I portion of the industry is that total tonnage carried by rail has been relatively constant since 1970, while ton-miles carried has more than doubled, owing to a steady increase in average shipment length of haul, up from 461 miles in 1960 to 843 miles in 1995. While the number of originating carloads had gone through a period of gradual decline through 1990, the trend since 1990 has shown an increase to pre-1980 levels, and throughout this period, the number of containers and trailers hauled by railroads has steadily increased. Freight revenues, measured in current dollars (not adjusted for inflation), have increased steadily over the period, from $8.0 billion in 1960 to $31.4 billion in 1995. In real terms, revenues have remained fairly constant, however.

The railroads have been able to retain and strengthen their position in the national freight system during this period of transition through concentration on most profitable routes and commodities, diversification into intermodal service, and greater efficiency and productivity in use of their capacity. Evidence of these trends is reflected in the table below:

Year	Average Tons per Trainload	Average Cars per Train	Average Tons per Carload	Ton-Miles per Employee Hour
1960	1,453	69.6	44.4	327
1970	1,820	70.0	54.9	584
1980	2,222	68.3	67.1	863
1990	2,755	68.9	66.6	1,901
1995	2,870	66.3	65.3	2,764

Source: AAR Railroad Facts (pp. 37, 35, 39, 41)

Measures of increased productivity are evident in the steady increase in the average number of tons carried per trainload, which has almost doubled between 1960 and 1995, and an increase in the number of ton-miles transported per employee hour. These increases have occurred despite no major change in the average size of trains (at about 70 cars) or increases in the load per car after 1980.

Markets in which the rail freight industry continues to be dominant are coal, farm products (grain), and chemical and allied products. Growth is projected in these bulk-freight markets, which should provide increased demand for both rail and waterway transport. The other market in which rail is expected to also continue its hold and exhibit growth is the intermodal container/trailer service.

Rail intermodal shipments are highly competitive with truck freight for distances greater than 600 miles. Equipment innovations and new marketing programs, partially fostered by the deregulation of this traffic in 1981, have boosted the competitiveness of the railroads in this market. Interest is increasing in containerized movement of domestic traffic throughout the US, but particularly in long-haul, densely traveled corridors which also have the capability to accommodate double-stack trains. Impediments to the growth of these services to their full potential include:

- Height clearances on some rail lines prevent double-stack operations, in particular on lines east of the Mississippi River.

- Competition with the trucking industry that causes railroads to charge lower rates and operate on a more narrow profit margin for intermodal service than is necessary for expansion of services and equipment.

- Proliferation of different equipment types and designs that create logistical problems and uncertainties in investment planning.

- Capacity limitations and access deficiencies at intermodal terminals.

- Technological factors and institutional/operational practices that discourage railroads from seamless transfer of intermodal shipments between lines, both between major Class I railroads and between Class I and the numerous shortline railroads that have been spun off by the many mergers.

2.4.2. Characteristics of the Intercity Trucking Industry

Of all the modes involved in intercity freight transportation, trucking and air cargo have realized the highest rates of growth over the past 20 years, mirroring changes in the economy and the geographic location of activities. As shown in the table below, truck's share of the intercity freight market has grown from 32.7% of total tonnage in 1960 to 45.5% in 1995, from 21.7% of all ton-miles to 28.2% over the same period, and from 37.5% of all freight expenditures to almost 50%.

Truck Share of Intercity Freight Market

	Tonnage		Ton-Miles		Freight Expenditures	
Year	Total (millions)	Pct. of All Modes	Total (millions)	Pct. of All Modes	Total (millions)	Pct. of All Modes
1960	1,181	32.7%	285	21.7%	$17.9	37.5%
1970	1,828	36.2	412	21.3	33.5	39.9
1980	2,007	36.3	555	22.3	94.6	44.3
1990	2,589	40.3	735	25.3	162.3	46.2
1995	3,373	45.5	921	28.2	219.6	49.8

Source: *Transportation in America, 1996.* Eno Foundation (pp. 40, 44, 46)

Some simple definitions are helpful in understanding the organization and operation of the intercity trucking industry:[11]

Private vs. For-Hire Carriers:

First, it is common to distinguish between "private" and "for-hire" carriers. Private carriers are defined as vehicle fleets which are operated by a company for the primary purpose of transporting its own materials or merchandise. For-hire carriers are those who provide transportation service to shippers as their primary business. These for-hire carriers are generally of two types: "Motor Carriers", generally seen as *trucking companies*

[11] *National Transportation Strategic Planning Study.* US Department of Transportation, 1990.

(e.g., Yellow Freight), and "Owner Operators", who are independent truckers that own or lease their own vehicles and hire their services out to shippers or trucking companies. These for-hire carriers have also been separated into "common" vs. "contract" carriers, where a common carrier may haul goods for anyone, while a contract carrier hauls goods only under individual customer contract arrangements. (There are certain cases where private carriers also hire out their fleets to others outside the company) Historically, the for-hire carriers involved in interstate transportation have been subject to regulation of rates and market entry by the Interstate Commerce Commission, whereas private carriers or carriers of certain "exempt" commodities, like agricultural goods, have not been regulated. Since the advent of deregulation of the intercity freight industry in the 1970's, a smaller and smaller proportion of the industry has been subject to regulation, dropping from 40.3% of all intercity trucking in 1945 to 28% in 1992, and by 1995 being almost free of regulation except for antitrust activities, safety, and size and weight restrictions.[12]

Truckload vs. Less-Than-Truckload Carriers:

For-hire trucking is also frequently discussed in terms of its basic types of service, which are Truckload (TL), Less-than-Truckload (LTL), and Parcel.

- Truckload (TL) operators, accounting for the largest share of tonnage among motor carriers, consists of shipments directly between sender and receiver. These shipments typically do not go through sorting at terminals, and may often move under "contract" arrangement. Most owner operators serve truckload (TL) freight movements.

- Less-Than-Truckload (LTL) operators, historically defined by the ICC as shipments weighing less than 10,000 lbs., involves the collection of shipments from numerous sources, consolidation of these shipments at a terminal, transporting the consolidated cargo via line-haul carrier to a second terminal, where it is again sorted and distributed to final destinations. These services are most often provided by "common" carriers.

- Parcel, or small package services, is similar in operation to LTL trucking, except that it generally involves smaller (package) shipments, which are frequently fairly time sensitive. This service encompasses the 2-to-3 day ground delivery market introduced by UPS, as well as the next-day delivery market dominated by air-express carriers. Distinctions between the ground and air carrier services are becoming less obvious over time, as ground delivery services are making increased use of air cargo and rail intermodal service for longer trips, while next-day air services are increasing their use of truck for the line-haul portions of shorter trips.

The deregulation of the trucking industry has generally been credited with producing a more competitive, efficient trucking industry, where the increased competition has b helped to keep costs down, with the savings from improved efficiency being passed on to shippers. Because of eased entry, many new truckload carriers have entered the industry, most of them small. Few new LTL carriers have been established, though existing LTL carriers have expanded their geographic scope. Before 1979, no motor carrier had complete 48-state general commodity LTL authority, and today more than 8,000 carriers

[12] *Transportation in America: 1996.* Eno Foundation, (p. 51)..

have this authority, which has increased the competition for LTL traffic. LTL carrier operations resemble those of the Small Package carriers in the use of regional or national networks, sophisticated sorting terminals, and local pick-up and delivery service. Information technology is rapidly reshaping trucking operations and service levels.

Two important changes are affecting the for-hire trucking industry: declining lengths of haul and increased use of information technology. Declining lengths of hauls are being shaped by shipper's streamlined product manufacturing cycles and the desire for just-in-time delivery service, which imply shorter, reliable truck supply routes. Railroad double-stack competition has forced truckers to concede a number of long-haul routes over to the railroads, while a growing number of trucker-railroad alliances are developing where truckers handle the pickup and delivery segments of the trip. Finally, the need to retain drivers by limiting their time away from home has pressured companies to focus on shorter regional markets, typically 250 to 500 miles in length. Targeting shorter routes reverses a 1980s trend where some carriers were achieving lengths of haul of 1,100 miles or more.

When viewed from the level of a metropolitan area, it can be difficult to separate out – definitionally or in terms of available information – truck activity that would be classified as "intercity" vs. that which is local freight, or commercial or personal use truck/van. The following definitions may be useful:

- Line-Haul Intercity Truck: A true intercity movement is one which has at least one trip end outside a given metropolitan area. These may be either trips which emanate or terminate in the given area, or are simply moving through the area on the local transportation network enroute to somewhere else. This service is typically provided by heavy-duty combination trucks (truck-trailer with 3+ axles), which are also generally diesel powered. This clearly applies to TL carriers, and may also cover some LTL carriers if they have one trip end outside the metropolitan area.

- Drayage Operators: A considerable level of heavy truck activity may occur locally in the movement of containerized shipments or trailers to or from an intermodal terminal, or between terminals. While this operation may not extend outside the area, it would be considered part of the intercity freight system, and would be regarded as *drayage*. A different class of truck operators provide this service, frequently with numerous assigned loads and possibly different destinations during the day.

- Local Freight: Local freight delivery sometimes blurs in distinction between a direct intercity delivery (i.e., out-of town truck to final customer), local terminal to end user, and the more conventional local merchant/supplier to local manufacturer/customer. Typically, an important characteristic which distinguishes local freight movement from intercity is the use of single unit trucks with no more than 2 axles.

- Commercial Truck: A considerable number of trucks in operation on a metropolitan highway network are not carrying freight, but are performing service functions, such as craftsmen, repairmen or utilities. Generally, these would be excluded from the definition of intercity truck because of weight or axle size limits.

2.5 Key Factors That Affect Level of Freight Activity and Choice of Mode

One of the uncertainties that makes freight a difficult subject for planners is the nature of freight demand. The level of activity occurring in the freight sector, and the shifts in the patterns of that activity by location, mode and service type, are heavily influenced by forces and factors which are external to the public planning/decisionmaking process. Yet, in order to realistically deal with freight issues, and suggest realistic solutions, it is important to have a good understanding of the basic forces that drive freight demand, and influence the level of freight activity, and the service types and patterns that result.

The following are factors important in the generation of freight demand. This summary has been abstracted from NCHRP Report 8-30, Characteristics and Changes in Freight Transportation Demand, which is strongly recommended as a reference for those dealing with freight planning or policy issues[13].

- **Condition of the Economy** – Since the demand for transportation services is derived from the level of economic activity, the most basic influence on total freight demand is the volume of goods produced and consumed. Freight demand is closely related to the goods production component of gross domestic product (GDP), though it measures goods production in dollars rather than in weight or volume. It is important, therefore, to distinguish between commodities when incorporating production forecasts into forecasts of freight demand.

- **Industrial Location Patterns** – Industrial location patterns are critical to determining transport demand as measured in ton-miles or other units which reflect length of haul. The spatial distribution of economic activity also influences mode choice, as a result of trip length or availability of alternatives.

- **Globalization of Business** – Many companies today manage worldwide production and distribution systems, and national economies are increasingly being integrated into a global economy. As production facilities are shifted to locations around the globe where products can be produced more economically, the demand for world trade will continue to increase. The changing patterns of world trade influence both transport flows and mode choice, since most worldwide freight flows are intermodal.

- **International Trade Agreements** – Global production and distribution are affected by international trade agreements, quotas, and tariff restrictions. The dynamics of the global marketplace have driven the formation of numerous large regional trading blocs including the European Union (EU), the ASEAN Free Trade Area (AFTA), and the North American Free Trade Agreement (NAFTA). The implications of NAFTA have been significant for freight transportation in reducing the costs and encumbrances of

[13] NCHRP Project 8-30; *Characteristics and Changes in Freight Transportation Demand, a Guidebook for Planners and Policy Analysts.* Cambridge Systematics, Inc., et al, for the National Cooperative Highway Research Program, October, 1995.

international trade, which will induce freight activity in affected industrial and geographic sectors.

- **Just-in-Time (JIT) Inventory Practices**[14] – JIT systems focus on keeping shipper inventories at minimum levels by coordinating input deliveries with production schedules. The effects on freight demand are to increase the number of individual shipments, decrease their length of haul, and increase the importance of on-time delivery. Generally, this means more truck trips and greater demand for service during primary business hours.

- **Carrier-Shipper Alliances** – Shippers' demands for faster, more reliable, door-to-door "seamless" transportation services may increasingly be made available through a single vendor who can arrange, manage, and monitor the movement. Dramatic changes in the institutional relationships among transportation providers and users have made this possible.

- **Centralized Warehousing** – As transportation systems have become more efficient and more reliable, there has been more consolidation of warehousing and distribution. The results are increases in the demand for transportation and in associated reductions in inventory costs.

- **Packaging Materials** – The use of lightweight materials as protective packaging for many manufactured products has resulted in a reduction in the average density of shipments. The increase in low-density shipments has created a demand for larger truck trailers and shipping containers.

- **Recycling** – Increased use of recycled materials affects origin/destination patterns, lengths of haul, and modal usage of several commodities. Recycling plants frequently are located near the markets they serve, which also provide them with materials for recycling.

- **Economic Regulation and Deregulation** – Deregulation within the transportation industry has encouraged greater price and service competition, and increased intermodal opportunities among and within the various modes.

- **International Transportation Agreements** – Bilateral and multilateral international transportation agreements occur when nations seek to protect their interests and to create opportunities for trade and economic growth. Where carrier entry or participation is restricted in a particular market because of such agreements, rates tend to be higher. New international trade agreements, such as NAFTA, however, can have the effect of reducing some of these restrictions, and affecting service and rates through increased competition.

- **Intermodal Operating Agreements** – Transportation carriers have become increasingly multimodal, looking for the most effective ways to integrate and market their capacity and to combine the services of rail, truck, water, and air modes. As a

[14] "Just-in-time delivery" is being supplanted by the term "definite time delivery" in the freight industry.

result, carriers are able to offer a broader range of services and to tailor service packages for individual shippers.

- **Single-Source Delivery of International LTL Shipments** – Since the early 1980s, less-than-truckload (LTL) carriers have established separate units, referred to as non-vessel operating common carriers (NVOCCs), to arrange for the integrated, door-to-door international transport of LTL shipments.

- **Fuel Prices** – For all modes of transportation, fuel is a large and volatile cost component. An increase in fuel prices is likely to result in greater rate increases for faster modes (e.g., air) and for premium services provided by a given mode (e.g., high speed rail container and trailer carriage). Accordingly, some shift of demand may occur.

- **Publicly-Provided Infrastructure** – Carriers (except for rail) rely heavily on publicly-financed and maintained infrastructure. Changes in the capacity or condition of these facilities is thus dependent on public policy and funding decisions.

- **User Charges and Other Taxes** – User charges are the principal means of financing publicly-provided infrastructure. Government efforts to recover an increasing portion of the costs of building and maintaining transportation infrastructure from users will continue to affect the competitive position of the modes involved.

- **Government Subsidization of Carriers** – Government subsidization of carriers reduces transport costs and affects competition between classes of carriers, between modes, and between operators of carriers registered in different countries.

- **Environmental Policies and Restrictions** – Environmental policies and restrictions affect all modes of transportation. In addition to the impacts of environmental policies on modal costs, freight demand also is affected by environmental policies which affect decisions on the locations of industrial sites and the locations at which raw materials are produced.

- **Safety Policies and Restrictions** – Safety regulations generally increase carrier capital and operating costs while reducing accident-related costs, but their overall impact on freight demand is relatively minor. Safety regulations influence carrier behavior only when the perceived costs exceed the perceived benefits to the carrier.

- **Effects of Changes in Truck Size and Weight Limits** – Changes in truck size and weight limits can have a significant impact on the cost of goods movement by truck, since they control the amount of payload that can be carried on a truck and fewer truck trips are required to carry the same amount of freight. Changes in truck size and weight limits may result in shifts of freight to or from other modes, particularly rail.

- **Congestion** – In many urban areas, increasing highway traffic congestion and incident-related congestion are reducing the efficiency of freight transportation and the reliability of just-in-time shipping. In port areas, there is a need to coordinate vessel loading and unloading with rail and truck schedules and with peak/non-peak traffic flows.

- **Technological Advances** – A number of significant technological advances in equipment and information systems over the past three decades have had a profound impact on freight transportation. Many of the technologies which enable significant increases in productivity are readily available, while others require significant financial investment before achieving wide application.

■ 2.6 Freight Contribution to Emissions and Air Quality

The movement of goods within, between and through metropolitan areas or in major intercity corridors generates emissions which affect air quality. Freight contributes to emissions inventories both ***directly*** and ***indirectly.*** Freight contributes ***directly*** in the production of VOCs, CO, NOx, SOx and primary and secondary PM from diesel-powered vehicle operations. Freight transportation also contributes ***indirectly*** to emissions and air quality as a result of its contribution to congestion and flow of other traffic on already-crowded facilities, and at peak hours of demand. As many states and regions continue to strive toward attainment or maintenance of NAAQS standards for Ozone, CO, and PM, the direct and indirect contributions of freight will clearly draw greater attention than in the past.

Emissions inventories which catalogue the volume of pollutants for an area by type and by source are comprised of four sources:

- Mobile Sources, which includes all highway-based transportation modes, including cars, light and heavy-duty trucks, and buses.

- Off-Road Sources, which are comprised of other transportation-related sources, but which do not occur "on" the highway system, such as railroad (freight and passenger), barge/marine, aircraft, construction and maintenance equipment, lawn and garden equipment, and recreational vehicles and pleasure boats.

- Point Sources, which are essentially major definable stationary emission sources, such as power plants, factories, etc.

- Area Sources, which comprise broad-area, non-specific types of emitters, such as dry cleaners, bakeries, households, service stations, etc.

As part of this study, an attempt was made to estimate freight contributions to overall emissions in three major US metropolitan regions that were chosen as case studies, where freight is an important part of the regional transportation system: Chicago, Los Angeles, and Philadelphia. A comprehensive discussion of freight issues and investigations performed at these three sites is presented later in Chapter 5, and in Appendix B. "Freight" emissions must be *estimated,* since they are not identified as a specific source in the SIP inventories. Truck freight is included as a subcategory of Mobile Source emissions, while emissions from rail and other freight modes are included among Off-Road sources. Using methods which are presented in Chapter 4 and Chapter 5, an assessment of the emissions impact of intercity freight in these three air quality nonattainment areas suggests the following:

Truck Emissions:

Intercity truck emissions are primarily associated with diesel-powered, heavy-duty combination trucks. Factoring methods which are described in Chapter 5 are used to isolate the intercity truck fraction from the HDDV class in the Mobile Source emissions inventory. The results of this analysis for the three case study sites are presented in the table below:

Pollutant	Contribution	Chicago	Los Angeles	Philadelphia
VOC	Mobile Source	3.8%	3.0%	2.2%
	Total Region	**1.5%**	**1.3%**	**0.8%**
CO	Mobile Source	2.3%	1.5%	1.7%
	Total Region	**1.5%**	**1.3%**	**0.9%**
NOx	Mobile Source	39.1%	19.7%	24.1%
	Total Region	**20.7%**	**10.8%**	**5.6%**
Share of Regional VMT		**7.2%**	**2.6%**	**3.5%**

Using these three regions as examples, intercity truck activity is estimated to account for about 3% to 7% of total daily regional VMT. Its contribution to VOC and CO emissions are fairly small – about the same or less than its share of total VMT. Its contribution to NOx, however, is quite large: between 19.7% and 39.1% of all Mobile Sources. Even when viewed at a Total Regional level (all sources), intercity truck's NOx contribution is considerable: 20.7% in Chicago, 10.8% in Los Angeles, and 5.6% in Philadelphia (which appears to underestimate Mobile Source contributions to NOx because its inventory is based on statewide, not metropolitan, totals). Particulate matter emissions could not be estimated since they were not included in the emissions inventories for any of the locations for this time period, although PM emissions from diesel-powered intercity truck would be expected to be disproportionately high, as with NOx.

Rail Emissions:

A complicating factor in trying to make an estimate of the emissions which are generated by the other intercity freight modes, including rail, air, waterway, etc. is that these modes are not part of the Mobile Source inventory. They are included in the Off-Road Source category, which is produced by the state environmental agency, and the state inventories generally do not offer breakdown of individual activity emission contributions. Of the three case study sites we investigated, a breakdown of Off-Road source emission contributions was found only for Chicago. Results are summarized here to provide at least some comparison of the role of rail to truck in emissions production.

Intercity Truck vs. Rail Emissions for Chicago, 1990

Pollutant	Chicago Intercity Truck: Portion of Mobile Source Emissions	Chicago Intercity Truck: Portion of Regional Emissions	Intercity Rail: Portion of Off-Road Source Emissions	Intercity Rail: Portion of Regional Emissions
VOC	3.8%	**1.5%**	4.0%	**0.5%**
CO	2.3%	**1.5%**	0.8%	**0.2%**
NOx	39.1%	**20.7%**	14.0%	**2.3%**

From these data, it appears that rail activity contributes considerably less to regional emissions than does intercity truck, particularly for NOx, where rail generates only 2.3% of the region's emissions of NOx while intercity truck accounts for 20.7%. This differential exists even in light of the fact that Chicago is the largest rail center in the nation[15].

While state or regional transportation planners would not generally concern themselves with the emissions from rail or other off-road operations, it may be quite valuable to be familiar with the emissions characteristics of both truck and rail [off-road] freight sources when attempting to find optimum emissions reduction opportunities in relation to NOx and PM.

2.7 Factors Which Affect Freight Efficiency and Emissions

2.7.1 Intermodal Impediments

A substantial and increasing amount of freight, particularly international cargo, is being shipped via intermodal means. These containerized or trailer shipments must be handled several times between origin and the final destination, which generally means mode-to-mode or intra-mode transfers, such as truck to rail, rail to rail, marine/barge to rail or truck, or even truck to truck. Physical impediments or institutional practices of various types may cause these movements to be inefficient:

- The intermodal facilities may lack sufficient capacity for the demand they serve, causing delays in handling or storing of cargo.

[15] Figure 5.3 in Chapter 5 illustrates that the great majority of NOx emissions in the off-road source category are from heavy equipment.

- The terminals for connecting modes, e.g., an ocean port and an intermodal rail yard, are frequently not physically adjacent, requiring physical break-and-transfer between carriers, typically by over-the-road truck (drayage). Even the railroads sometimes use over-the-road truck to transfer cargo from line to line or terminal to terminal (especially in Chicago).

- Terminals may be inefficient because of their location. Rail terminals are often located in the older, more congested core areas of major cities, so that their access and use conflicts with other traffic. In contrast, trucking terminals may be located in the outskirts of the urban area, where access to major highways may be maximized, but connections with other modes or pickup/distribution of goods may require considerable over-the-road travel within a metropolitan area.

2.7.2. Infrastructure and Flow Impediments

Freight movements may be impeded as a result of capacity, design or flow restrictions. For example:

- Truck restrictions may ban truck traffic from certain facilities or areas.
- Geometric constraints (turn radii) or clearance problems may impact the routing of truck traffic and add VMT as a result of circuity.
- Through-traffic may not be able to skirt around the more heavily-traveled central portion of an urban area.
- Poor signage may contribute to poor routing choices and unnecessary VMT.
- Inefficient signalization schemes may require trucks to experience substantial idling and acceleration/deceleration cycles.
- Inadequate height and width clearances for double-stack trains.

2.7.3. Traffic Conflicts

Truck traffic not only generates its own VMT and emissions, but plays a secondary role in the flow of and emissions from other traffic. A substantial portion of truck traffic occurs during peak travel hours for personal travel. Work days for local service and delivery operations tend to coincide with the busiest 8 to 10 hours of the work day. Truck/auto conflicts tend to be greater under congested conditions, with statistics suggesting that half of all major "incidents" in urban areas are on freeways/expressways, and half of all those incidents involve trucks. At-grade highway-rail crossings can cause traffic delays on highways. Rail freight and passenger services that share tracks can hinder shipment times because of track priorities. Sharing of trackage rights may impede level of service or access for the railroad that does not own the track.

■ 2.8 Potential Enhancement or Emissions Control Strategies for Freight

The literature speaks to a wide range of strategies that address the problems or deficiencies discussed above, and hold potential for enhancing freight performance and efficiency, and reducing emissions. The Project Advisory Panel was also a major source of informed "inside" ideas on effective improvements. A selected list of actions is presented below:

2.8.1. Strategies to Enhance Intermodal Freight Movements

- Improved rail-to-rail interconnections between intermodal terminals, or ports and terminals
- Terminal consolidations or expansions to improve capacity
- Improved technology or management to improve efficiency and turnaround at terminals
- Terminal relocations and/or specialization
- Rail yard or corridor flow improvements
- Financial, regulatory or other incentives to transfer shipments from over-the-road truck to rail intermodal
- Market-based highway-user measures, including VMT fees, tolls, fuel taxes, registration fees

2.8.2. Infrastructure Investments & Improvements

- Bridge clearance projects (to allow double-stack rail movements or to alleviate truck barriers)
- Highway-rail grade separations
- Alleviate critical geometric constraints for trucks
- Double-stack rail line capabilities (beyond bridge clearance adjustments)
- Truck-only or priority facilities; metropolitan truck bypass routes
- Net new rail capacity additions or upgrades

- Terminal [capital] access projects; in particular, strategic connections to national highway system

- ITS concepts

2.8.3. Traffic Flow Improvements

- Designation of truck routes or "freight beltways"

- Progressive signal timing on arterials and truck connector routes

- Elimination of bottlenecks, turning restrictions or other flow impediments

- Elimination of truck restrictions in particular areas or on particular facilities

- Special vehicle loading/unloading zones in high-traffic areas

- Incident management systems (alternative routing, rapid attention to breakdowns)

- Better signing/information

- Congestion pricing

2.8.4. Improvements in Operations and Management

- Reduce idling and delays (truck, rail or dray) at terminals and intermodal facilities

- Reduce empty backhauls/increase load factors in dray or other freight distribution operations

- Educate management and operating personnel in ways to improve operational efficiency while minimizing emissions

- Change work rules of haulers or terminal facilities to expand hours of operation to increase service for shippers and increase opportunities for off-peak shipments, while avoiding congestion delays during peak demand hours

- Incentives to shippers (or freight haulers) to ship/receive goods at non-peak hours of day

2.8.5. Technology & Alternative Fuels Programs

- Emissions fees, possibly coupled with expanded I&M or VMT fees to increase incentive for cleaner vehicles

- Enhanced I&M for trucks
- Emissions credits and trading schemes
- Targeted incentives to dray operators to use newer, cleaner vehicles
- Incentives for alternative fuels, possibly through or in addition to fuel pricing
- Emissions regulations/standards for freight vehicles

2.9 Analytic Issues and Needs

States and MPOs are becoming increasingly aware of the importance of including freight in transportation planning and programming activities, based on the types of issues and requirements described above. However, the means to analyze and quantify the impacts of the types of measures cited in the preceding section are quite limited. The Project Advisory Panel was specifically asked about the nature of current freight analysis capabilities and needs, in relating to the types of transportation or air quality problems that were being addressed. They were also asked to characterize the types of analytic improvements and assistance to which they would assign priority. These needs and concerns are summarized below:

2.9.1. Problems Experienced When Integrating Freight Concerns into the Public Planning Process

- MPOs generally focus on commuter travel issues, and very little on freight. Hence, knowledge and capabilities for freight are quite inferior to those for passenger transportation.
- Many areas now acknowledge that freight is an important factor in managing transportation system performance and emissions, but they haven't had the ability to identify effective strategies or assess what those strategies can do.
- Lack of hard data on goods movement has been a big handicap.
- Intermodal transportation has become a strong interest for states and MPOs under ISTEA, but it has been difficult to get the different public agencies to think/act intermodally. In particular, modal agencies tend to have a view of a problem or solution as it concerns their mode, funding, charter, or geopolitical constituency.
- With many needs and limited funds for planning agencies and transportation programs, freight issues are not comprehensively studied, and project decisions which impact freight are typically made because of other transportation considerations.

- How to integrate the perspectives of the freight industry into the public planning process; how to educate the public sector on the needs and workings of the freight industry.

- How to identify and implement solutions from the public side which emphasize "eliminating barriers", and not advocating use of one mode or the other.

- How to get private industry to support initiatives like improved air quality that have primarily public benefits.

- A big challenge is in identifying strategies that have air quality benefit but that don't disrupt the operations and economics of the industry, or prices/service to shippers/customers.

- A stronger, more visible link between ISTEA and air quality planning/programs is needed.

- Things change so fast in the freight industry (e.g., mergers, technology) that some strategies may be obsolete by the time they are implemented.

- MPOs must plan and execute improvements, but may not have full buy-in from industry or other jurisdictions or agencies, which places anticipated benefits in doubt (e.g., for CMAQ type projects).

- Is intercity freight an activity that can be affected by MPOs, or do some strategies require a view and an analytic or institutional approach that is larger than a single metropolitan region? Should emissions credits be valued and solutions implemented over a larger "area of influence"

- Identifying strategies or actions that states or MPOs can actually affect and incorporating these considerations into the tools and guidance which are developed. Can MPOs or states affect emissions rates themselves?

- How may "national" solutions, requirements or conditions get factored in?

- If terminal connectors are warranted, what is the proper public and private role? How can planners make sure that industry is in agreement, and will use, support, even help finance the improvements?

- Should only those strategies that are within the power of MPOs or states to accomplish or affect be considered? Where should the line be drawn between industry prerogatives and decisionmaking and public policy or action?

2.9.2. Analytic Needs and Concerns Related to Freight Emissions Planning

- How to evaluate intermodal strategies.

- How to incorporate drayage movements in an intermodal analysis.

- How to define *intercity* freight, as distinct from *local.*

- How to make sure effects of emissions reductions of intercity vs. local freight are not double counted.

- How to isolate freight emissions in SIP inventories.

- Truck and rail emissions are estimated by different agencies, using different procedures and data:

  - MPOs responsible for truck activity and emissions as Mobile Source.
  - State environmental agency responsible for rail, marine, air emissions as Off-Road Sources.

- Concern about the accuracy and assumptions made by MOBILE model:

  - Truck load is an important factor in emissions, but currently all trucks of same class carry same emissions rate.
  - Speed, grade and operating condition are very important to emissions rate, but not dealt with by MOBILE.

- How to account for different lengths of haul for freight when identifying potential strategies.

- For either mode, how to determine the effect of changes in technology on emissions rates due to incentives, strategies or over time.

- How relevant and reliable are existing freight planning models?

- Does the type of strategy to be considered and the size of its impact dictate the usefulness and accuracy of analysis options?

- How to define and treat ITS type measures that improve capacity or reduce congestion delay.

- Extent to which national and local strategies should be/can be integrated in proposed analysis methods.

- Proper understanding of the interactive role of NOx and VOCs in creating/reducing ozone, and guidance on identifying optimum reduction levels of either pollutant.

- Impact assessment in relation to conformity analyses on CMAQ project evaluation.

- Data to perform freight analysis, and/or techniques to make best use of available resources; ideas/concepts for enhancing current models or databases to make them better able to address freight issues.

- Improving the accuracy and comparability of the emissions estimating procedures themselves (rail vs. truck, plus accounting for major sensitivity variables).

- Ability to address modal shifts, operational improvements, and changes in fuels or technology.

- Ability to group strategies into packages.

- Ability to plan for intermodal connectors to NHS, as required under ISTEA.

- Guidelines/methods for calculating costs/economic implications.

3.0 Review and Assessment of Existing Freight Planning and Emissions Procedures

3.1 Overview

The objective of this research effort was to expand upon the tools and information available to professionals who are dealing with emissions-related aspects of intercity freight transportation movements and activities. Since entirely new analytic methods were not envisioned, the goal was to gather and synthesize, in a practical but useful way, reasonable techniques that can be used to help classify freight problems or needs, identify candidate strategies with emissions as well as efficiency benefits, and provide the means to evaluate the effectiveness of those strategies.

To support this objective, an emphasis was placed on identifying existing models, data and empirical studies that address intercity freight-related problems, including rail or truck freight movements and modal shifts, intermodal issues including congestion, changes in pricing or policy, and technology/operational changes affecting the emissions characteristics of freight vehicles. This was accomplished through an extensive literature review, including both formal literature searches as well as tapping the experience of research team specialists.

The organization of the material in this section is easily understood through a simple expression of the methodological approach that estimates intercity freight emissions impacts.

The relationship:

$$\Delta \textbf{ Freight Emissions} = \Delta \textbf{ Freight Activity} \times \Delta \textbf{ Emissions Rate}$$

indicates that the change in freight emissions is a product of the change in ***Freight Activity*** level or pattern, and the independent or corresponding change in the freight ***Emissions Rate*** itself. Freight Activity is generally reflected in a "transportation-related" change, such as a change in volume, direction, mode, time of day, or route. The Emissions Rate is determined independently as a result of the vehicle, its technology and fuel type, though the emissions rate may also be directly linked to the Activity change, seen in changes in operating conditions or speed that would accompany shifts in route, volume, time of day, etc.

Therefore, this study's literature review has investigated techniques and data that have been developed in conjunction with either the Freight Activity aspect or the Emissions Rates themselves, as well as studies that may have formally married the two concepts.

3.2 Freight Planning Procedures and Data

3.2.1. Introduction to Freight Planning and Forecasting Tools

The planning and forecasting science for freight in general, and intercity freight in particular, is not nearly as advanced as it is for passenger travel forecasting. This limitation applies to both the analytic tools and the data to support them

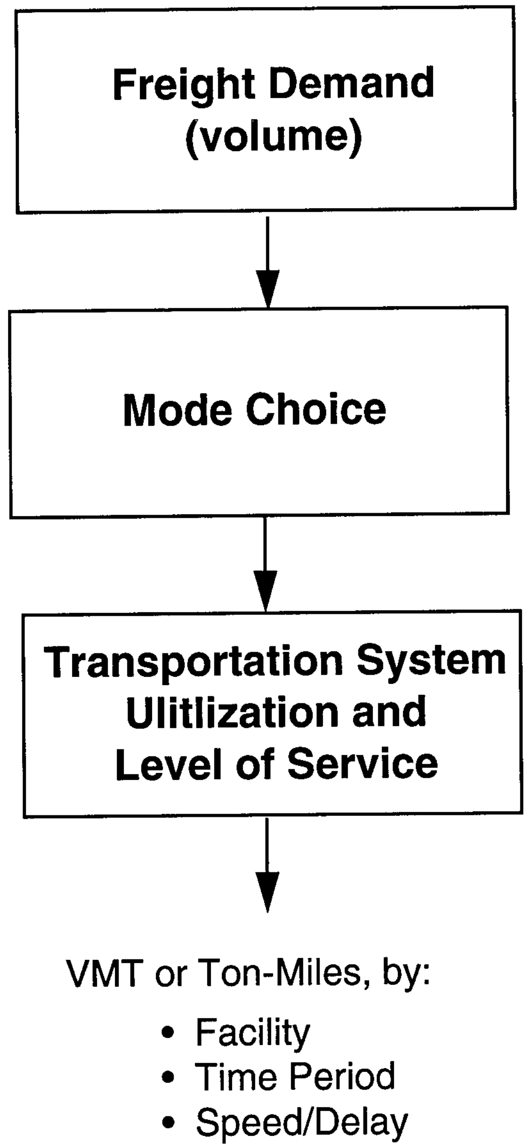
Recognizing the complexity of the task of analyzing intercity freight, this study has attempted to capitalize on the research that has gone on before. Hence, rather than attempt to build a new and better "model", the effort has been aimed at better defining the steps that would be involved in analyzing the effects of a strategy *sufficient to accurately determine its emissions* , and showing how to make the most judicious use of the tools and data that are available, with knowledge of their limitations.

Many of the same planning steps or elements that apply in passenger transportation also apply in freight. As highlighted in Figure 3.1., these steps include determining freight volume (how many trips are demanded, and where they are going, by origin-destination), mode choice (by what mode or mode combination), and transportation system utilization and level of service (time of day, choice of route, and resulting traffic/speed conditions). Out of this process come the necessary descriptors of freight activity to support an emissions estimate. They would ideally include number of trips and VMT by type facility and location, by mode/type of vehicle, by speed and time of day. Unfortunately, where it can be difficult to generate such detail for urban passenger travel, it is particularly difficult for freight.

Of the planning steps described below – trip generation and distribution, mode choice, and system utilization (network assignment) – perhaps the one given most attention has been mode choice. Freight volume, or "demand", may be estimated from various economic forecasting models. The lowest level of analysis – network assignment – which produces the estimates of trips, VMT, and speed that are key inputs to emissions, is perhaps one of the weakest portions of the current analysis chain. This element of the analysis is most important in appraising the movement of trucks in metropolitan areas, where congested conditions elevate emissions concerns and impacts.

A general observation on the models that have been reviewed is that the vast majority are directed at fairly "macro-level" situations, or contain very restrictive assumptions. This means that many of the methods are not particularly suitable for the scale or types of projects or actions that are of interest. Much more flexible and site/sub-area techniques are suggested.

Figure 3.1 Basic Hierarchy of Elements Contributing to Freight Activity Level



The following sections describe in greater detail the issues of importance in forecasting intercity freight, and provide an overview of some of the most significant and potentially useful modeling efforts.

3.2.2 Forecasting Level of Freight Activity

An important issue in freight or emissions planning is how activity levels may change over time or at a given point time in response to economic factors or transportation system changes. Thus, there are two somewhat separate planning and analysis concerns:

- Demand response to changes in existing facilities or conditions;

- Demand response to new facilities or shifts in long-term conditions

NCHRP Report 8-30[1] addresses these issues and planning needs in a fairly comprehensive way, offering guidance and suggestions as to how these needs might be addressed through application of existing methods and data. These suggestions are accompanied with insights into somewhat innovative methods of application, to get the most value from the available or easily-acquired resources. Some of the major concepts gleaned from this research are summarized below, while the unabridged segment from the study report is presented in Appendix A-1.

Guidance for forecasting freight activity levels for existing facilities and conditions is presented in the following steps:

1. *Data Resources*

The study suggests that the most readily available and practical information about the demand behavior at an existing facility is found in records of its past and present utilization in relation to prevailing market and service conditions. Three data sources are described that can be of potential use:

- Facility data compiled by the respective facility operator.
- Data collected and published by Federal or other public agencies or private entities that monitor or analyze transportation activity on a regional, state, national or international level.
- Data collected as part of a special survey designed to supplement the data from the above sources.

Examples and recommendations for each type of source are provided.

2. *Sources of Economic Forecasts*

Economic forecasts of production and consumption, and the locations of production and consumption are important inputs to developing freight demand forecasts. Numerous national, state, or special proprietary sources are described for potential use, including:

- State-funded research groups, such as the Center for Continuing Study of the California Economy, which develops 20-year forecasts of the value of California products by 2-digit Standard Industrial Classification (SIC).
- The Bureau of Labor Statistics (BLS) publishes low, medium and high 12-to-15 year forecasts of several economic variables for each of 226 sectors which generally correspond to the SIC classifications.

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[1] NCHRP Project 8-30: *Characteristics and Changes in Freight Transportation Demand*. Cambridge Systematics, et al, for the National Cooperative Highway Research Program, October 1995.

- The Bureau of Economic Analysis develops 50 year regional projections of population and personal income as well as employment and earnings by industry sector, by state for 57 industries.
- Short and long-term proprietary data bases available from private forecasting services. The best known of these are DRI/McGraw Hill and the WEFA group.

3. *Techniques for Forecasting Demand*

Several techniques are presented that can be used for deriving estimates of freight demand from the economic forecasts. Methods discussed include:

- **Economic Indicator Variables Method**, which relates freight demand of various commodity groups to corresponding economic *indicator* variables. These indicator variables can be used to either derive annual growth rates or growth factors to direct adjustment of base-year activity level. A five-step procedure is presented for deploying this method, along with several examples.
- **Statistical Techniques** of various types which have been used are introduced, including Regression Analyses, Univariate Time-Series Techniques, the Auto-Regressive Integrated Moving Average model (ARIMA), exponential smoothing, and curve fitting techniques.
- **Alternative Futures** is the final technique presented, which allows that procedures which produce a single estimate of demand may place an undue reliance on either the models or the analyst's ability to predict future outcomes of the independent variables. The alternative futures approach allows for some of the key assumptions or variables to vary over plausible ranges, resulting in more than one possible freight activity outcome

The reader is encouraged to consult Appendix A for a more complete discussion of these techniques and their applicability and use in freight activity forecasting.

3.2.3. Review of Mode Shift Models

Transportation efficiency and emissions benefits may result from shifts in mode of carriage from truck to rail intermodal, provided, of course, that the assessment accounts for the total movement of the shipment, including intermediate handling. An important issue in assessing these modal shift impacts is whether analytic tools and data exist to permit estimates of modal diversion under different policy, investment or demand scenarios. This section presents an overview of freight mode choice/diversion models that are currently in use or under development. Mode choice models can be used to examine such questions as how much freight transportation shifts from rail to trucking if the relative cost of rail increases.[2] Major sources of information used in this review

[2] Because very little information on truck traffic is available, most freight diversion models have dealt with the shift from rail to truck only. The TransMode Model, discussed in the review, has attempted to incorporate truck-to-rail diversion in its structure.

included "Memorandum on Past and Current Efforts Related to Intermodal Goods Movement" prepared by Mercer Management Consulting, Inc. for the Southern California Association of Governments' (SCAG) Interregional Goods Movement Study, the University of California's MELVYL bibliographic search system, and reports obtained from the University of California-Berkeley's Institute for Transportation Studies library, and the Washington Resource Library Consortium.

Existing freight modal diversion models fall into two general classes: **Aggregate** and **Disaggregate.**

Disaggregate models predict the *probability* that any individual shipment will travel on a particular mode (e.g., rail or truck). These models can include as variables any or all of the key determinants of demand: commodity, shipment size, length of haul, freight rates, transit time, etc. Parameters are estimated for each variable in the model using regression techniques applied to the characteristics of a sample of actual shipments. When the models are then used to predict mode choice, they require a database containing the characteristics of a sample of shipments. The values of individual variables can be altered for each individual shipment and when the results of the model computations are summed over all of the shipments in the sample, the model will predict what proportion of the shipments will select a particular mode. Unfortunately, disaggregate shipment-by-shipment freight databases are relatively rare, and they are frequently collected only on a case-by-case basis for particular studies. More often, data on freight transportation are aggregated into what is described as transportation or commodity flows. In some cases, these databases may include the percentage of the shipments made by rail, truck, air, etc. The databases may also differ in the level of commodity and geographic detail they contain; many databases which use the Standard Transportation Commodity Classification (STCC) system to classify commodities may report data at the 1-digit level (very aggregate) or the 5-digit level (very disaggregate), and commodity flows may be reported between states, between regions within a state, or between cities.

Because commodities flow data are generally more available than disaggregate shipment data, some economists and planners have instead developed **aggregate models** to predict freight mode choice. These models assume a set of *average* characteristics for many of the same variables that are included in disaggregate models (e.g., average length of haul for flows between two states). Nonetheless, these models are useful when the analyst is interested in mode choice effects on aggregate flows (e.g., how do mode shares change for all shipments in California) and disaggregate data are available. In the case of aggregate models, it is necessary to have data on the baseline commodity flows and modal shares in order to exercise the models. If these flow data are not available for a particular time period that is the subject of the analysis, they may often be estimated using economic data and projection. Examples of each type of model are presented below, and their characteristics are summarized in Tables 3.1 and 3.2 . For more detail the reader is referred to the earlier-referenced NCHRP 8-30 report, from which these summaries were abstracted.[3]

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[3] NCHRP Project 8-30: *Characteristics and Changes in Freight Transportation Demand.* Cambridge Systematics, et al, for the National Cooperative Highway Research Program, October 1995.

Aggregate Mode Choice Models

- ***Babcock and German's Changing Determinants of Truck-Rail Market Shares*** – Babcock and German's objective was to determine the impact of deregulation on truck and rail market shares at the national level. Two equations were estimated separately for the periods before and after deregulation, respectively. For each period, each equation was also estimated separately for seven two-digit manufacturing groups.

  The equations were estimated using ordinary least squares, and specify rail market share as a function of relative rail and truck rates, the nominal interest rate, and relative services. The equations estimated for the post-deregulation period also include yearly dummy variables to measure the effects of deregulation and changes in the truck size and weight regulations. The Babcock and German models were estimated for the entire US, with no origin-destination pairings or length of haul distinctions. A weakness in this regard is that the truck and rail rates used are suspect because they employ different units for rail and truck, they assume that trucking rates do not differ by commodity, and they use national rates without O-D detail, which does not account for local variations nor distance of haul.

- ***Friedlander and Spady: A Derived Demand Function for Freight Transportation*** – Friedlander and Spady model the demands for truck and rail services to deliver outbound goods as factors in the production process. Their approach uses a system of non-linear equations which calculate the total cost of production for an industry, and the share of those costs contributed by each production input. The equations include rail and truck cost share equations to represent transportation inputs, with truck and rail rates as variables. Thus, if rail rates are increased, the model can be used to determine the change in the rail cost share and the truck cost share for a given industry. The model does include service characteristics, such as value of shipment, density of commodity, average length of haul, and average shipment size as variables, but only as determinants of inventory costs and not as determinants of rail or truck costs. While this model is one of the most sophisticated tools identified, there are difficulties in using it to assess freight mode shifts. The limitation is that the model represents modal activity in terms of cost share, such that if rates are changed, the model tells how much the given industry will spend on rail and truck transportation. These "cost share" changes as a proxy are difficult to translate into activity units such as ton-miles.

- ***Oum: A Cross-Sectional Study of Freight Transport Demand and Rail-Truck Competition in Canada*** – This procedure is similar to the Friedlander and Spady approach in that it is based on a system of cost and input demand equations which specify transportation services used to deliver outbound goods as a factor of production. However, a major difference between the two approaches is that Oum's model was developed from cross-sectional data of inter-regional commodity flows rather than regional industry data. An appealing aspect of the model is that for each commodity, truck and rail expenditure shares to deliver a ton on a given link are defined as a function of link-level modal freight rates, average speeds, reliability, and distance.

- *University of Montreal Box-Cox Logit Model of Intercity Freight Mode Choice* – Picard and Gaudry of the University of Montreal developed an approach to calculating mode choice which applies the "Box-Cox transformation" to explanatory variables in a logit model.[4] The Box-Cox transformation is thought to be an improvement over the linear logit form because the impact of a unit change in any of the independent variables changes in a non-linear fashion depending on the value of the independent variable when the change is made. Thus, for example, the impact of a $1 increase in shipping rates is greater for a $50 shipment than for a $100 shipment. The Picard and Gaudry models include freight charges and transit time as independent variables. The models were estimated from intercity commodity flows for 64 commodity groups using aggregate [Canadian] interprovincial flow data which were disaggregated to the intercity level using input-output techniques and a modified gravity model.

- *California Freight Energy Demand Model* – The California Energy Commission's Freight Energy Demand Model (CALFED), which was developed by Jack Faucett Associates in 1983, projects VMT by mode and rail-truck modal diversion as part of an overall framework for forecasting freight energy consumption. The CALFED procedure disaggregates freight flows in California by 16 commodity/activity categories, five sub-state regions, and six origin-destination (O/D) regions. Modal diversion is determined as a function of the relative cost of rail and trucking, and is calculated for each commodity and each O/D region. A parameter that measures the sensitivity to service cost (i.e., rail costs as compared to truck costs) has been calculated for each commodity and this is applied to the change in the rail cost advantage per ton-mile for transport of each commodity to or from each O/D region. This parameter is a measure of how much the rail share (expressed in terms of ton-miles) of the shipments of a given commodity will change for every dollar change in the rail cost advantage per ton-mile as compared to truck costs. An adjustment is made which takes into account the current mode split for each commodity shipped between each O/D pair. Thus, flows which have a relatively even mode split are assumed to be very *competitive* and the sensitivity to each mode's cost of service is the major determinant of mode shift when the relative costs of rail and trucking change. Whereas, flows which are *dominated* by one mode or the other are less competitive and experience less relative

[4] The logit model is often used to estimate a variable which is a proportion (for example, mode share). This is a nonlinear functional form that is used when it is believed that the impact of a unit change in the independent variables does not have a constant impact on the proportion being estimated. The standard form of the logit model for two choices is:

$$S = \frac{expU_1}{expU_1 + expU_2}$$

$$\text{where } \quad U_1 = a_0 + a_1 X_1^b$$
$$U_2 = a_2 X_1^b$$

are called utility functions, and there can be as many explanatory variables X_n as are necessary. If the parameter b=1, the equation is called the linear logit form, and this applies to a situation in which the impact of the explanatory variable on the share variable, S, is constant over most values of X but which varies as S approaches either 0 or 1. In cases in which the impact of X on S depends on the value of X over all values of X (such as the example provided above for the impact of shipping rates on modal shares), the Box-Cox transformation can be used to convert the terms in the equations for U_1 and U_2 to non-linear terms for all values of the parameter b.

diversion in response to a change in rail or trucking costs. Aside from this adjustment (which implicitly takes into account the importance of non-cost variables on the historic mode split for a given commodity shipped between a given origin and destination), the CALFED modal diversion algorithm only considers explicitly the impacts of changes in the relative costs of rail and trucking and does not consider the impacts of changes in other service variables.

Disaggregate Mode Choice Models

- ***The AAR Intermodal Competition Model (ICM)*** – The Association of American Railroads' (AAR) ICM model was originally developed at MIT by Chiang, Roberts, and Ben-Akiva.[5] The model uses a logit formulation to predict mode choice probabilities for each shipment in a sample of shipments. A weighted sum of these probabilities based on the distribution of shipments in the sample, provides an estimate of market share for each mode. The utility functions in the model *are* a function of transport rates, storage costs, capital costs in transit, loss and damage costs, order costs, loss of value in shipment, shipping distance, shipment value, and commodity use rate.

  Originally, transport rates for the model were *estimated* using a side procedure developed at MIT. In the current version, rail costs are computed using the Uniform Rail Costing System and truck costs are estimated using a detailed truck costing model developed for AAR. Most other level of service attributes are estimated with models based on survey data collected by AAR or others and maintained in proprietary data bases. Commodity attributes, such as value, shelf life, etc., are contained in a commodity attribute file which has been periodically updated for AAR by Roberts. The model is solved by taking a sample of rail shipments from the ICC (now STB) Waybill Sample as a starting point. The rail costs for these shipments are then calculated by the model, taking into account any changes in costs associated with the policy scenario being analyzed. The alternative trucking modes are then identified and the AAR WINET model is used to compute the trucking costs. Total logistics costs for rail and trucking alternatives for each shipment are calculated, and the logit model is used to determine the probability that the shipment will go *by rail*. The probabilities for each shipment are weighted by the percent of the total tons that each shipment represents in the sample. These weighted probabilities are summed to get the rail share.

  While the ICM is an attractive mode share model because of the its level of detail and its disaggregate approach, the original published version of the model was estimated with data which by now are extremely dated, and much of the input data which are necessary to apply the model are in proprietary data bases that were never published (such as the Commodity Attribute File). The level of detail in the model makes it prohibitive to construct these data files from published sources, so its use for most ordinary analyses is limited.

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[5] *Development of a Policy Sensitive Model for Forecasting Freight Demand, Final Report*, Y.S. Chiang, P.O. Roberts, and M. Ben-Akiva, Center for Transportation Studies, Massachusetts Institute of Technology, Cambridge, MA, for Office of the Secretary, US Department of Transportation, December 1980.

- *Transmode Rail-Truck/Truck-Rail Diversion Model* – The US Department of Transportation contracted Transmode Consultants, Inc. to develop a disaggregate truck-to-rail/rail-to-truck diversion model (shippers logistics cost model). This model, completed in 1995, runs on a personal computer. An important aspect of this model is the incorporation of a module that performs *truck-to-rail* diversions. Unfortunately, this is perhaps the weakest part of the model since there is no good up-to-date truck flow data to measure truck-to-rail diversions. The rail portion of the model is the strongest and employs the Interstate Commerce Commission's (now STB) confidential Carload Waybill Sample. The model still requires refinement of parameters and the more detailed capability to handle longer combination vehicles.

  The Transmode model runs in Microsoft Access and Excel, and while complex, it has a great deal of flexibility built into it so the user is able to adjust any of the multitude of variables necessary to test different policy scenarios. The model shows strong potential as a tool for estimating modal diversions.

- *Winston Disaggregated Qualitative Mode Choice Model for Intercity Freight* – This model was developed by Winston at UC-Berkeley in the late 1970s at the same time that the original version of the ICM was being developed at MIT. As with the MIT work, Winston sought to model shipper/receiver behavior in mode choice using disaggregate probability techniques. His model is estimated using a probit form and includes variables such as shipment size, commodity value, freight charges, transit time, service reliability, location relative to a rail siding, and annual sales as explanatory variables for mode choice. The model was developed from a shipment sample, and would be used to forecast mode choice for other simple shipments.

- *University of Calgary Logit Model for Intercity Goods Movement* – This model approaches the goods movement problem in much the same way as does a disaggregate model. Using interprovincial commodity flow data disaggregated to intercity flows, data are further disaggregated to determine the number of shipments by commodity in each of several weight groups for each city pair, and a logit model was estimated with rail and truck utility functions determined as a function of travel time and the product of freight rates and shipment size. The test model was estimated for meat shipments only using 1981 data from the Statistics Canada Record. While the model is useful for identifying modeling techniques and their reliability, the actual parameter estimates are only for a single commodity and are based on outdated Canadian data.

Summary of Modal Diversion Methodologies: Critical Features

Tables 3.1. and 3.2. summarize the critical features of the models that are discussed above. One of the most disconcerting findings to come out of the literature review was that, with the exception of the current AAR model (which is proprietary), few of the models reviewed were estimated with post-1977 data. In the US, this is because no comprehensive shipper survey has been conducted since the 1977 CTS. While there are more current data for rail shipments, there are no other shipment data bases for trucking. At present, the US Census Bureau is in the process of completing the 1993 Commodity Flow Survey (CFS) which will replace the old CTS as a primary commodity flow data base.

Table 3.1.
Aggregate Models

Model	Variables	Pros	Cons
California Freight Energy Demand Model (1983)	• Transport Cost • Prior Year Mode Split	• Provides O-D detail • Provides commodity detail • Modal cost sensitivities based on length of haul • Based on regional shipment data	• Estimated with 1977 CTS data • Does not include time variable or other non-transport logistics costs
Babock and German: Changing Determinants of Truck-Rail Market Shares (1989)	• Truck and rail rate • Prime interest rate • Truck/rail services • 1982 STAA	• Simple regression • Requires minimum amount of data • Accounts for inventory costs	• National level study: no length of haul, shipment size, or OD distinction • Can't use parameter estimates • Model is based on time series
Friedlander and Spady: A Derived Demand Function for Freight Transportation (1980	• Prices and quantities of production inputs • Price and quantity of output • Truck and rail rates • Density, length of haul, shipment size	• Models freight transportation as a factor in production process • Addresses simultaneity of transport rates, inventory costs, length of haul, and shipment size • Translog specification	• Estimated with 1972 cross-sectional data of 3-digit manufacturing industries • Inventory specification suspect • Difficult to implement, especially at BEA regional level
Oum: A Cross Sectional Study of Freight Transport Demand and Rail-Truck Competition in Canada (1979)	• Total tons by commodity by mode for each link • Model freight rates • Distance of link • Transit time • Reliability	• Freight transportation modeled as input into production process • Designed around same data limitations faced in this study • Translog specification • Addresses speed, distance, reliability, commodity characteristics • Feasible to estimate	• Estimated with 1970 Canadian traffic flows • Specification may be more accurate for commodities delivered primarily by private trucks • Assumes constant returns to scale and strict separability of transport related variables
Univ. of Montreal (Picard and Gaudry): A Box-Cox Logit Model of IntercityFreight Mode Choice (1993)	• Transport Cost • Transit time	• Provides O-D and commodity detail • Includes important policy variables • Non-linear model	• Estimated with 1979 Canadian data • Difficult to implement; required data are not available

Table 3.2.
Disaggregate Models

Models	Variables	Pros	Cons
AAR Intermodal Competition Model	• Transport Cost • Inventory Carrying Cost • Ordering Cost • Loss and Damage Cost • Loss of Value in Shipment • Origin county • Destination county • Distance • Shipment Value	• Detailed representation of mode choice with all relevant decision variables • Commodity characteristics and shipment characteristics specified in detail • Focuses on rail-truck diversion • Parameters and commodity attributes estimated with recent data: e.g., rail shipment taken from recent STB Waybill	• Published version of the model uses 1977 CTS and earlier data sources • Current parameters and commodity attributes are proprietary • Relies on survey data to estimate values of key variables • Most variables are not policy sensitive for ARB analyses
Transmode Rail-Truck/Truck-Rail Diversion Model (1995)	• Origin county • Destination county • Annual units shipped • Size/weight per unit • Value per unit • Shelf life • Warehouse requirements • Ordering cost • Cost of capital	• Estimates truck-to-rail modal diversions • Great user flexibility to test policies • Runs on personal computer (Microsoft Access and Excel)	• Incorporates several questionable parameter values • Truck-to-rail module hampered by lack of current/reliable truck flow data • Needs refinement to handle longer, combination vehicles
Winston Disaggregated Qualitative Mode Choice Model for Intercity Freight Transportation (1979)	• Shipment Size • Commodity Value • Freight Charges • Transit Time • Reliability of Service • Location relative to rail siding	• Estimates separate models by commodity group • Includes most of relevant service characteristic variables • Estimates rail and truck diversion in both directions	• Parameters estimated with 1975-77 data • Requires survey data to solve model, which are generally unavailable
University of Calgary (Sargious and Tam): Data Disaggregation Procedure for Calibrating a Logit Model for Intercity Goods Movement (1984)	• Transport Cost • Transit time • Shipment Value • Length of haul (dummy)	• Simulates a disaggregate approach with disaggregated data • Provides commodity and O-D detail • Includes all key policy variables	• Estimated with 1981 Canadian data for one commodity group • Costly to estimate with U.S. data • The quality of disaggregated data are questionable

Unfortunately, the parameters that were estimated with these models are now all biased because freight markets have undergone tremendous changes since 1977. The Railroad Revitalization and Regulatory Reform Act (4R Act) of 1976 and the Staggers Rail Act of 1980 eased numerous long-standing legal and regulatory restrictions on the railroads, and strongly affected the growth in double-stack containerized shipments since 1980. Similarly, the 1980 Motor Carrier Act (MCA) and the 1982 Surface Transportation Assistance Act (STAA) both relaxed federal regulations in the trucking industry. Prior to deregulation, trucking firms competed through levels of service rather than through rates, since rates were regulated. Rates, therefore, probably did not accurately reflect differences in service between truck and rail. After deregulation, however, rates began to more accurately reflect those differences. As a result, the information contained in rate variables today is different than it was in 1977. The STAA also helped to bias parameters estimated in 1977 because it led to efficiency improvements through changes in average shipment sizes.

Another factor contributing to the bias of these parameters is the change in the product mix of aggregate commodity groups that has taken place since 1977. As commodity groups change in consistency from relatively heavy, lower-valued goods to relatively light, higher-valued goods, the likelihood of their being hauled by truck increases. On the other hand, in some long-haul traffic corridors, double-stack trains are moving goods previously carried by truck.

Other changes that could have biased parameters estimated in 1977 are the length of haul distributions of commodities. Shifts in these distributions toward longer or shorter hauls will increase the tendency for a commodity to move by rail or truck, respectively. Furthermore, deregulation resulted in changes in the relative costs of truck and rail.

3.2.4 Rail/Truck Diversion through Use of Elasticities[6]

It is possible to estimate shifts in mode of carriage for freight when formal models, such as those described above, are not available, through the use of elasticity methods. Generally, the choice of a freight mode for a particular commodity shipment is determined by comparing the [perceived] total logistics costs (TLC) for the candidate modes or modal combinations that are practical for a given set of shipments. TLC consists of actual transport costs (or carrier charges) incurred by the shipper plus a variety of other logistics costs (including inventory costs, stock-out costs, etc.) incurred by the shipper or receiver. Any increase or decrease in TLC for use of a particular mode can result in diverting some traffic to or from the competing mode(s).

Modal shifts can be estimated using either disaggregated data on a sample of affected movements, or more aggregate data in which the total volume of such movements has been summarized by one or more key variables, such as commodity type. The diversion

[6] This section has been prepared from material found in *Characteristics and Changes in Freight Transportation Demand: A Guidebook for Planners and Policy Analysts.* Cambridge Systematics, et al, for National Cooperative Highway Research Program, Project NCHRP 8-30, June 1995. (Appendices F and G).

estimates can be derived from estimates of before-and-after TLC, from absolute or percentage changes in TLC, or for situations where other logistics costs are essentially unaffected from changes in transport costs incurred by the shipper.

Results of Effects of Changes in Truck Costs

The section below presents two sources of aggregate data that can be used for performing modal diversion when formal models are not available. These data are presented as elasticities of modal demand (in tons or ton-miles) relative to changes in rail rates or truck costs. Truck costs are used instead of rates because they are more easily estimated, and because the highly competitive nature of the trucking industry causes trucking companies to pass costs on to shippers in a fairly direct manner.

Cross-Elasticities from the ICM: One set of cross-elasticities was developed by Jones, Nix and Schwier,[7] using results obtained from the ICM model. These cross elasticities are presented in Table 3.3. Each elasticity represents the percentage change in rail ton-miles that would result from a 1% change in truck costs. For example, using the relationship shown for Food Products, between 2.0 to 2.2% of ton-miles would divert from rail to truck in the case of a 1% decrease in the cost of truck.

The elasticities shown in Table 3.3 are generally high (greater than 2.0) for most categories of finished or highly processed goods and much lower (below 1.0) for all categories of bulk materials and for automobiles. In using the elasticities from Table 3.3 a basic assumption must be that the relationship between truck and rail costs is reasonably *uniform* across the different market and service types, such that long-haul traffic would not be affected differently from short haul, nor would tank truck be affected differently from vans for hauling the same commodity.

An alternative to the use of elasticities for individual commodity groups is to use *overall* elasticities, such as shown in Table 3.4. This table presents six sets of overall cross elasticities developed from published results using the ICM data. For each source, the elasticities show the effects of a 1% change in truck costs on rail ton-miles, and on rail revenue. The estimated effects on rail revenue include revenue lost both as a result of lost traffic and due to rate reductions adopted to avoid further traffic losses.

The elasticities in Table 3.4 show some important differences. The first two elasticities assume a uniform change in costs for all use of combination trucks, while the last four assume that the changes in truck costs are relatively concentrated on longer-haul truck movements that tend to be more competitive with rail. The concentration of cost savings on relatively competitive operations results in greater diversion than would occur under a more uniform distribution of the cost savings.

[7] J. Jones, F. Nix and C. Schwier. *The Impact of Changes in Road User Charges on Canadian Railways*, Transport Canada, Sept. 1990 (Table 4.2).

Table 3.3 Implicit Cross Elasticities by Commodity Group Derived from ICM Results

Commodity	Rail Ton-Mile Cross Elasticities
Bulk Farm Products	0.02 - 0.03
Finished Farm Products	3.5 - 3.7
Bulk Food Products	0.62 - 0.83
Finished Food Products	2.0 - 2.2
Lumber and Wood	0.57 - 0.73
Furniture	4.0 - 4.7
Pulp and Paper	0.71 - 0.93
Bulk Chemicals	0.49 - 0.67
Finished Chemicals	3.2 - 3.5
Primary Metals	1.2 - 1.5
Fabricated Metals	5.2 - 7.3
Machinery	3.7 - 4.8
Electrical Machinery	4.1 - 4.8
Motor Vehicles	0.21 - 0.28
Motor Vehicle Parts	1.1 - 1.4
Waste and Scrap	0.17 - 0.22
Bulk All Else	0.14 - 0.19
Finished All Else	3.9 - 4.5

Source: J. Jones, F. Nix and C. Schweir, *The Impact of Changes in Road User Charges on Canadian Railways*, prepared for Transport Canada by the Canadian Institute of Guided Ground Transport, Kingston, Ontario, September 1990, Table 4.2

Table 3.4 Implicit Overall Cross Elasticities from the ICM

	Cross Elasticities	
	Rail Ton-Miles	Rail Revenue
1. Uniform Change in Truck Costs[1]	0.52	0.81
2. Canadian Tax Policy[2]	1.00	–
Size and Weight Analyses		
3. Bridge Formula B[3]	0.99	1.43
4. Twin 33s[3]	1.50	2.30
5. Twin 48s[4]	2.09 - 2.30	2.43 - 2.91

Elasticities derived from:

[1] Scott M. Dennis, *The Intermodal Competition Model*, Association of American Railroads, September 1988, pp. 7-9.

[2] J. Jones, F. Nix and C. Schwier, *The Impact of Changes in Road User Charges on Canadian Railways*, prepared for Transport Canada by the Canadian Institute of Guided Ground Transport, Kingston, Ontario, September 1990, p. 27.

[3] Jack Faucett Associates, *Modal Diversion Effects of Changes in Truck Size and Weight Limits*, Working Paper prepared for the Federal Highway Administration, July 1990, Exhibit 5.

[4] Sydec, Inc., Transmode Consultants, Inc., and Jack Faucett Associates, *Analysis of Longer Combination Vehicles*, Final Report, prepared for the US Department of Transportation, November 1993, Exhibits IV-4 and IV-11.

Cross Elasticities from CN/CP Study: Another set of cross elasticities comes from a set of modal diversion estimates that were developed by the Canadian Northern and Canadian Pacific railroads as part of a 1987 study in which the two railroads provided estimated ranges for the expected effects of three possible changes in truck size and weight limits on their traffic volume and revenue. Using estimates of the average reduction in truck costs for the three scenarios (which ranged from 8 to 14%), Jones, Nix and Schwier derived the implicit cross elasticities shown in Table 3.5.

The CP diversion estimates tend to produce slightly larger cross elasticities than the CN. More significantly, both sets of elasticities are appreciably *smaller* than those produced by the ICM for the effects of changes in truck size and weight limits. Part of the reason is assumed to be because the Canadian railroads have relatively large volumes of long-haul movements of low-value commodities, which tend to have lower elasticities.

Table 3.5. Implicit Cross Elasticities from CN and CP Analyses

	Cross Elasticities	
	Rail Ton-Miles	**Rail Revenue**
Canadian National	0.39 - 0.51	0.54 - 0.71
Canadian Pacific	0.35 - 0.59	0.59 - 0.92

Source: J. Jones, F. Nix, and C. Schwier, *The Impact of Changes in Road User Charges on Canadian Railways*, prepared for Transport Canada by the Canadian Institute of Guided Ground Transport, Kingston, Ontario, September 1990, Table 4.3.

Based on the results shown, it was concluded that, for *uniform* changes in truck costs, is its appropriate to assume cross elasticities of about **0.5 for rail ton-miles**, and **0.8 for rail revenue**. Separate cross elasticities were not obtained for rail *tons*. However, most rail traffic diverted to truck is likely to be intermodal, frequently moving long distances, or single carload traffic, most typically being shipped more moderate distances. (Most short-distance single carload shipments have already been diverted to truck while the longest haul movements are more insulated from rail competition than more moderate-haul movements). Therefore, the length of haul of newly diverted rail traffic is likely to be slightly higher than average, and the cross elasticity of rail tons is likely to be slightly smaller than that of rail tons. Hence, for a *uniform* change in truck costs, a cross elasticity of **0.4** might be a reasonable estimate. For changes in truck costs that are concentrated on the more rail-competitive truck operations, when expressed relative to the *average* change in costs for combination trucks, the cross elasticities are higher. In the case of the truck size and weight studies, the cross elasticities ranged from **1.0 to 2.3 for rail ton-miles** and from **1.4 to 2.9 for rail revenues**. Accordingly, for nonuniform changes in the cost of operating combination trucks, some judgment is necessary to determine the extent to which the changes are focused on rail-competitive truck operations, and hence the extent to which the elasticities should be modified.

Since rail routes usually are more circuitous than truck routes, the change in truck ton-miles will generally be smaller than the change in rail ton-miles; Multiplying the rail estimate by -0.85 can compensate for this difference.[8]

Effects of Changes in Rail Rates and Costs

The information about the modal diversion effects of changes in rail rates and costs is less readily available than the effects of changes in truck costs. Most traffic currently carried

[8] In *Modal Diversion Effects of Changes in Truck Size and Weight Limits*, by Jack Faucett Associates, 1990, rail routings were shown to average 16 to 18% more circuitous routings than truck.

by rail is fairly insulated from intermodal competition, though the portion of rail traffic that is not well insulated is somewhat larger than the corresponding portion for truck. Because of this, *uniform* percentage changes in rail rates are likely to result in diverting somewhat more traffic between modes than would the same percentage change in truck costs and rates.

Based on the earlier discussion, a uniform 1% change in truck costs would result in a 0.5% diversion of rail ton-miles and 0.4% of rail tons. However, because of rail's greater susceptibility to intermodal competition, a 1% change in rail rates might result in a diversion of about 0.75% of rail ton miles and 0.6% of rail tons (this implies that the *own elasticities* of rail ton-miles and tons to changes in rail rates are about -0.75 and -0.6, respectively, since an increase in rail rates will result in a decrease in rail traffic).

Changes in rail costs that apply primarily to truck-competitive traffic are likely to produce rate changes that are concentrated on this traffic. As in the case of truck costs, changes in rate that are concentrated on modally competitive traffic are likely to produce substantially higher elasticities than uniform changes in rate, with the highest elasticities (perhaps in the 2 to 4 range) likely for double-stack and trailer-on-flatcar traffic.

3.2.5. Estimating Freight Transportation Costs[9]

Transport costs are an important factor in the selection of freight transport mode, and are therefore relevant in the analysis of modal diversion as discussed in the previous section. There are a variety of measures commonly used for expressing the costs of a freight shipment. Transport costs vary with shipment size and length of haul, so measures which relate cost per ton-mile, cost per shipment-mile, or cost per container-mile are generally the most useful. This section presents estimates of costs for truck and rail freight transport.

Truck Costs

In general, truck costs rise with distance at a somewhat less than linear rate, although for lengths of haul above 50 or 100 miles, they increase only slightly more slowly than length of haul. Accordingly, cost per vehicle-mile is a particularly useful measure for analyzing truck costs. Although the cost per mile of haul for intercity truck is fairly independent of length of haul, there are a number of factors that influence this cost, including trailer type, configuration, annual mileage, percent of empty miles, payload, driver costs, fuel efficiency, type of vehicle ownership, truckload vs. less-than-truckload operation, and various traffic, topographical and taxation factors.

Table 3.6 offers estimates of costs for truckload operations for different truck configurations. Truckload operations are the truck shipments which are generally

[9] NCHRP 8-30: *Characteristics and Changes in Freight Transportation Demand.* Cambridge Systematics, et al, for the National Cooperative Highway Research Program, June 1995. (Appendix F).

Table 3.6. Estimates of 1995 Costs for Truckload Operations (1995 dollars)

Configuration	GVW (lbs)	Cost per Vehicle Mile	Percent Miles Empty	Cost per Loaded Mile	Payload (lbs)	Density (lbs/ft³)	Cost per Ton-Mile (cents)
Dry Vans							
5 Axle 48'	52,000 61,000 78,000	$1.19 1.20 1.25	15% 15% 15%	$1.39 1.40 1.45	24,500 33,000 50,000	7.0 9.4 14.3	11.31 8.51 5.79
5 Axle 53'	56,000 78,000	1.20 1.26	15% 15%	1.40 1.46	27,100 49,100	7.0 12.7	10.33 5.93
6 Axle 48'	54,000 80,000 86,500	1.23 1.28 1.31	15% 15% 15%	1.43 1.49 1.51	24,500 50,500 57,000	7.0 14.4 16.3	11.71 5.92 5.31
5 Axle Twin 28'	59,800 80,000	1.24 1.29	15% 15%	1.45 1.50	28,600 48,800	7.0 12.0	10.13 6.15
7 Axle 40' + 28'	105,500	1.34	15%	1.56	69,200	14.0	4.77
9 Axle Twin 48'	95,200 127,400	1.47 1.58	15% 15%	1.72 1.84	49,000 81,200	7.0 11.6	10.17 4.52
7 Axle Triple 28'	83,400 116,000	1.46 1.55	15% 15%	1.70 1.79	42,900 75,500	7.0 12.3	8.59 4.74
Other Trailer Types							
Refrigerated Van (5 Axle 48')	78,000	1.35	15%	1.57	48,100		6.53
Flatbed (5 Axle 48')	78,000	1.25	25%	1.62	50,400		6.43
Tank (5 Axle 42')	78,000	1.56	45%	2.73	53,400		10.23
Hopper (5 Axle 42')	78,000	1.20	40%	1.93	53,400		7.18
Dump (5 Axle 36')	70,000	1.18	40%	1.90	43,600		8.70

Source: Jack Faucett Associates, The Effects of Size and Weight Limits on Trucks Costs, Working Paper, Revised October 1991 assumed to be most competitive with rail. These estimates were originally developed by Jack Faucett Associates in 1991, using forecasts of 1995 conditions and expressed in 1988 dollars; they have since been converted to 1995 dollars using an inflation factor of 1.16 (derivation covered in the referenced NCHRP report). The table illustrates how costs – measured in cost per ton-mile – vary by vehicle configuration, weight (GVW), trailer type, empty ratio, and payload.

The data show that for a given truck configuration and trailer type, costs per mile rise slowly with GVW and payload, but costs *per ton-mile* drop appreciably. Costs per vehicle mile range from $1.19 to $1.25 for 5-axle 48-foot dry vans to $1.46 to $1.55 for 7-axle Triple 28-foot configurations. Cost per vehicle mile increases as payload to GVW ratio increases. Costs per ton-mile range from about 6 to 11 cents per ton-mile for 5-axle 48-foot dry vans (with the lower costs coming at higher payloads to GVW ratios), to 5 to 9 cent per ton-mile range for 7-axle Triple 28-foot configurations (again with lower costs coming at higher payload to GVW ratios). For purposes of having an order-of-magnitude estimate, $1.25 per vehicle mile is suggested, and about 8 cents per ton-mile.

Rail Costs

Table 3.7 presents average railroad rates per ton mile for selected major commodity groups. The rates are in cents per ton mile, shown in 1995 dollars (table has been updated from 1992 dollars using the Railroad Cost Recovery Index[10]). The commodity groups shown in the table account for about 87% of rail tonnage and 88 percent of revenue.

The average railroad rate in 1995 was 3.24 cents per ton-mile. Rates per ton-mile tend to vary inversely with length of haul, size of shipment, and commodity density. For estimates of rates and costs are required that must account for the effects of these factors, use of the Surface Transportation Board's (formally ICC) Uniform Rail Costing System (URCS) can be considered. Also, several commercial sources are available, including MicroURCS (by Snavely, King & Associates of Washington DC). For most analytic purposes, such precision will probably not be necessary and the estimates in Table 3.7 should be adequate. The average rates in this table are all between 2 to 4 cents per ton-mile, with one notable exception, transportation equipment, which is about 9.6 cents per ton-mile. This is because assembled motor vehicles constitute a fairly low density per carload compared to other commodities.

[10] *Railroad Facts, 1996 Edition.* Association of American Railroads.

Rail Cost Recovery Index: 1992 = 149.8; 1995 = 160.4 Multiplier: 1.0707

Table 3.7 Average Rail Rates per Ton-Mile for Selected Commodity Groups

STCC Code and Commodity Group		Cents per Ton-Mile (1995 Dollars)
01	Farm Products	2.34¢
11	Coal	2.25
14	Nonmetallic Minerals	3.19
20	Food Products	3.13
24	Lumber and Wood Products	3.09
26	Pulp and Paper Products	4.21
28	Chemical Products	4.18
29	Petroleum and Coal Products	4.31
32	Clay, Concrete, Glass, and Stone Products	3.84
33	Primary Metal Products	3.40
37	Transportation Equipment	9.65
40	Waste and Scrap Materials	4.10
42	Empty Shipping Containers	4.10
46	Miscellaneous Mixed Freight	3.12
All Commodities		**3.24¢**

3.2.6. Transportation System Utilization and Level of Service

As described earlier, the translation of freight activity into an estimation of emissions occurs through a set of descriptor variables of freight traffic's utilization of the transportation system and the ensuing level of service that it experiences. This is the third step in the framework shown back in Figure 3.1. These variables relate freight transportation activity in terms that are meaningful for emissions, most particularly in VMT or ton-miles by facility, time of day, and average speed. In the conventional (4-step) transportation planning process, these activity variables are determined through the Traffic Assignment procedure, which loads vehicle trips from origin-destination trip tables onto a "coded" transportation network. Relationships between highway capacity and volume are then related to speeds, and these volumes by speed group are then input to the emissions model.

For freight, the issues are somewhat more complex, and perhaps less developed. First, the conventional transportation planning process does not do a very accurate or rigorous job in representing truck trips. The basis for projecting freight transportation levels and representing those trips in trip tables is greatly limited by the lack of good data on truck travel, including purposes, trip lengths, ultimate origin-destinations, etc. In particular, *intercity* freight traffic, which has one or more of its trip ends outside a metropolitan area, would be treated as an "external" trip, and aggregated into the total for an "external station", with ultimate origin/destination unknown. When truck trip tables are assigned to the transportation network, it is not with much sensitivity to route "choice" factors as might be important in real life, but on stochastic factors like capacity and minimum time path. The larger capacity requirements of trucks are generally handled by assigning them a Vehicle Equivalent factor, representing how many light-duty vehicles that the given type of truck would represent on the facility. Generally a factor of 2 is used for single-unit trucks, and 3 for heavy combination trucks.

A real concern is in how route choices would actually occur if freight operators (or the customers they serve) were faced with changes in service or conditions based on changes in the transportation system, or governing rules and policies. The reader is referred to Section 4.3.1 in Appendix A-1 which presents a thorough discussion of the factors involved in route diversion for freight, including:

- Transportation infrastructure capacity and performance levels;
- Cost, quality and reliability concerns of shippers;
- Specialized facility and service requirements;
- Industry decisionmaking processes and control; and
- The nature of the competitive environment.

These considerations are described, and examples given illustrating their application.

Given the factors that become important in route choice, which then determines trip length, VMT, level of service and speeds, the issue then is how to relate this to the traffic assignment approach. While there are no obvious overall "fixes" to the current assignment procedures, one technique that may be of considerable practical value for applications where the number of sites or facility choices is of manageable size is the *sample shipment* approach adopted by NCHRP project 8-30 and seen in many of the freight modeling studies. This approach is also being incorporated in a Quick-Response Freight Planning Manual which is currently being developed for FHWA, and seen as a complement to this Freight Emissions study. The "sample shipment" approach addresses the complexity of a freight movement (mode, route, commodity, origin-destination, time of day, etc.) by tracking the characteristics of a given trip from point A to point B. The trip is mapped out as it would normally occur, and then the profile of the trip as it would be expected to change under the strategy would also be developed; the difference in characteristics of the two trips is used to estimate the net impacts of the test strategy.

3.2.7. Data Resources for Freight Planning

The existence and quality of data are extremely important factors in setting the parameters on a freight analysis. A major impediment to better freight planning has traditionally been the limitation in the availability of appropriate data on freight movements and choices. The techniques that are presented in this study must all be framed in the context of presumed availability of data.

Data sources are generally characterized into "primary" and "secondary" sources. Primary sources are those which are obtained directly and specifically to support the particular analysis need, whereas secondary data are those found in pre-existing sources and used with acknowledgment of the respective compromise in their not being specific to the given problem.

Primary data sources that are valuable in addressing freight planning and emissions analyses include:

- Surveys which provide specific information on shipments, such as origin-destination, mode, commodity distribution, and vehicle type, class and weight; these may be performed by local, regional or state agencies, may vary greatly in size, coverage and objective, and are typically done only at infrequent points in time. These may be done by mail, by phone, by direct interview, or through intercept methods
- Direct interviews with shippers or freight haulers to get at information on market characteristics, commodity movements, economic/service issues, and types of operational problems experienced or solutions recommended.
- Traffic monitoring data, including truck volumes by functional class, truck class, time of day.

Secondary data sources can be of significant value to local or state planning or evaluation interests. These data are often compiled at a national level by, or under direction [or regulation] of a federal agency, although there are numerous state, industry and private vendor services. Some of the key data bases that exist to support freight/emissions analysis include:

- Truck Inventory and Use Survey, of the US Census
- National Truck Activity Survey, by the US Census
- Highway Performance and Management System, of the FHWA
- The National Commodity Flow Survey, by Census and US DOT
- Carload Waybill Sample, from the Interstate Commerce Commission (now the STB)
- AAR's weekly railroad traffic statistics
- National Truck Trip Information Survey, of the University of Michigan Transportation Research Institute
- American Intermodal Equipment Inventory, from MARAD/US DOT
- Port Import/Export Reporting Service of the Journal of Commerce
- TRANSEARCH, a private database compiled and administered by Reebie Associates
- World Sea Trade Service, of DRI/McGraw-Hill
- State fuel tax reports

Each of these secondary sources is briefly profiled below, and their essential characteristics are tabulated in Tables 3.8. to 3.10. beginning on page 3-28. These characteristics include:

- Agency or firm which compiles the database
- Mode or modes covered
- Scope of the data/survey

- Whether it addresses/contains information on:
  - Freight Shipments
  - Commodity distribution
  - Origin/destination

- Facility conditions:
  - Condition
  - Capacity
  - V/C ratio

- Level of Applicability:
  - National
  - State
  - Region
  - County
  - Corridor
  - Facility

- Collection Frequency:
  - Periodic
  - Multi-year
  - Annual
  - Quarterly

- Analytical Issues in Considering Use:
  - Historical
  - Summarized in publication
  - Easily understood, used
  - Cost, and cost-effective
  - Availability
  - Forecastibility

Descriptions of Existing Secondary Databases

- *Truck Inventory and Use Survey (TIUS)* – is a vehicle-based survey of truck activity conducted by the Bureau of the Census as part of the quinquennial Census of Transportation. TIUS collects data to measure truck usage from a sample of approximately 150,000 trucks, vans, and minivans out of an entire population of 50 million private and commercial registered trucks. Data collection is performed through a mail survey sent to vehicle owners covering physical and operational vehicular statistics. TIUS data are available on public use tapes; however, records are modified to avoid disclosure of sampled vehicles or operating companies.

- *Highway Performance Monitoring System* – includes universe data consisting of a small amount of information *for* all public road mileage in each state. Additional information on physical characteristics, condition, use, and performance for sample roadway sections within the state are included in the sample data. Sample data are statistically valid data, consisting of accident data, system length and travel by functional system, and travel activity by vehicle type are also reported in summary form. Accident data contains summary statistics on fatal and non-fatal injury accidents.

- *1993 Commodity Flow Survey* – is an extensive survey of commodity movements by type of transportation mode in the United States. The CFS is a continuation of statistics collected in the Commodity Transportation Survey from 1963 through 1977 with improvements to the methodology, sample size, and scope. The survey, designed to collect data on the flow of goods and materials by transportation mode, has become a regular part of the quinquennial Economic Censuses. The Bureau of the Census and the US Department of Transportation conduct the CFS sampling approximately 200,000 randomly selected domestic establishments. Each selected establishment reports a sample of 30 outbound shipments for a two week period in each of four calendar quarters for the sample year. Information collected includes origin, destination, commodity classification, and mode of transport.

- *Carload Waybill Sample* – is a confidential, stratified sample of rail carload waybills representing the movement of rail cars and commodities over the nation's rail system. Large railroads have supplied the government with a stratified sample of waybills for the past 40 years to produce the waybill sample database. The primary purpose of the sample was to enable planners to estimate flow and rate characteristics of rail carload traffic on a continuous national *level*. Information provided in the ICC waybill sample includes origin, destination, routing, type of car, commodity classification, mileage, revenue, carloads, tons and ton-miles. The public-use file uses aggregated regions and provides no railroad detail.

- *American Intermodal Equipment Inventory* – This system records all intermodal equipment of US-flag intermodal marine carriers and major container leasing companies operating in the US It includes for each company the type, number, and dimensions of containers and trailers. Chassis are shown by type, number of units, and containers carried. The size and number of slots available on container vessels and barges is recorded. Forty-foot equivalent units of trailers along with automobile capacity are also included for Ro/Ro ships and barges.

- *Port Import/Export Reporting Service* – is a database of intermodal containerized shipments information for containers entering or leaving US ports. The PIERS database is collected and maintained by The Journal of Commerce. Data are collected from import manifests and export bills of lading, either electronically or directly from hard copy documents. Intermodal carriers, steamship lines, and US port authorities all subscribe to this reporting service for container shipment planning purposes. Shipment, carrier, and container characteristics are entered in the database; however, data are taken from shipping documents rather than from physical inspections. Beginning in 1994 origin/destination information is available for intermodal shipments; however, reported origins and destinations may be billing addresses rather than shipment points.

- *TRANSEARCH* – is a traffic flow database providing transportation information of domestic freight traffic movements by market area, traffic lane, commodity, and mode of transport. The database has been developed and maintained since 1978 by Reebie Associates and is targeted for use by motor carriers, railroads, steamship companies, equipment suppliers, public sector agencies, and major shippers. A variety of data reports is available by origin/destination markets, commodity, or traffic lane. Traffic flow information is taken from a number of sources such as ICC Waybill Sample, Census of Transportation, and Import/Export Trade Statistics.
- *World Sea Trade Service* – is a commodity flow database developed and maintained by DRI/McGraw-Hill. The data service provides forecasts and assessments of global commodity flows for use in policy analysis, port traffic forecasting, and world seaborne trade. Data are organized by country (origin/destination), commodity, service liner type, and cargo weight. Data reports can be generated on short-term quarterly movements or long-term five-year horizons.

Table 3.8. Scope and Coverage of Data Sources for Freight-Intermodal Planning and Analysis

Data Source	Agency/Firm	Modal Coverage						Scope
		Highway	Rail	Waterborne	Transit	Air	Intermodal	
American Intermodal Equipment Inventory	MARAD/U.S. DOT			●			●	Record of all intermodal equipment of U.S.-flag intermodal marine carriers & container leasing com.
Carload Waybill Sample	Interstate Commerce Comm.		●				○	A stratified sample of all rail waybills - traffic, commodity, revenue, and routing characteristics.
Commodity Flow Survey	Bureau of the Census/U.S. DOT	●	●	●	●		●	Tracking commodity movements and transportation usage for policy analysis of U.S. transportation.
Highway Performance Monitoring System	FHWA/U.S. DOT	●						Includes universe data consisting of a small amount of information for all public road mileage.
National Truck Activity Survey	FHWA/FRA/OTS/U.S. DOT	●						Follow-on of 1987 TIUS designed to collect detailed information on travel characteristics.
Port Import/Export Reporting Service	Journal of Commerce			●				Detailed information on maritime shipments to facilitate international trade of intermodal containers.
TRANSEARCH	Rebie Associates, Inc.	●	●	●	●	●	●	Multimodal traffic statistics between 183 Business Economic Areas by commodity type.
Truck Inventory and Use Survey	Bureau of the Census	●						A survey of registered trucks producing state universe estimates of the nations truck population.
World Sea Trade Service	DRI McGraw-Hill			●				International waterborne shipments to anticipate changes in liner and bulk cargo movements in future.

● Complete ○ Partial

Table 3.9. Type of Information by Modal System of Data Sources for Freight-Intermodal Planning and Analysis

	Highway							Rail						Intermodal					
					Facility						Facility						Facility		
Data Source	Vehicles/Passengers	Freight Shipment	Commodity Distribution	Origin/Destination	Condition	Capacity	V/C Ratio	Freight Shipment	Commodity Distribution	Origin/Destination	Condition	Capacity	V/C Ratio	Freight Shipment	Commodity Distribution	Origin/Destination	Condition	Capacity	V/C Ratio
American Intermodal Equipment Inventory																		●	
Carload Waybill Sample								●	●	●									
Commodity Flow Survey		●	●	●				●	●	●				●	●	●			
Highway Performance Monitoring System	●				●	●	●												
National Truck Activity Survey		●	●																
Port Import/Export Reporting Service														●	●				
TRANSEARCH		●	●	●				●	●	●				●	●	●			
Truck Inventory and Use Survey			●																
World Sea Trade Service		●	●					●	●					●	●				

● Complete ○ Partial

Table 3.10. Collection, Distribution, and Utilization of Data Sources for Freight-Intermodal Planning and Analysis

	Area						Collection				Sponsorship					Media				Analytical Issues					
Data Source	National	State	Region	County	Coridor	Facility	Multi-year	Annual	Quarterly	Periodic	U.S. DOT	Bureau of Census	Army Corps of Eng.	Private	Other	Hard Copy	Computer Disk	Public Use Tape	CD-ROM	Historical Data	Summarized in Publication	Easily Understood	Cost Effective	Readily Available	Forecastable
American Intermodal Equipment Inventory	●						●				●					●							●	●	
Carload Waybill Sample *	●		●					●			●				●			●	●	●		○	●	●	●
Commodity Flow Survey	●	●	●				●				●	●				●				○	●	●	●	●	
Highway Performance Monitoring System	●	●		●	●			●			●						●		●	●	○		●		●
National Truck Activity Survey	●	●									●								●			○	●	○	
Port Import/Export Reporting Service	●					●		●						●		●	●			●	●	●			●
TRANSEARCH	●	●			●			●						●		●				●	●	●			●
Truck Inventory and Use Survey	●	●					●					●				●		●	●	○	●	●	●	●	○
World Sea Trade Service	●							●						●		●				●	●	●			●

● Complete ○ Partial

* Public Use File readily available, but confidential file; government agencies require confidentiality agreement and ICC approval. (Pulic Use File may not be useful for a particular MPO because BEA level of aggregation is typically larger than MPO coverage)

3.3 Freight Emissions Estimating Procedures

3.3.1 Introduction

Agencies who have attempted to estimate the air quality impacts associated with freight activities or changes in those activities due to changes in policy or operation have generally had a difficult time. Freight transportation itself is a difficult analysis topic for transportation planning agencies, since freight is generally not well accounted for in conventional transportation planning models and systems. As discussed in the earlier sections of this chapter, the shortcomings in transportation data and models have been a major impediment to good analysis, and this problem is only magnified when the specific subject is *intercity* freight. However, when the process reaches the stage of estimating freight emissions, a separate set of issues and challenges arise.

Freight emissions are, of course, accounted for in emissions inventories. However, they are embedded in the reported totals, and not specifically as *freight emissions*, and they appear in different source groups which are calculated by different entities using different methods. Those methods are described below in Section 3.3.2. The specific question of what emissions are generated by freight-related modal activities is a separate analytic challenge, since the emissions methods estimate emission productions from vehicle or equipment classes, which do not directly correspond to the freight activity segments. Hence, it is necessary to develop side procedures to allow for separation of the given freight activity. Procedures have been developed by this study, and are presented as part of the methodology in Chapter 4.

Still another issue concerns the accuracy, flexibility, and comparability of the emissions factors or rates themselves. Trucks and rail emissions are calculated on a very different basis. Truck emissions are linked to vehicle miles of travel, while rail emissions are based on energy consumption. Thus, when activity is shifted between the two modes, a number of issues are raised when attempting to allege differences in emissions changes. Also, these methods do not allow for [easy] manipulation of key variables which are known to affect the emissions rates, such as speeds, acceleration, grade, load, technology or fuels. A number of important studies have looked at the emissions from freight transportation and the challenges of obtaining more reliable and versatile forecasting methods. These research efforts were reviewed in the conduct of this study, and are summarized in Section 3.3.3. Drawing upon these earlier studies, plus the specific expertise of study team members with developing emissions estimating methods, some important new emissions procedures and capabilities have been developed as part of this study; they, too, are introduced as part of the methodology in Chapter 4.

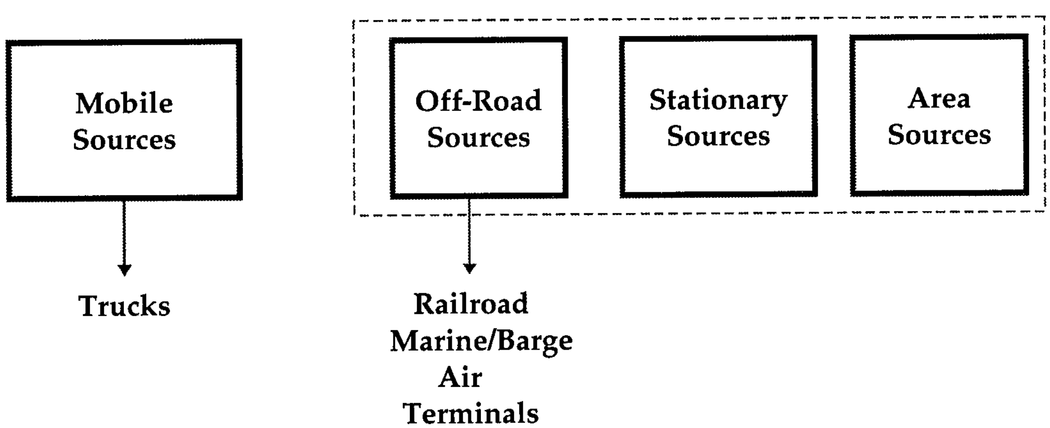
It should be noted that the material presented in the main body of this report is intended to be of an overview nature. More in-depth, technically-oriented presentations of these subjects are included in the appendix.

3.3.2 Current Emissions Estimating Procedures

This section describes the procedures that are currently used to estimate freight-related emissions. The fact that the methods do not lead to a direct assessment speaks to the degree that freight emissions have been considered by transportation planning agencies. The discussion is held to a summary level only, in order to maximize the communication of key issues. There are clearly more details to these procedures than it is possible to cover in a short summary. Readers are encouraged to consult the documentation that appears in Technical Appendices A-3 and A-4 for more depth in understanding these methods and their implications.

Freight emissions are neither calculated as a separate category in emissions models nor presented as such in inventories. Rather, emissions from freight activities are subsumed within broader modal groupings and across more than one primary "source" category, as indicated in the following diagram:

Freight Emissions Location Within Inventory Source Groups



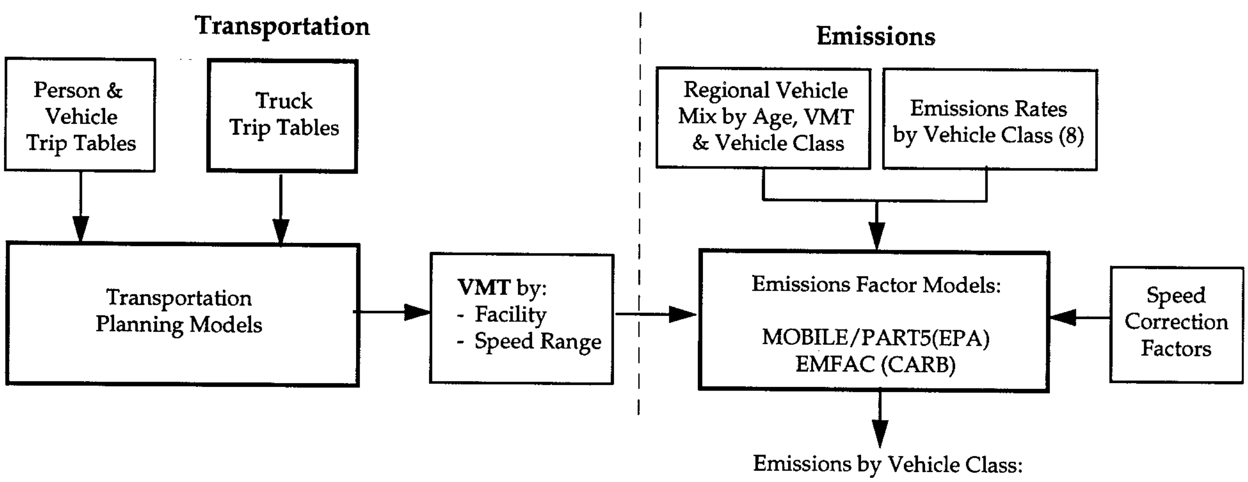
Trucks are contained within the Mobile Source group along with all other highway-based transportation modes, while Railroads and Air (passenger and freight), Barge/Marine, and related terminal and port activities are part of the Off-Road Source category. There are some important issues in this source distinction: different procedures are used in estimating Mobile and Off-Road emissions, and different groups have responsibility for the estimates. Generally, the accounting for Mobile Source emissions is the responsibility of regional MPOs and state DOTs, while the Off-Road Sources, along with Stationary and Area Source emissions, are usually prepared by the state/regional environmental agency. This separation of technique and authority raises issues of comparability, and of how effectively and realistically freight modes and freight strategies are made to "interact" when assessing their travel and emissions impacts.

Neither truck nor rail freight emissions are broken out as a separate inventory category. In the case of truck, *intercity* emissions must be factored out from vehicle size, weight and fuel type categories, while for rail, passenger and freight operations must be separated.

Truck Emissions

Truck emissions are calculated as a product of truck *activity level* (usually VMT from transportation models) and *emission factors* (grams of pollutant per vehicle mile) which are accessed, adapted and applied through emissions factor models. The U.S. Environmental Protection Agency (EPA) uses the MOBILE series of models (currently MOBILE5a) to estimate emission rates for volatile organic compounds (VOC), carbon monoxide (CO), and oxides of nitrogen (NOx), while the PART5 model is used for particulate matter (PM) and sulfur oxides (SOx) estimates; the California Air Resources Board (CARB) uses the EMFAC series of models (currently EMFAC7F) for all five pollutants. This linkage is illustrated graphically in the following diagram:

Calculation of Truck Emissions



The estimate of truck transportation activity is normally derived from regional transportation planning models, consisting of some form of the traditional "4-step" planning process. This process is fairly coarse in its treatment of truck relative to passenger transportation. Truck trip tables, along with person-vehicle trip tables, are assigned to the transportation network, resulting in estimates of trip volume and VMT by facility/functional class. Travel speeds for those facility segments are calculated from the respective volume/capacity/speed relationship.

The representation of truck activity in current-generation transportation models is limited in several ways. First, the activity data on truck travel going into the model as reflected in the truck trip tables is very weak. Original trip tables may be formed from results of a truck activity survey, although such surveys are very infrequently done. The trip movements are linked to economic activity levels by geography, to obtain origin-destination trip flows. These tables are updated through association of new economic activity data with truck ratios determined in periodic roadway classification counts. The transportation model's function is primarily one of *assigning* these truck trips to the travel network using statistical parameters, and not in any ability to reflect behavior in response to changes in travel conditions or policy. This means that there is little or no capability within the transportation models to test sensitivity of transportation actions which are directed at or may impact upon trucks. Also, truck VMT *per se* is not a direct input to the emissions model. Rather, truck's influence on emissions is through the VMT proportion it represents in the regional vehicle stock.

When the analysis shifts to the emissions models, important detail in the transportation activity outputs is lost through averaging. A composite emissions factor is developed which represents the weighted average emissions rate for the entire regional vehicle base. This vehicle base is defined in terms of the 8 MOBILE/EMFAC vehicle classes, and weighted by their respective age distribution and annual VMT (in the local population, or using national defaults provided in the models). The vehicle classes used in MOBILE/EMFAC are as follows:

LDGV: Light-duty gas-powered vehicle (primarily passenger cars)

LDDV: Light-duty diesel-powered vehicles (under 6,000 lbs., GVW)

LDGT1: Light-duty gas-powered trucks (under 6,000 lbs, GVW)

LDGT2: Medium duty gas trucks (6,000 to 8,500 lbs. GVW)

LDDT: Light duty diesel trucks (6,000 to 8,500 lbs. GVW)

HDGV: Heavy duty gas vehicles (over 8,500 lbs., GVW)

HDDV: Heavy duty diesel vehicles (over 8,500 lbs., GVW)

MC: Motorcycles

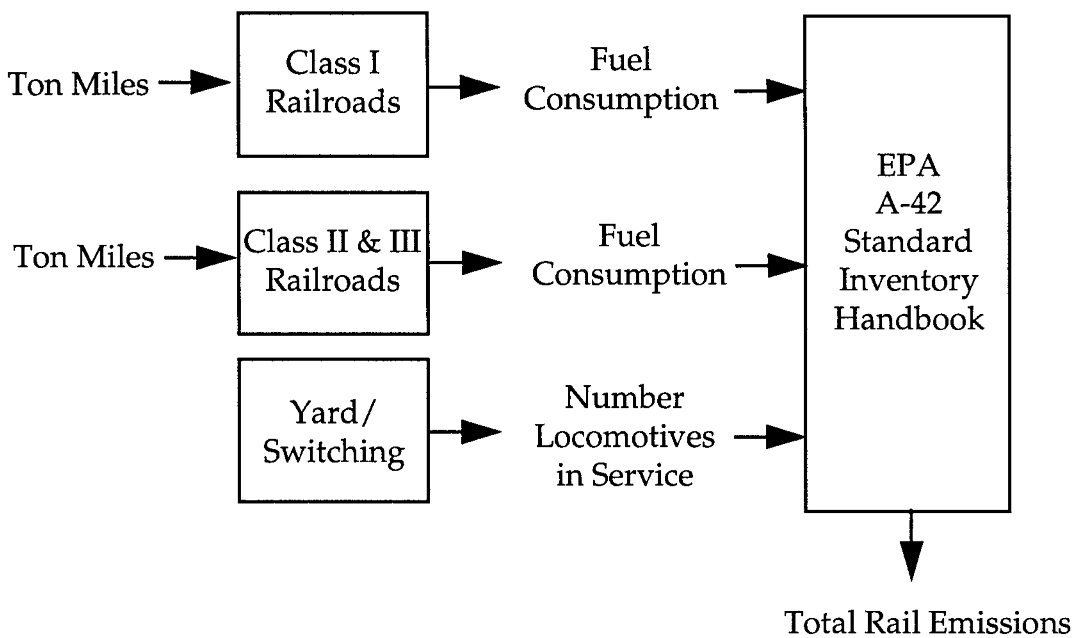
The emissions rates themselves are obtained from standard "drive cycles", which are usage profiles thought to be typical of how an average vehicle is used. The drive cycle incorporates start-up, speed/acceleration cycles, and cool-down periods for a "typical" trip, each of which contributes to an average "emissions rate" that is then associated with VMT to determine emissions. The speed associated with a particular VMT (by functional class, facility, time of day, etc.) may be compared with the average speed upon which the drive cycle emissions rates for VOC, CO and NOx were based, and the emissions rates adjusted accordingly using "speed correction factors". However, these corrections do not extend to the individual vehicle classes. Idling emissions and added emissions from acceleration events or system queuing and delay, which are common for freight, are not distinguishable from the average drive cycle emissions rate.

Separate estimates of emissions for freight activity, and "intercity" freight in particular, are not currently prepared. Rather, these emissions are embedded in the emissions model's HDDV (heavy-duty diesel) vehicle class. The HDDV class is comprised of diesel-powered vehicles having a gross vehicle weight (GVW) of over 8,500 pounds. Since trucks used for intercity (line-haul and drayage) applications are almost exclusively 3+ axle combination units with GVWs in excess of 33,000 lbs., side calculations are necessary to estimate the intercity freight contribution. Procedures for this calculation are presented later in Chapter 4 as part of the new methodology.

Rail Emissions

The method for computing rail emissions is prescribed by EPA in its Standard Inventory Handbook A-42[11]. This procedure first determines rail fuel consumption which has occurred as a result of ton-miles of activity generated in the subject region, and then multiplies that fuel consumption times an emissions factor, using factors provided in A-42. Somewhat different guidelines apply to estimating activity/fuel consumption for national (Class I) vs. regional (Class II and III) railroads. Emissions from local yard and switching operations are estimated through the number of locomotives in service, rather than fuel consumption. This process is profiled schematically on the following page:

Calculation of Rail Emissions



EPA recommends the following procedures for obtaining local fuel use data. For Class I railroads, EPA suggests application of national fuel use rates (gallons per ton mile), as contained in annual submittals to the STB (formerly ICC), to data on ton-miles of freight carried on local tracks from the individual railroad company. Because the STB data are considered proprietary, they would not be readily obtainable, and it would be necessary to use national data on fuel consumption multiplied by the local freight tonnage carried.

Data for Class II and III railroads must be obtained from individual railroads. Since these railroads are not required to keep track of fuel consumption, there are questions as to the availability and reliability of these data. The emissions from yard (i.e., "switching") locomotives are based on a separate "duty cycle", which reflects yard operations and a

[11] "Handbook of Air Pollution Emission Factors", US Environmental Protection Agency, AP-42, 1985. (With supplements A through F, 1993).

national locomotive roster for yard operations. These yard emissions are then obtained by multiplying an annual emissions rate which assumes 365 days of typical operation times the number of locomotives normally in service.

Some adjustments are available within this current methodology, although they are relatively limited:

1. Adjustment of the SO_2 emissions factor to account for fuel sulfur content.
2. Accounting for the actual locomotive fleet composition in a local area.
3. Using the actual locomotive duty cycle(s) for the project area.

3.3.3. Findings from Prior Freight Emissions Studies

In attempting to address the shortcomings in existing emissions estimation techniques for freight, a literature review was conducted to identify possible insights from other related research. This review indicated that while there have been many studies of fuel use by various freight modes, there has been only limited study of emissions from freight. However, since emissions relate significantly to engine energy and fuel use, which is dependent on travel amount, load, power ratios, empty backhauls, etc., it appeared that some insight could be derived from these freight energy studies toward improved emissions relationships.

Thus, in considering emissions associated with freight transport, it appears to be useful to have some way of relating emissions to "freight moved", measured in terms of tons or ton-miles. For intercity freight, when comparing truck and rail, one finds that truck freight is often measured in vehicle miles, while rail is much more likely to be expressed in ton-miles. This is mainly because of rail's bulk-commodity character and historical regulatory reporting requirements, while truck is more often expressed in terms of cargoes (shipments), rather than ton-miles, with much less of a reporting requirement.

Therefore, studies of freight energy use were thought to be of potential value in obtaining both estimates of freight emissions. Brief descriptions of key freight energy/emissions studies are furnished below. A more detailed discussion can be found in Appendix A-5.

Great Lakes Study: The Great Lakes Commission published a study in 1993 which compared energy use and emissions for truck, rail and marine freight in the Great Lakes and St. Lawrence River areas.[12] The report considered 11 scenarios which represented shipping routes and products shipped in this region. Thus, all 11 scenarios considered both marine and rail shipments, while only 3 also involved truck shipments. Commodities were mainly bulk items such as coal, potash, ore, limestone and grain.

Truck energy requirements were evaluated by assuming a fuel economy of 5.3 miles/gallon, and round trips with empty backhauls were assumed to have the same

[12] Steve Thorp, "Great Lakes and St. Lawrence River Commerce: Safety, Energy and Environmental Implications of Modal Shifts," Great Lakes Commission, Ann Arbor, MI, June 1993.

fuel economy with no freight carried as for a fully-loaded truck. Rail freight movements also used various fuel efficiencies depending on the cargo carried. These ranged from 467 ton-miles/gallon for petroleum product shipments to 877 ton-miles per gallon for taconite pellets. Round-trip fuel efficiencies were reduced to account for empty backhauls.

The emission rates for truck were obtained from the EPA MOBILE4 model. (1988 model year trucks operating in 1993). Rail emission factors were taken from a 1991 Booz·Allen Locomotive Emissions Study for the California Air Resources Board.[13] These factors are shown in Table 3.11., along with the fuel-based factors used for trucks.

Table 3.11. Emission Factors from Great Lakes Study Units of pounds per gallon of fuel for each mode		
Species	Rail	Truck
HC	0.0179	0.0198 (1.7 g/mi)
CO	0.05905	0.1039 (8.9 g/mi)
NOx	0.499	0.2266 (19.4 g/mi)

All modes were assumed to have empty backhauls with essentially the same fuel usage as a loaded haul. The study did not account for loading (drayage) operations. Only the destination to destination emissions for the individual mode were considered.

In the three comparisons of truck versus rail, rail usually had an advantage in fuel efficiency and emissions. The only case where trucks had an advantage over rail was for a short-distance shipment where the truck distance was 194 miles while the rail distance was 360 miles. For this scenario, the truck NOx emissions were 113.1 tons/year as compared to 114.97 tons/year for rail, though NOx emissions were the only pollutant where trucks had an advantage over rail.

Abacus Study[14] - This study, which was done for the Federal Railroad Administration in 1991 by Abacus Technology Corporation, examined the relative fuel efficiency of truck vs. rail freight. The intent was to compare fuel use for a variety of route and commodity combinations in which truck and rail are competitive. Fuel consumption for both truck and rail were determined through simulation programs. The simulations showed a ratio of truck to rail fuel use for comparable commodity/route combinations in the range of

[13] "Locomotive Emission Study," prepared by Booz Allen & Hamilton, Inc., for California Air Resources Board, January, 1991.

[14] "Rail vs. Truck Fuel Efficiency: The Relative Fuel Efficiency of Truck Competitive Rail Freight and Truck Operations Compared in a Range of Corridors." Abacus Technology Corporation, Report DOT/FRA/RRP/91/2 for Federal Railroad Administration, U.S. Department of Transportation, April 1991.

1.40 to 5.61 for trip lengths of over 100 miles, and between 4.03 to 9.00 for trip lengths under 100 miles

The Abacus study was motivated by the objective to develop reasonable comparisons of truck vs. rail energy intensiveness under specified conditions. It was recognized that any such attempt to compare the two modes would depend greatly on the context of the test, with parameters to include commodity, trip length, loads, and equipment. To provide this control over context, the Abacus study defined 27 long-distance and 11 short-distance routes where the two modes were believed to be relatively competitive.

The truck simulations were done by Cummins using its proprietary Vehicle Mission Simulator (VMS). The tests used a variety of truck types (van trailer, flatbed, container trailer, dump trailer and auto hauler). Aerodynamic aids (low-restriction trailers, low profile tires, etc.) were assumed to be in place, and the truck engine used was a Cummins F-350, a very efficient engine. The effect of empty backhauls was not considered, which has the effect of making truck fuel consumption lower than it would be in a typical (round-trip) operating environment.

The estimates of rail fuel use were performed using a simulation model initially developed by the Missouri Pacific Railroad, and later acquired and modified by the US Department of Transportation. The simulations were done in consultation with Class I railroads to ensure the use of realistic train consists. In the simulations, each train had a mix of locomotive and freight car types believed to be typical. Some of the simulations had empty cars, but the study did not attempt to simulate the average number of empty cars. The particular commodity considered in each simulation occupied one freight car with a known tare weight. The total weight of the car (tare plus lading) was used to compute the fuel used to transport the freight through a formula that apportioned the fuel for the shipment from that of the entire train by the ratio of the total weight of the subject rail car (tare plus lading) to the gross weight of the train. This assumption of the methodology has been seen by some reviewers as a potential inaccuracy, in that it does not assign the total fuel use of the train to freight. The method assumes that all loaded freight cars carry the same lading, and since these weights are variable (and an unknown number are empty), the procedure might be expected to underestimate the rate of fuel consumption.

The results of the Abacus study are presented as a series of fuel economy comparisons. While the study did not investigate truck or rail emissions per se, the study is significant because of the close relationship between fuel consumption and emissions, and its results have been used by others for emissions purposes. As part of the rulemaking on the California Federal Implementation Plan, EPA used the study results in evaluating NOx emissions from truck and rail freight, and concluded that truck freight produced about three times the NOx emissions per ton mile of rail freight[15]. Also using the Abacus findings, an ASME task force conducted analysis which concluded that switching 10% of

[15] Peter F. Hutchins, "Estimate of Relative NOx Emissions Resulting from Movement of Freight by Truck and Train," departmental memorandum, US EPA Vehicle Regulation Branch, Feb. 14, 1994.

intercity freight from truck to rail would decrease overall NOx emissions by 6.2%, PM by 4.4%, HC (hydrocarbons) by 1.6%, and CO by 2.9%[16]

Transport Canada Study – This study examined both the fuel use and emission rates for freight transport by truck, rail, marine vessel, air freight, and pipelines in Canada[17]. Two analysis approaches were used: the first examined the aggregate statistics for energy use and total freight transported; the second approach, similar to the Abacus study, compared truck and rail fuel economy and emissions for selected routes. The author also used a freight demand model to predict (1) the generation and/or attraction of freight on an origin-destination basis, (2) modal splits, and (3) interzonal freight flow. Fuel consumption data for rail were obtained from Canadian railroads; data for trucks were taken from average fuel consumption rates.

Unlike the Abacus study, the simulations performed in the Transport Canada study assigned all the fuel used by the train to the freight. The study also examined only a limited number of routes, and the power-to-weight ratios used in those simulations (1.0 to 2.1 HP per trailing ton) were lower than those used in the Abacus study (0.8 to 5.7 hp per trailing ton). This study initiated a debate among Canadian trucking and rail groups regarding the relative merits of rail and truck freight. Critique of the study[18] contended that: drayage energy associated with rail was not accounted for, nor were different shipment lengths by rail and truck; low values for freight fuel efficiency were assumed; whether *overall* comparisons between "all" truck freight and "all" rail freight account for commodities that are shipped exclusively by one freight mode; and whether the use of ton-miles per gallon as a measure of freight efficiency is most appropriate in comparison to say, energy use per dollar of revenue or energy use per dollar of gross domestic product.

The debate over the results of the Transport Canada study highlights the need to ensure that freight emission and fuel economy studies fully account for all emissions and energy use between the origin and the final destination. Comparisons of specific routes and commodities, which can provide a direct comparison, do not allow any statement about overall energy use and emissions from a freight system.

Envirotrans: Envirotrans[19] did a recent study for Canadian freight transport which considered truck, marine, rail and air freight. This study did consider emissions as well as energy use. It also considered emission of CO_2 as a greenhouse gas in addition to the traditional criteria pollutants. This study provides a direct contrast to the route-specific

[16] "Statement on Surface Transportation of Intercity Freight", Internal Combustion Engine Task Force, American Society of Mechanical Engineers, May 1992.

[17] A.M. Kahn, "Energy and Environmental Factors in Freight Transportation," Transport Canada Publication Number TP 10492, Ottawa, Ontario, July 1991.

[18] Fred P. Nix, "Trucks and Energy Use. A Review of the Literature and the Data in Canada," prepared for Ontario Trucking Association, Quebec Trucking Association, and Canadian Trucking Association, August 23, 1991.

[19] Chris Holloway, "The State of Canada's Railway Industry and Resulting Environmental Implications. A Review," submitted to Environment Canada, Transportation Systems Division, by Envirotrans, Ottawa, Canada, May 1994.

study by Abacus; it relied on overall energy use for the various transportation modes to arrive at an overall emissions impact. However, this has the net effect of lumping together urban areas and rural areas where air emissions may not be a significant problem. The emission factors used in this study show a higher NOx emission factor for trucks in 1990 than for rail; this does not agree with the data presented previously on the standard EPA emission factors and raises questions about the usefulness of the study findings.

Conclusions on Freight Studies - Studies of emissions and energy consumption studies related to freight transportation can be categorized as comparisons of individual shipments or as comparisons of overall freight systems. The former group of studies is useful in considering relative modal efficiencies for specific routes and commodities, but does not give any information on overall efficiency or emissions from an entire modal freight system. However, studies that compare entire freight systems are subject to the criticism that they do not compare equivalent types of shipments under equivalent circumstances.

The review and assessment of these various studies has produced some important insights, however, into the development of freight emissions estimating procedures. First, it is essential that any analysis which compares emissions generated by truck or rail in relation to strategies that would divert activity from one mode to the other must make every effort to account for the key variables that contribute to fuel use and emissions and which may be different across modes. This implies an analysis which focuses on the movement of a shipment from door to door, accounting for intermediate handling and distribution as well as the line-haul portion of the trip. It also means consistency with regard to commodities carried, trip length, circuity, load factors, and empty ratios. The findings have been taken into account in the development of the methodology which is presented in the next chapter.

4.0 Methodology for Freight Emissions Analysis

4.1 Freight Emissions Issues and Analytic Needs

4.1.1. Purpose

The 1990 Clean Air Act Amendments (CAAA) and the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) dramatically raised the level of attention to be devoted to transportation and emissions in general, and freight/intermodal activities as an important component. The CAAA imposed National Ambient Air Quality Standards (NAAQS) for critical pollutants, and schedules for attainment of those standards linked to the level of severity and the type of pollutant. State Implementation Plans (SIPs) constitute the state's and region's action plan for achieving the standards, and the Conformity requirement under ISTEA reinforces this plan and commitment by requiring annual Transportation Improvement Programs (TIPs) to conform with the provisions of the SIP. ISTEA also introduced new requirements with regard to management of congestion, pavements and bridges, and intermodal facilities, all of which have an important and obvious connection with freight transportation.

These procedural and regulatory requirements have stretched many states' and MPOs' abilities to meaningfully respond with effective analyses and actions, particularly in relation to freight activity and its emissions. Whereas freight operations may play an important role in transportation system demand and performance, and contribute to the emissions levels of potentially "critical" pollutants, the data and analytic tools available to most planners can be quite limited. Examples of the types of issues that are raised in connection with freight transportation and emissions include:

- Freight Emissions: What contribution is made by freight activity to regional or intercity corridor emissions and air quality? What is the relationship between freight activity and specific pollutants, such as VOCs, CO, NOx, and SO_2 which may be critical by themselves or as contributors to other pollutants, such as ozone or secondary PM? Will total or relative contributions change/increase over time, and by how much?
- Capacity Enhancements: What impact do transportation system improvements (infrastructure or management) have on freight activity levels, location, operating practices/efficiency and emissions? Does the impact of the improvement on freight help or detract from the project satisfying conformity requirements?

- Control Measures: What are the effects of specific freight-oriented Transportation Control Measures (TCMs) on freight activity and emissions? Which are the most effective TCMs for particular areas, freight systems, or pollution problems?

- Intermodal Activity: Do local travel levels and emissions increase or decrease when freight is shifted from truck to rail-intermodal (i.e., when terminal handling and local drayage are considered)? What emissions are generated by prolonged idling delays at terminals? What are the best strategies for increasing intermodal connectivity and efficiency? What benefits from intermodal shifts accrue to the initiating metropolitan area vs. elsewhere (e.g., in an intercity corridor or other metropolitan area vs. intercity corridor)?

- Operating Efficiency: What is the sensitivity of freight emissions rates to operational factors such as speed, delay, ramp accelerations, load, grade, etc.? Which strategies yields the most cost-effective change in emissions through changes in these factors?

- Technology/Fuel Improvements: What potential for emissions reduction lies in [further] improvements in vehicle/emissions control technology, stronger standards, alternative or enhanced fuels, or intensified inspection/maintenance of freight modes? Which have the most potential? How do they compare with other emissions control measures? What is the most effective way of increasing their rate of introduction?

- Cost-Effective Emissions Reductions: What is the cost to reduce a given quantity of emissions of a particular pollutant through actions directed at freight as opposed to accomplishing the reduction credit through some other source, such as Stationary or Area?

- Secondary Impacts: What impact does freight activity have on other traffic when the two are juxtaposed, e.g., trucks traveling on peak-period/congested highways or railroad/highway vehicle conflicts at rail at-grade crossings?

- Effects of Background Trends on Freight Activity: How do macro-level changes in economic trends, national policies, markets, prices, shipper or customer preferences affect overall freight activity levels, their distribution by mode, or their resultant emissions impacts?

Addressing issues such as these calls for an analytic capability and a level of familiarity with freight industry practices and transportation concepts that likely does not exist at the typical state or metropolitan planning agency. The purpose of this study has been to assess these needs and to provide a comprehensive package of information and planning aids to help these organizations better cope with these important emerging issues and identify effective solutions. This Chapter presents a methodology that permits the assessment of many of the questions that were posed above. It is intended to both help planners and decisionmakers increase their familiarity with freight issues, and also to be able to work through a fairly comprehensive family of transportation or emissions related questions or control actions. The methodology has been purposely scaled to adapt to a range of needs and capabilities, from fairly simple (e.g., screening) analyses where the level of accuracy demanded or the availability of local data are limited, to situations where accuracy and realism is critical to the assessment. The following section describes the development of this methodology.

■ 4.2 Considerations in Development of the Freight Analysis Methodology

4.2.1. Desired Characteristics

Discussions with state and metropolitan planning professionals suggested that freight issues are often not addressed in current transportation or emissions planning efforts because:

- The relationships can be foreign and intimidating to traditional transportation planning agencies, encouraging freight issues to be treated cautiously and conservatively, potentially obscuring the identification of relevant improvements or actions.
- Because of its concentration of infrastructure holdings and decisionmaking in the private-sector, the freight industry is often considered outside the range of public-sector planning and decisionmaking.
- Freight transportation is heavily driven by market forces, the relationships for which are not easily captured through traditional deterministic "choice" models such as are used in passenger transportation to evaluate price and service change effects on demand levels, destination, mode, route or time of day.
- The data on freight activity and operations are very limited for planning purposes.
- Intercity freight, in particular, poses problems with regard to market definition, separation from local freight, external forces, intra and intermodal competition, scarce data, and geographic authority and control.

The "methodology" that has been developed under this study is best seen as a first-generation effort to elevate the analysis capabilities of MPOs, States and others to a higher level than the "residual" methods that are typically used. The goal is that this methodology would enable, and thus encourage, planning and regulatory agencies to more readily and systematically consider freight, and enjoy the flexibility to look at a wider range of potential actions that could have benefits not only in terms of reduced freight emissions, but economic and mobility objectives as well, to shippers, haulers, and the general public.

The following, therefore, are the guiding principles that are used in developing the methodology:

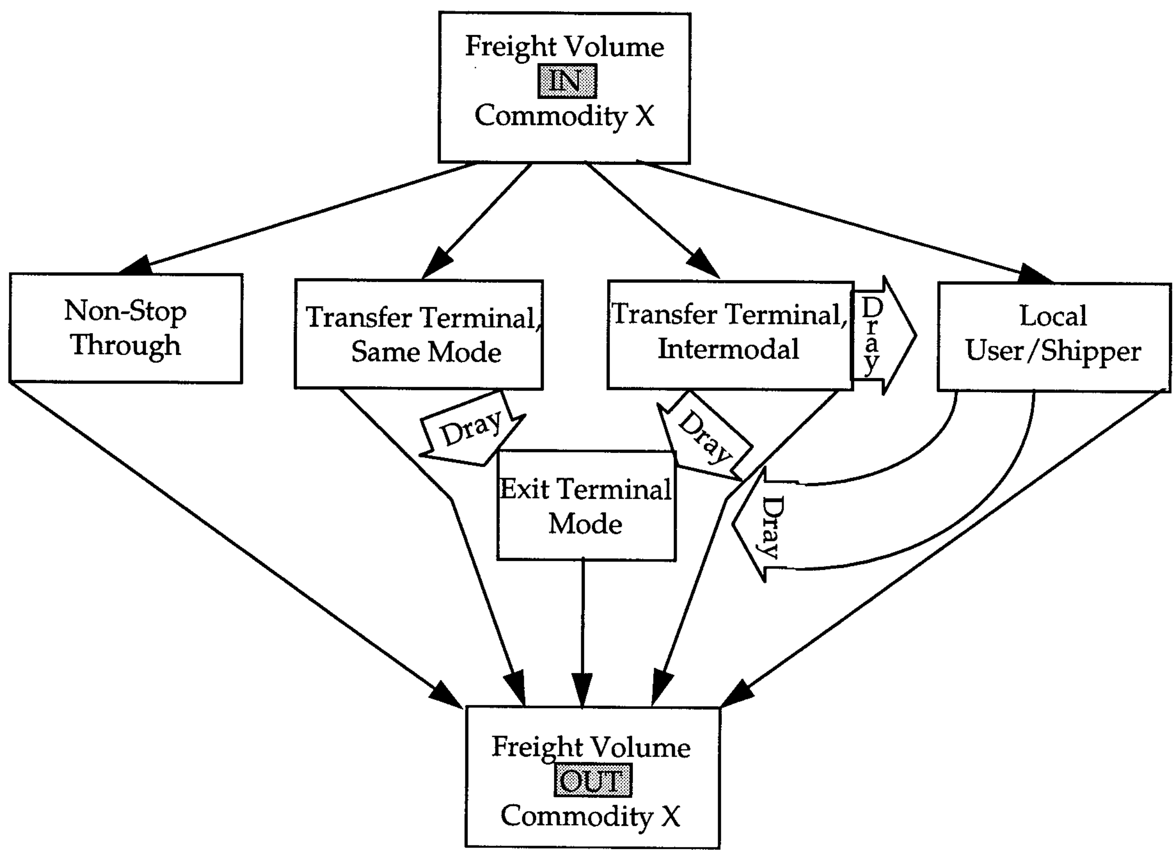
1. *To improve overall understanding of freight transportation patterns, relationships, issues and problems, so that the context is more clear, and*
2. *To help identify potentially effective strategies, to make evident where and how they would be effective, and to provide useful guidance in how to most effectively evaluate them.*

4.2.2. A Descriptive Framework of the Intercity Freight System

The starting point for a methodology which serves the dual objectives framed above is to create a descriptive model, or "framework" of the system that is being addressed, highlighting its major components and key relationships. Strategies and analysis methods can then be associated with this framework to impart realism and accuracy.

Basic characteristics of the primary intercity freight modes were described in Chapter 2. In this section, a schematic rendering of this system is offered as a way of isolating the different types of intercity freight movements that occur, which constitute primary market segments that have distinct service characteristics and analysis requirements. Figure 4.1. pictures a flow of a given commodity "X", at a certain volume level, traveling into, through, and/or out of a hypothetical area/region. The type of commodity, X, the volumes which are shipped, and the O/D pattern of shipment are a function of national and regional economic conditions and relationships, the local economy as a user or supplier of the commodity, the position/function of the area in the regional, corridor and national/international transportation system, and the quality and capacity of its facilities.

Figure 4.1. Intercity Freight Flow Patterns Highlighting Intermodal Transfer



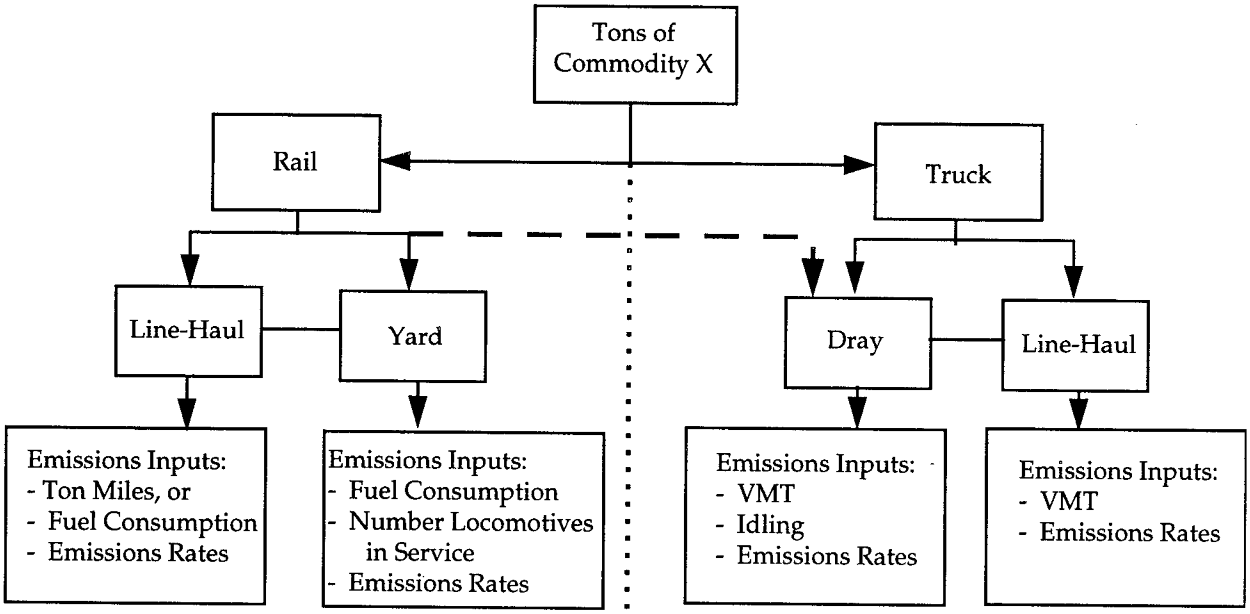
Four generic types of movements describe the major flow options for intercity freight:

- **Direct "Through" Shipment:** The shipment neither begins nor ends in the given area, but does make use of the region's transportation system as a corridor *without any transfer taking place.*
- **"Intra-Modal" Transfer:** The shipment passes through the region and remains on the same primary mode (truck, rail, air, waterborne, etc.) *but undergoes transfer & handling from one transport unit to another.* This transfer may occur directly, from one unit to another, or *it could involve secondary handling (drayage) from one terminal or yard to another.*
- **"Intermodal" Transfer:** The shipment enters the region by one mode but leaves by another primary mode. This transfer between mode *A* and mode *B* may occur directly at a single terminal, or *it could (and frequently does) involve transfer between terminals by a secondary mode, generally local drayage truck.*
- **Local Shipper or User:** For those goods that have an origin or destination in the subject area, there are different transport options. Some shipments may go directly from/to the local shipper/user and the external shipper/user; this is certainly possible with intercity truck carriage, and to a much more limited/conditional extent with the other modes (rail, water, other). In many instances, however, *it is necessary for a local shipper to rely on a secondary mode to transport cargo to/from the primary modal carrier, and this is generally local drayage truck.*

In practice, it can be difficult to distinguish between what is regarded as "drayage" activity -- defined as moving cargo between terminals -- and local distribution. Local delivery of a trailer or container, for example, from a local port or rail terminal to an end user would probably look more like a *drayage* move because of the load and the type of truck. However, smaller shipments which are distributed in 2-axle trucks may be regarded as local delivery, and not associated with the intercity movement. These distinctions are not particularly important for the analysis technique introduced in this report, but would become a concern in terms of proper accounting in a regional inventory.

Figure 4.2. further separates these typical freight movements into their distinguishing modal features which are relevant for determining emissions. Assuming that the choices for shipping Commodity *X* are either via rail or truck (the coverage of the present methodology), and that the basic options are either of the two modes exclusively, or transfer of the shipment within mode or between mode via a terminal exchange and some secondary handling, the emissions categories which will require accounting for in an analysis are as portrayed in Figure 4.2.

Figure 4.2. Accounting for Rail/Truck Emissions Impacts



The categories are:

- Line-haul truck, for which the primary determinants for calculating emissions are VMT and the corresponding Emissions Rate.
- Line-haul rail, for which the primary inputs to the emissions calculation are Fuel Consumption (a derivative of ton-miles of load transported) and Emissions Rate.
- Dray truck, for which the primary inputs to emissions are VMT and the applicable Emissions Rate(s), but where substantial periods of idling emissions may require special accounting.
- Rail yard or switching operations, for which emissions are currently estimated through the number of locomotives in service, but for which fuel consumption and emissions rate(s) are the underlying determinants, as are idling emissions (which the "locomotives in service" relationship tries to account for).

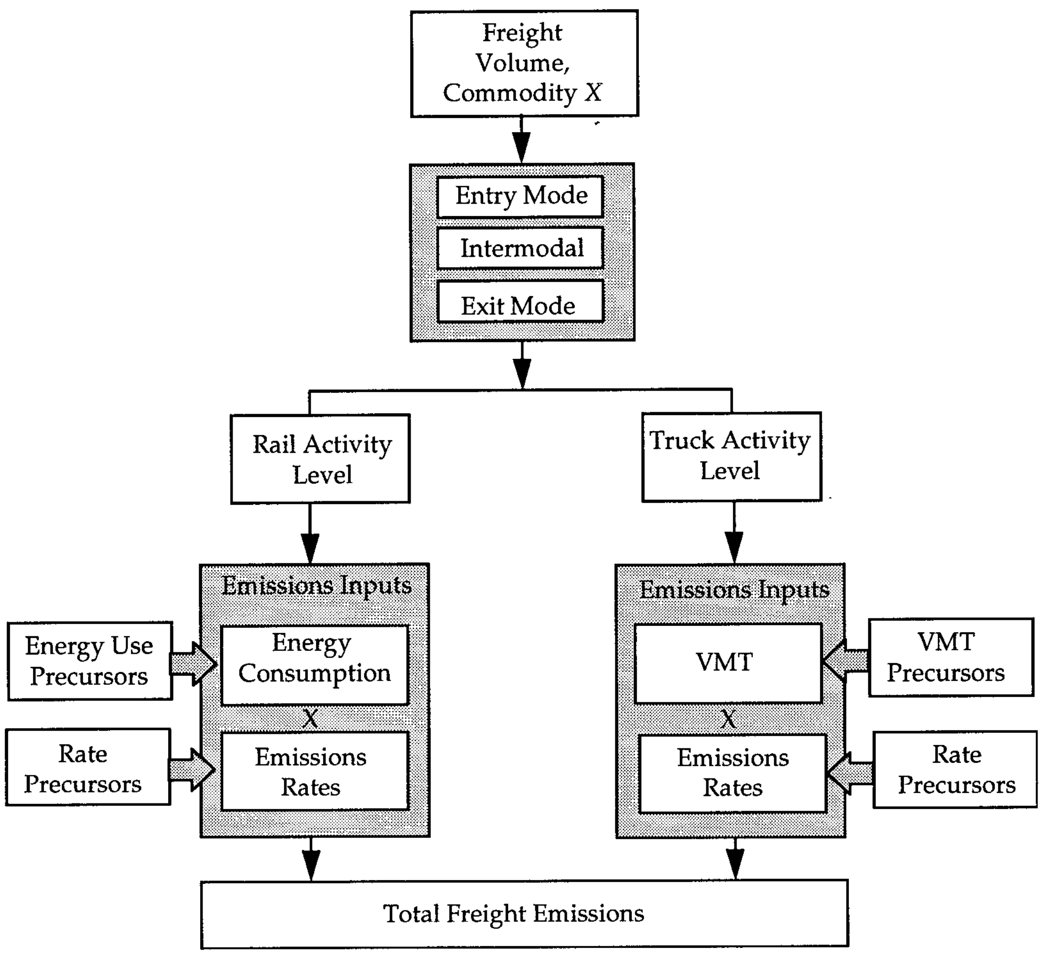
It is important to note that higher levels of intermodal activity [associated with rail or other] are likely to be accompanied by higher levels of secondary handling, either by dray truck or rail, and should be appropriately allocated to the relevant mode or program when the overall emissions results are compared. It is also important to note the effects that these movements have on other transportation activity, and the effect that freight has in stimulating "secondary" emissions.

4.2.3. Translation of Actions, Events or Programs to Freight Emissions

If the primary inputs to calculating emissions for the major freight modes and movements are as described above, the essence of a freight analysis methodology is to determine how to systematically translate the influence or effect that any of the broad range of actions, events or programs which directly or indirectly influence freight activity into changes in these primary emissions inputs.

As a framework for making this association, Figure 4.3. further structures the set of relationships to highlight the fundamental linkages that influence the emission inputs and ultimately emissions. The elements in this framework constitute a "hierarchy" of events or steps in the translation of a freight commodity flow through the intricacies of the economic and operational details that determine bottom-line travel and emissions results. This hierarchy assumes the following set of relationships:

Figure 4.3. Freight Emissions Framework

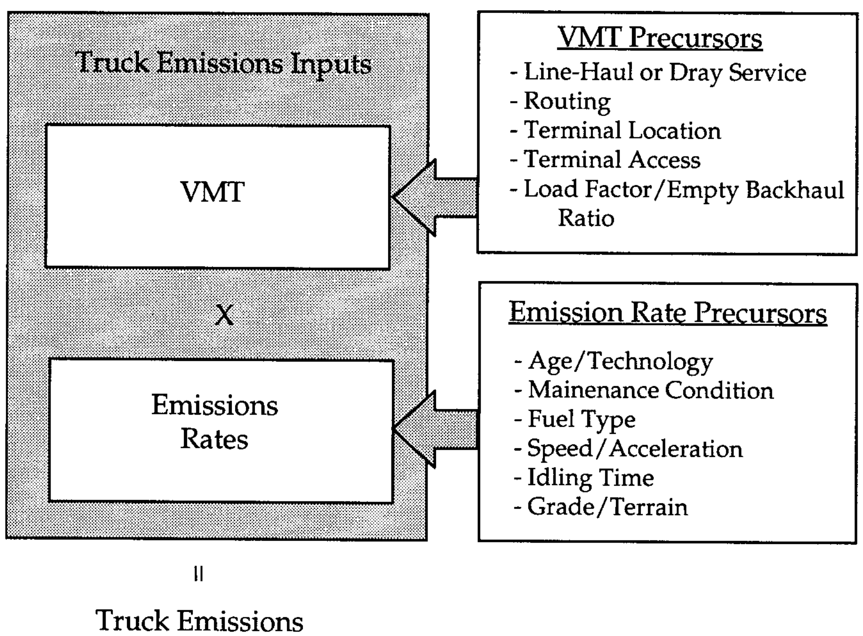


- An overall volume of freight (of a given commodity) will move into, out of or through the given area.

- This volume will be carried into, out of or through the area by a given mode, and may involve intermodal transfer and secondary handling (consistent with the breakdown in Figure 4.1.).
- The net result of this freight activity is a given level of "rail activity" and "truck activity".
- The freight "activity" is linked to the appropriate emissions inputs -- either fuel consumption and emissions rate for rail, or VMT and emissions rate for truck.
- The products of the respective activity variables and emissions factors are summed into an estimate of total freight emissions.

A very important qualifying step is performed by the "Precursors", shown in the diagram as the arrow boxes adjacent to the respective Emissions Inputs. Each mode's emissions are a function of the two inputs -- an activity measure (VMT or fuel consumption) and an emissions rate, or factor, either of which can be affected independently or jointly by a given action or policy. Figure 4.4. provides detail on the Truck Emissions Precursors.

Figure 4.4 Truck Emissions Precursors



If the truck activity input to emissions is VMT, then factors which influence that VMT and act as "precursors" to determining the salient emissions input are:

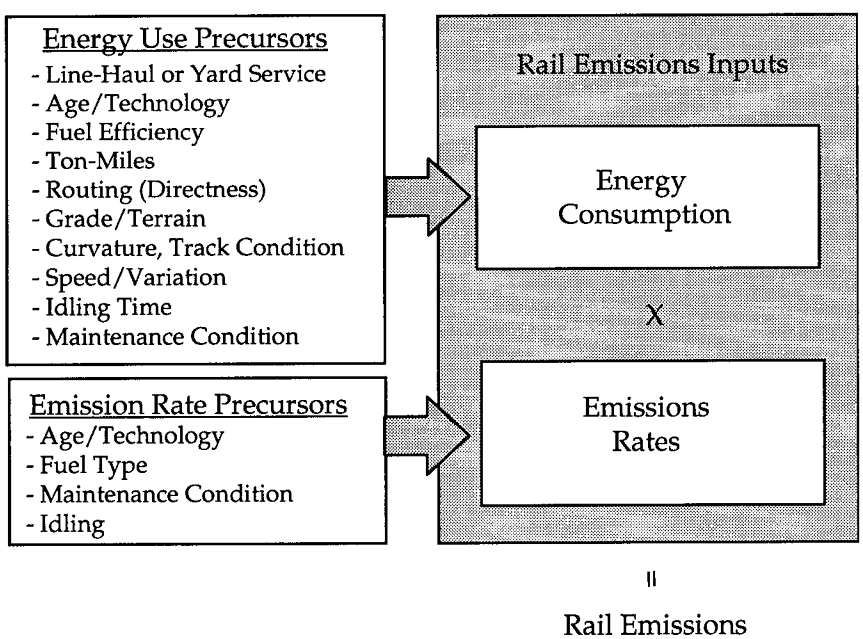
- The degree of intermodal transfer performed by truck.
- The routing, in terms of location in the region and directness of path.
- The location of terminals in the region relative to development and traffic densities, transportation facilities/capacity, and other terminals.
- Terminal access.
- VMT per load delivered based on load factors, empty backhaul ratios, scheduling, etc.

Truck emissions rates are affected by the following factors:

- The age of the vehicle, which also tends to reflect the sophistication of the technology.
- The maintenance condition of vehicles.
- Use of Alternative Fuels.
- Average speed levels, as well as variation in speeds (acceleration/deceleration cycles).
- Idling periods, especially at terminals, but also under congestion and breakdown conditions.
- Grade, terrain and other condition of roadway.

The equivalent set of relationships underlying Rail Emissions are illustrated in Figure 4.5.

Figure 4.5. Rail Emissions Precursors



Rail is fundamentally different from truck in this comparison because of the convention of computing rail emissions from fuel consumption, rather than VMT (ton-miles may be used, but are converted to fuel consumed later). What this means is that most of the factors which serve as emissions precursors relate to Energy Use, and a much smaller set relate to the Emissions Rates themselves. This is because most everything that influences energy use also directly influences the quantity of emissions which are generated.

The factors which directly lead to the determination of rail energy consumption are:

- Whether the service is in Line-Haul or Yard mode
- Age (technology) of equipment, and level of maintenance
- Fuel efficiency
- Ton-miles, which also reflects backhaul ratios
- Routing directness
- Speed (average and variation)
- Track condition, curvature, grade, etc.
- Idling time (especially yard locomotives)

This leaves a relatively small set of factors to serve as direct precursors for rail emissions rates, limited to largely:

- Age/technology of equipment
- Maintenance condition
- Type of fuel (use of alternative fuels)
- Idling

The role of these emissions precursor factors becomes crucial in a methodology, since a policy action or improvement strategy would not typically try to impact VMT, energy use or emissions rates directly, but rather would attempt to influence one of these intervening variables. Hence, the precursors become an important media for focusing an action and for translating its effects to transportation activity changes and emissions.

4.2.4. Strategies, Actions or Events that Affect Production of Freight Emissions

Tables 4-1 and 4-2 list a range of actions or events which could influence freight activity (its overall levels, mode, efficiency) and/or freight emissions. Table 4-1 describes actions that can be taken to specifically affect the nature and performance of freight activity, so these are strategies defined as having an "active" impact on freight. Table 4-2, in contrast, lists actions or events that are largely exogenous, but which are likely to have important impact on the underlying forces which determine freight activity levels, industry trends, or regulatory conditions.

Table 4-1 describes **Transportation System Enhancement or Regulatory Actions** which are either intended to have a direct effect on freight activity or emissions because they are developed as "freight strategies", or which are broader transportation system actions that, by their range of influence over all transportation sectors, will also affect freight. Four types of actions are cited, subgroup into categories which show their applicability to Truck/Highway, Rail, or Intermodal activity:

1. **Capital Infrastructure Improvements** or enhancements to increase capacity, and/or provide specialized capacity for freight.
2. **Low-capital, Transportation System Management (TSM) Actions** to increase capacity and improve flow conditions.
3. **Actions to Affect Emissions Rates** directly, either through fuel or technology improvements, or incentives to reduce emissions through better maintenance or more efficient operation.
4. **Regulatory/Pricing Actions** which either impose conditions directly on freight activity or emissions, or indirectly influence activity/emissions through pricing mechanisms.

Table 4-2 lists a range of **Background Trends or Exogenous Factors** that may not be specifically directed at freight/emissions, but which would inevitably have freight activity or emissions implications. Here there are also four groups of actions, subcategorized into the three primary modes of operation -- Truck, Rail, and Intermodal. These include:

1. **Economic Trends and Conditions**, which determine the overall level of freight activity based on rates of production/consumption, the distribution of activity based on user and supplier markets, condition of the transportation system and the given region's role in that system.
2. **Industry Trends and Practices**, including structure and health of the various freight industries, shifts in service levels or coverage, shifts in commodities or markets, shipper preferences for time vs. cost in delivery, organized work rule or freight management practice changes.
3. **Technological Shifts**, including introduction of improved roadway/track flow management, scheduling/tracking systems, power/carrying capability or efficiency of freight modes, changes in engine/fuel technology, or non-travel alternatives to goods movement.
4. **Policy or Regulatory Shifts**, such as further tightening/loosening of environmental standards or requirements, changes in size & weight restrictions, tighter safety & inspection requirements, or general changes in funding or taxation.

Table 4.1. Freight-Related System Enhancements or Regulatory Actions

Type of Strategy or Action	Truck/Highway Related	Rail Related	Intermodal Related
1. Infrastructure Enhancements & Capital Improvements	• Truck-only highways • Truck bypass routes • Elimination of clearance or geometric constraints • Grade moderation • Ramp extensions • ITS improvements to increase capacity, provide information, manage delay • General capacity additions	• Track programs: upgrade replacement, expansion • Additional capacity in high traffic areas • Double stack capability • Separated grade crossings and priority corridors	• New terminals • Terminal modernization or capacity enhancements • Improved terminal access • Terminal relocation • Direct rail/port or rail/rail connections • NHS system connectors • Clearances
2. Low Capital/TSM System and Management Improvements	• Designation of truck routes among existing facilities • Ramp metering • Improved signing • Traffic engineering/flow improvements • Signal synchronization • Incident management	• Scheduling improvements • More flexible arrangements for shared trackage rights • Improved signal & mgm't systems for yard and main line	• Programs to reduce delay at terminals. • Improved scheduling & management at intermodal terminals
3. Modal Emissions Rates	• New/higher emissions standards • Incentives for more rapid fleet turnover • Alternative fuels incentives • Modified fuels • [Enhanced] I&M	• New/higher emissions standards • Incentives for more rapid introduction of new tech. • Alternative fuels incentives • Fuel Conservation Measures • Speed Management	• Emissions standards or budgets
4. Regulatory/Pricing Actions	• Fuel taxes/surcharges • Peak-period or facility truck restrictions • Truck size & weight limits • Weight/distance tax • Emissions fees	• Incentives for steel-wheel intermodal connections • Emissions fees	• Rules governing idling at terminal sites • Incentives to expand or shift operating hours • Emissions fees

Table 4.2. Background & External Trends & Events with Freight Implications

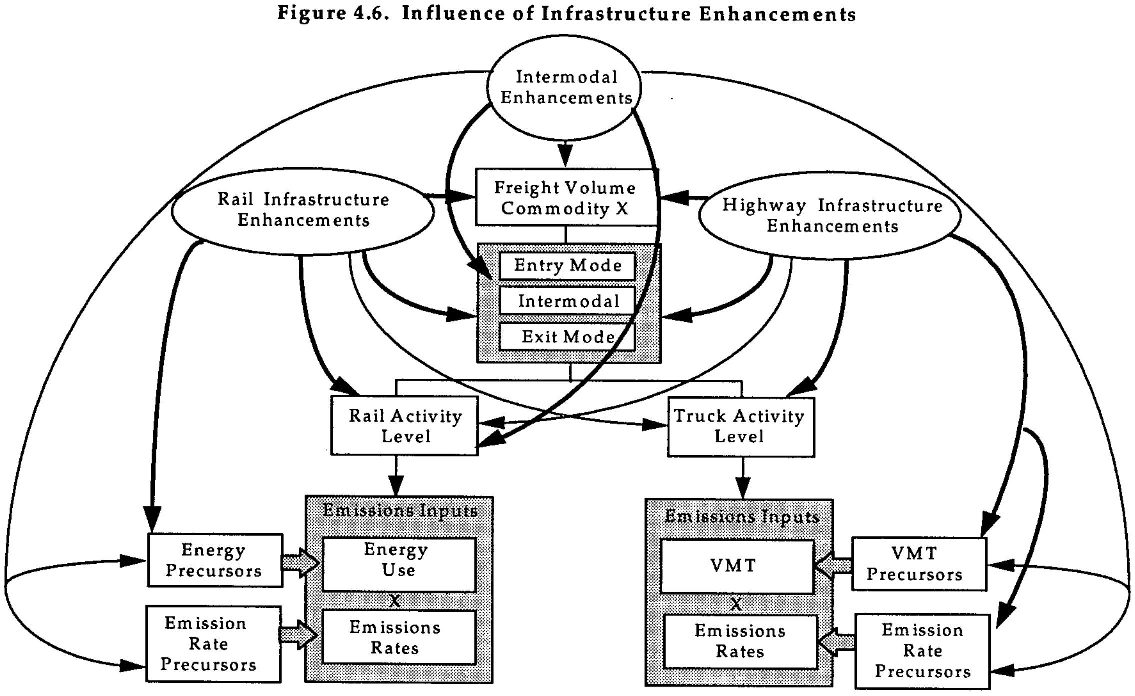
Type of Event or Action	Truck/Highway Related	Rail Related	Intermodal Related
1. Economic Trends and Conditions	• Overall economic conditions • New industry/commodity base in region • Shift in domestic or international markets • Shift in location of suppliers or end users	• Overall economic conditions • New industry or commodity base in region • Shift in domestic or international markets • Shift in location of suppliers or end users	• Overall economic conditions • New industry or commodity base in region • Shift in domestic or international markets • Shift in location of suppliers or end users
2. Industry Trends and Practices	• Change in structure of truck industry • Shipper preferences for time or cost in delivery • Changes in industry management practices	• General new railroad capacity or abandonments • Change in structure of rail industry, service coverage • Shipper preferences for time or cost in delivery	• Change in structure of freight industry • Intermodal connectors, level of service • Shipper preferences for time or cost in delivery
3. Technological Changes	• ITS deployments • Incident management • Shifts in power technology, fuel type & consumption, emissions rates • Change in carrying capacity/efficiency	• Improved scheduling and delay management systems • Shifts in power technology, fuel use or emissions rates • Change in carrying capacity, efficiency	• Improved scheduling and management systems • Shifts in capacity, ability to manage operations • Shifts in technology, emissions rates
4. Policy/Regulatory Shifts	• Changes in federal or state air quality standards or requirements • Changes in federal or state highway funding programs • Federal change in weight, size, or safety requirements	• Changes in federal or state air quality standards or requirements • Changes in federal or state regulatory requirements • Public regulatin of shipping rates • Changes in safety regs.	• Changes in federal or state air quality standards or requirements • Changes in federal or state funding programs • Changes in federal, state or local operating, safety regs.

4.2.5. Linking Freight or External Actions with Changes in Freight Activity & Emissions

The importance of the Framework and the Activity and Emissions Precursors introduced in the previous sections becomes evident when trying to fashion an analysis of the effect of any of the above actions or events on activity levels and emissions. A series of diagrams is provided in Figures 4.6. through 4.10. to illustrate where each of the different types of actions or events would have impact on freight activity levels, and hence, emissions. In these figures, the actions or events are shown as the "circled" items, with arrows extending from them into the framework to show where they would be expected to have their impact, and hence, where analysis attention should be focused. Heavy-weight arrow lines suggest an important effect of the action/event on that part of the framework; medium-weight lines suggest a secondary, but still possibly important effect, while dotted lines suggest a minor impact, but one which should still be considered for potential impact before being dismissed as unimportant.

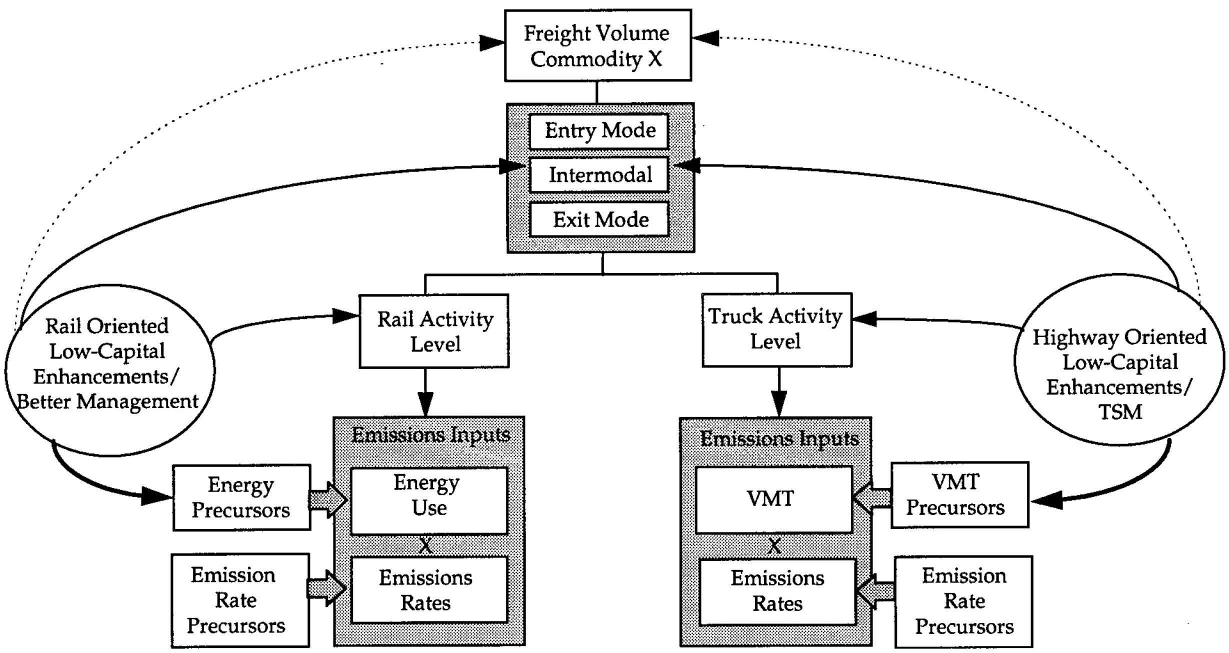
Figure 4.6. attempts to map the influence that would be expected from **Capital Infrastructure Enhancements** (Item 1 in Table 4-1). These actions would have comparatively broad-reaching effects throughout the framework. They would affect the overall level and quality of service for a given mode, but also create a comparative advantage for the mode receiving the greatest enhancements. All three groups of modal enhancements -- rail, truck and intermodal -- would be expected to have major influence on overall volume levels into/out of/through the region, the amount of product that would undergo intermodal transfer, and the choice of primary mode (rail or truck). The rail and highway infrastructure improvements would also have major direct impact on the usage and emission rate precursors, while the intermodal enhancements would have a secondary effect on these.

Figure 4.6. Influence of Infrastructure Enhancements



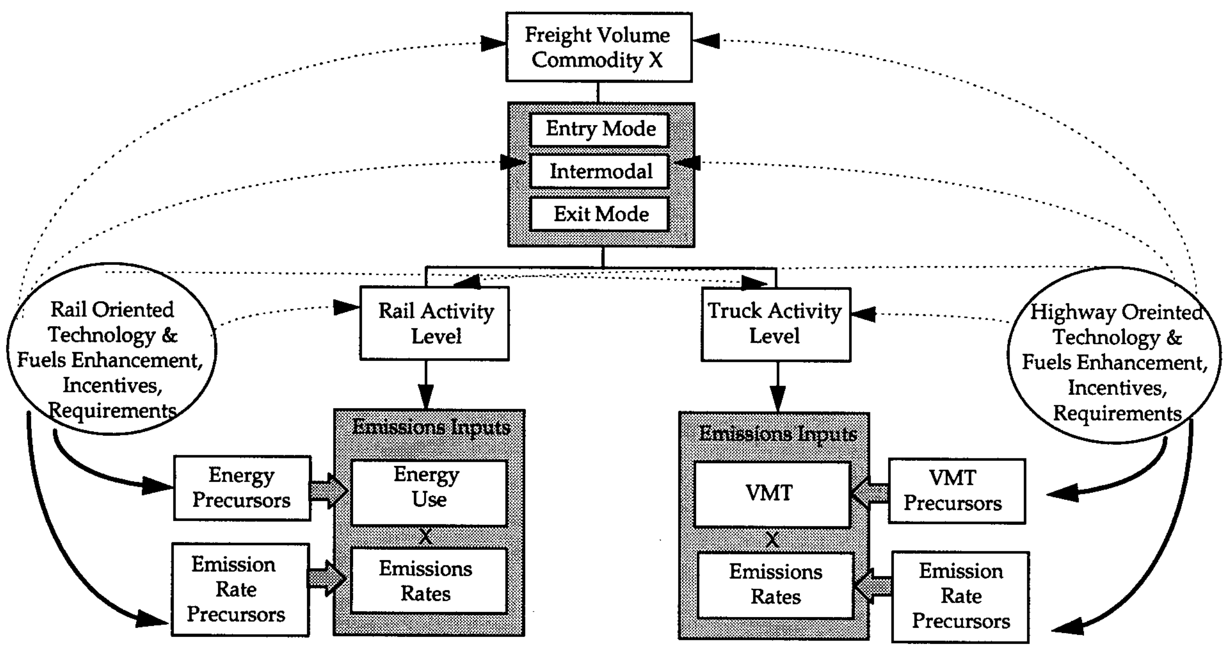
By contrast, Figure 4.7. below shows, the more limited influence and impacts generated by **Low-Capital/TSM** type actions. Only Rail and Truck/Highway oriented actions are shown, although it is conceivable that there could be Intermodal actions as well. The primary impact of these actions would be on smoother flow, with some increase in effective capacity, so the major effect is shown on the activity precursors: Energy Use for Rail, and VMT generation for truck. Secondary impacts might be expected on the distribution of freight activity between truck and rail, and also the level and pattern of intermodal activity. For significant versions of these actions, effects may extend to the overall freight volume level shipped into/through the region.

Figure 4.7. Influence of Low-Capital Improvements, TSM, Operational and Flow Improvements



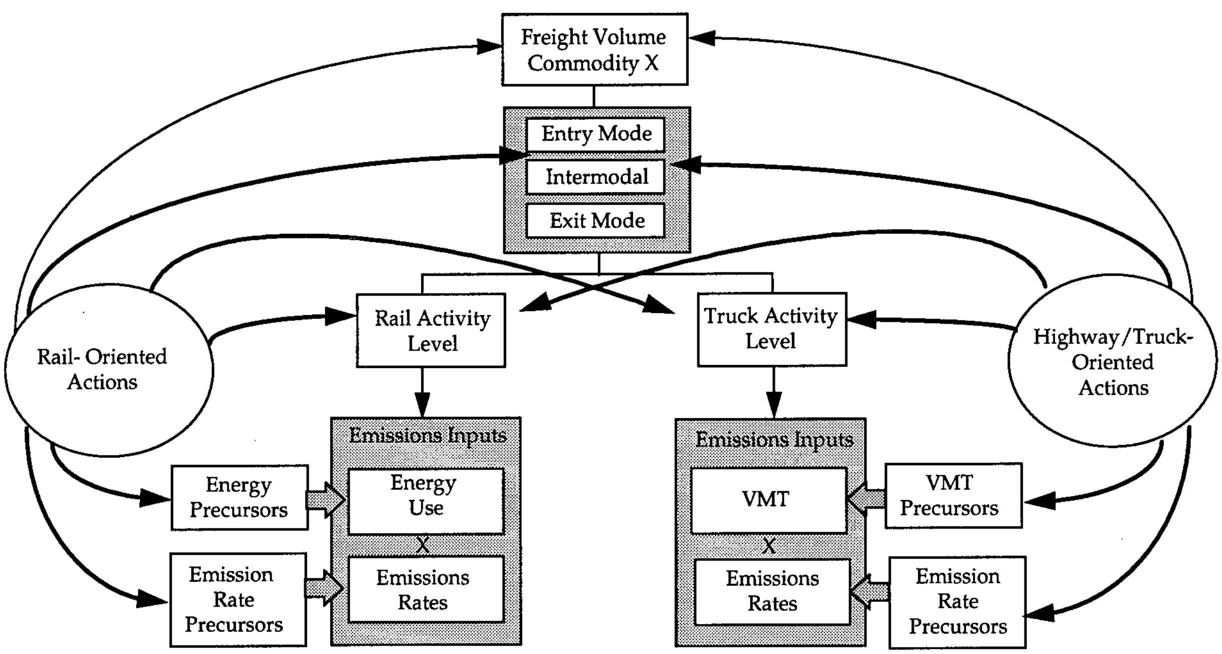
If the primary objective is to reduce freight emissions directly, and not as just as an after-effect to a change in freight activity, then perhaps the place to look first is in actions specifically oriented to improving emissions rates themselves, through technological measures. Shown as Item 3 in Table 4-1., these **Technology and Fuels** measures include better emissions controls for freight vehicles, better control of idling emissions, tighter inspection toward better maintenance, and alternative or modified fuels. Some or all of these strategies may already have been used or claimed in a given area as part of its earlier air quality planning, so it is important to record what is already in place. Figure 4.8., below, suggests that influence of these strategies in the framework is (as suggested) directly on the emissions precursors. It is less likely that major effects will extend "upstream" to mode choice, intermodal activity, or overall freight volumes, *unless the particular action has tangible cost or service effects that impact either shippers or the provider.*

Figure 4.8. Influence of Technology & Fuels Actions Directed at Emissions Improvements



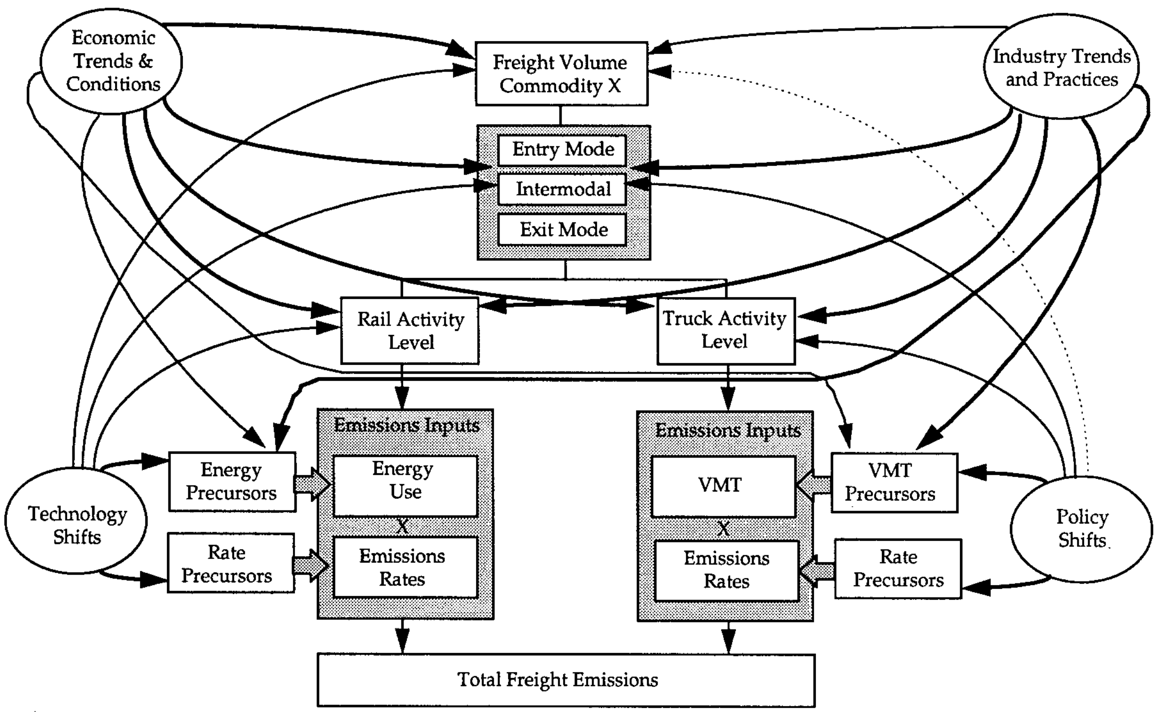
Item 4 in Table 4-1 describes various **Regulatory and Pricing Actions** directed at freight specifically, ranging from taxes, fees and surcharges that impact modal activity, efficiency or emissions levels, to rules and guidelines for operations. As shown in Figure 4.9. below, influence from these actions would be expected to extend throughout the analysis framework and hierarchy, since the definition of these measures can be as general or specific in their coverage as necessary. The important thing to note about this broad coverage potential is -- as in the case of Infrastructure Improvements -- that because these actions fundamentally alter the cost, time, or flexibility of shipment, they will affect both freight operators and shippers to the extent of the change in cost or service. Therefore, it is important that these upstream and downstream effects be treated in an analysis.

Figure 4.9. Influence of Regulatory and Pricing Actions



Finally, Figure 4.10., below, indicates the potential influence on the hierarchy of the various **Exogenous Factors** as were listed in Table 4-2. These are actions or events that are not specifically intended to affect freight activity or emissions levels, but would clearly have an impact on either. Any transportation or air quality analysis would clearly want to factor in these considerations for their effect on conditions over time, or their complementary effect on other freight-specific action strategies. The suggested lines of influence/impact are as follows:

Figure 4.10. Influence of Exogenous Factors



- **Economic Trends and Conditions** would be expected to affect overall freight activity, as well as the distribution by mode depending upon geographic and commodity factors, as well as shipper preferences relative to pricing/service.
- **Industry Trends and Practices** relate to changes in the structure of the respective freight-hauling industries, types of service and pricing, and underlying operating/management practice. Changes in these would be expected to show up in changes in mode choice and activity levels, and at a secondary level in terms of impact on VMT or Energy Use precursors to emissions. Obviously, major changes in service through industry practice shifting could influence overall levels of commodity shipped.
- **Technological Advancements** imply shifts in technology that are beyond the near-term freight emissions technology improvements in Table 4-1/Figure 4.8., that may entail jumps in power technology, modal carrying capacity or energy requirements, or may entail advancements in other transportation guidance or scheduling technology that may affect freight or other travel, or even the need to ship or the terms of shipment. These types of Technology Shifts might influence overall travel capacity

and volumes, as well as the distribution by mode. Also, primary effects would be expected to show up in the activity and emissions precursors.

- Finally, shifts in **Policy or Regulations** beyond freight specifically, or dealing with some other non-emissions characteristics (like safety or load limits) would be expected to have impact throughout the hierarchy, from overall commodity volume, through modal distribution, to the activity and emissions precursors.

These profiles are only intended at this point to raise awareness as to the types of measures or background events that are important in freight, and where in the hierarchy that their impacts would fall. Later, in the methodology section, specific guidance is given -- via tables -- as to what analytic steps/tasks should be performed for each fundamental type of strategy.

4.3 Overview of Freight Emissions Analysis Methodology

The methodological approach which has been developed by this study is in two parts, to assist users in performing two quite different tasks -- the first, a macro, big-picture view and assessment of the overall system, its linkages, problems and air quality. The second part deals specifically with estimating the impacts of strategies or actions which have been directly applied to freight, or which indirectly are expected to have impact on it. Applications of the second part are likely to be much more project or program-specific. Depending on their particular situation, users may find need and application for either or both of these procedures.

4.3.1. Part I: Assessment of Overall Freight and Air Quality Conditions

As illustrated in Figure 4.11., on the following page, Part I contains three separate Steps, or information modules. They are *independent* steps, without any formal connection intended or necessary. Each is optional, depending on the information needs and particular circumstances of the user/site. Their purpose and content is described briefly below:

Step 1: Freight Role in Regional Air Quality

For sites where attainment of regional air quality standards is a major issue, or where attainment is tied to the emissions levels of particular pollutants (e.g., NO_x, SO_2, PM), this step serves as a starting point for establishing freight's contribution to regional emissions inventories and air quality. It does this by suggesting a review and profile of emissions/air quality levels, for existing conditions and, as appropriate, for one or more **future** conditions associated with determining the effectiveness of air quality attainment efforts or the impacts of a transportation project or plan. It provides a methodology for estimating the emissions which are generated by [intercity] freight transportation, and the proportion freight contributes to total emissions. These two pieces of information (1) clarify whether there is or will be an emissions/air quality

Figure 4.11. Freight Analysis Methodology

Part I: Macro Assessment of Air Quality & Freight Conditions

Step	
Step 1	**Freight Role in Regional Air Quality** - Regional Air Quality Status - Attainment Problems - Freight Contributions to Emissions
Step 2	**Freight System Profile** - National/Regional Function - Physical Features, Activity Levels - Problems, Deficiencies
Step 3	**Freight Strategy Options** - Capital Enhancements - TSM Actions - Policy & Regulatory Actions

Part II: Emissions Impact Assessment

Step	
Step 1	**Preparatory Work** - Candidate Strategies/Actions/Events - Translate Strategies to Inputs - Initiate Analysis Plan
Step 2	**Primary Impact Assessment** - Complete Analysis Plan - Select Analysis Methods - Compile “Before” & “After” Spreadsheets
Step 3	**Impact Summary & Review** - Δ Emissions - Δ Activity Levels - Cost/Benefit

problem and of what type and magnitude, and (2) what specific role freight plays in that problem, as a basis for gauging its overall or strategic importance.

Step 2: Freight System Profile

This step may or may not be necessary, depending on the agency's or user's familiarity with regional freight operations and system characteristics. Whether the impetus behind a freight initiative is to modify freight operations or emissions levels, or to ascertain the impact on freight of non-specific actions or events, it pays to have a good basic understanding of the major structural, operating and institutional elements of the freight system. The objective of this step is to develop a profile which describes: (1) the role that the regional freight industry and infrastructure plays in the regional vs. national/international economic marketplace and transportation system; (2) the important physical and institutional features of that system, and the activity levels that it supports (or will support in the future); and (3) specific/obvious capacity or operational deficiencies, disconnects or dysfunctions that impede the system or that cause it to impact unfavorably on other activities.

Step 3: Freight Strategy Options

Assuming that the user/site is in search of options that can affect freight emissions levels, or to affect freight transportation patterns with emissions as a side benefit, this step provides guidance as to the range of strategies that might be available, and insight into what types of problems or operating conditions they would address. Broadly, this menu consists of (1) capacity enhancements (capital or management based), (2) technology-based actions to improve freight emissions rates directly, and (3) a range of policy and institutional actions.

4.3.2. Part II: Emissions Impact Assessment

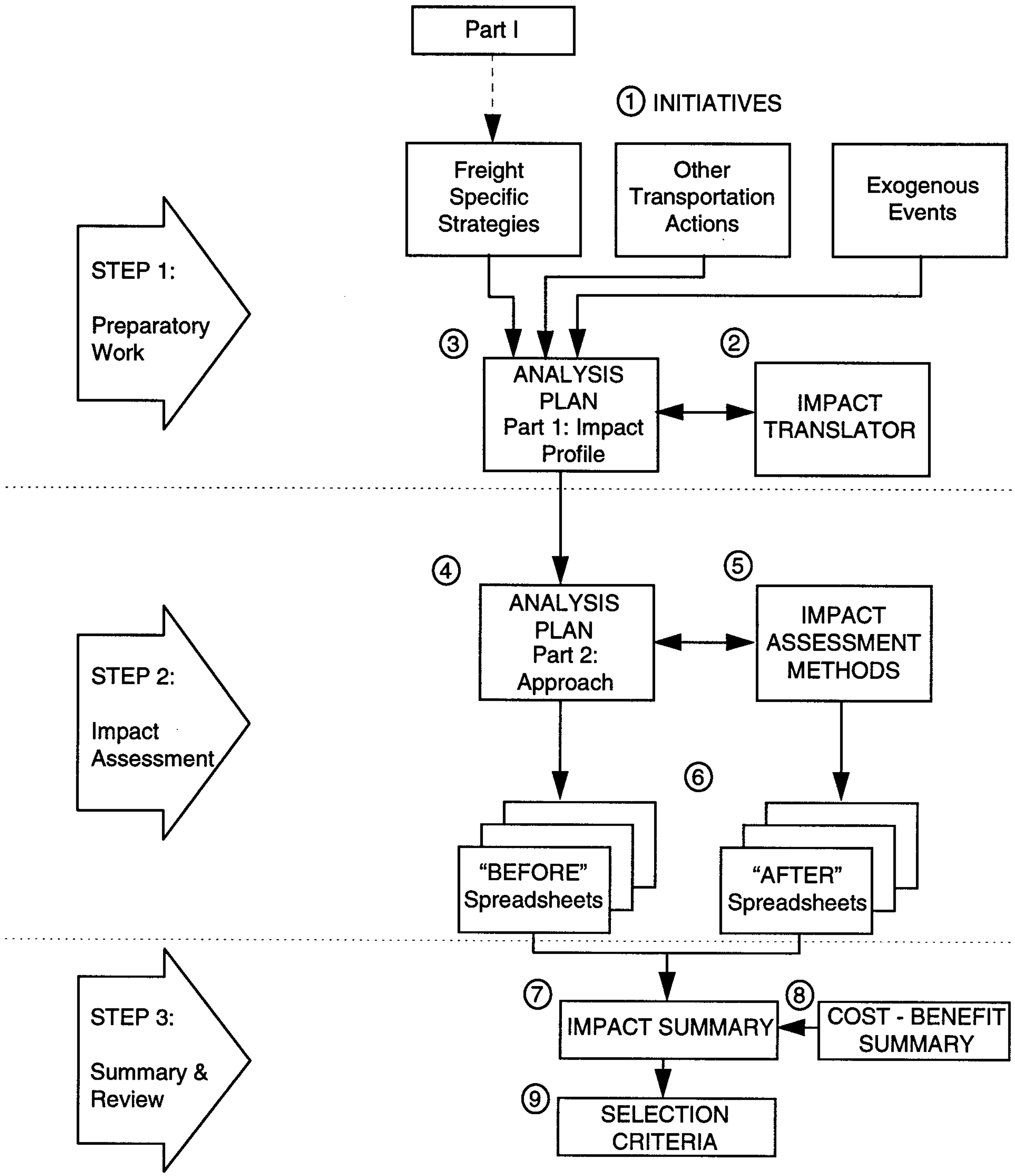
While Part I consists of "macro-level" investigations and baseline construction, Part II of the methodology contrasts by placing the focus on impact assessment of specific projects, policies or programs. It also consists or three basic "Steps", which in this case are interconnected, and require passing of information and findings through a system of spreadsheets (worksheets), used to support a series of computations, look-up procedures, tabulations and assessments.

The basic three steps are outlined in Figure 4.11., and summarized only briefly below. However, because Part I is much more procedural, a more "functional" version of the makeup of Part II is supplied by a flowchart diagram, pictured in Figure 4.12., on the following page.

Step 1: Preparatory Work

Part II begins with the delineation of the candidate strategies, actions or events that will be the subject of the analysis. Shown in Fig. 4.12. as **(1) Initiatives**, these may either be specific ***Freight-Related Strategies*** which were identified in Part I (if performed), they can be ***Other Transportation Actions*** where freight impacts are a concern, or they can be

Figure 4.12.
Part II Emissions Impact Assessment Procedure



Exogenous Events. Of course, they can also be any combination of the above, constituting a package or scenario.

Upon defining the set or strategies or actions to be tested, the next procedure is to transform the features of the strategies or actions to their essential characteristics that will serve as inputs to the analysis. This is done through the **(2) Impact Translator.** This is simply a series of reference tables that indicate where the particular actions are likely to have impact in the analysis hierarchy, which could be in ***Overall Volume** or **Direction, Mode,** or in specific **Emissions Precursors**,* similar in nature to the relational mapping shown in Figures 4.6. to 4.10., but specific to individual strategies and modes.

It is also recommended at this stage that the user construct an **(3) Analysis Plan.** This is a form that systematically profiles for the user the key characteristics of the strategy, the areas where impacts are anticipated, and hence where analysis should be directed. This plan serves to clarify where to look for impacts, as well as being a "checklist" when performing the analysis and assembling the needed information.

Step 2: Primary Impact Assessment

The preparatory work in Step 1 in laying out the candidate strategies/actions, and defining where to look for their impacts in the analysis hierarchy (and through which measures to trace those impacts) leads into Step 2, which is the most quantitative.

Largely, this Step will be carried out through the accounting media of ***Spreadsheets*** (or "worksheets" in manual form), and in particular in the development and comparison of **(6) Before and After Spreadsheets.** Step 2 starts out with completion of the **(4) Analysis Plan,** which at this time is extended to designate the anticipated **Analysis Approach**. The depiction of the existing situation for Rail and/or Truck is then conveyed via a ***Before*** spreadsheet. The Analysis Plan aids the user in determining the number of spreadsheets which will be needed, reflecting the degree to which the given system must be broken down by geography, facility, time of day, or other important precursor factor. The transportation activity summarized in the Before spreadsheets is then teamed with emissions rates and results in an estimate of pre-strategy emissions.

The change in conditions caused by application of the **Initiatives** is then determined through the application of the most appropriate **(5) Impact Assessment Methods**. These methods are aligned with the particular types of impacts profiled in the **(3) Analysis Plan Part 1,** and tailored to the level of accuracy/detail desired by the user and enabled by local data and analytic capabilities. The chosen approach is then noted in the **(4) Analysis Plan Part 2,** which lays out the analysis procedures and data which will be used. Impacts which result in changes in volumes, mode, route, time of day, VMT/energy use, and congestion/speed are described in the **(6) "After" Spreadsheets.**

Step 3: Summary and Review

This last step simply summarizes the results of the analyses in Step 2 into an **(7) Impact Summary**. In essence, it consists of subtracting the activity and emissions totals in the **Before** spreadsheet from those in the **After**. However, the task can be complicated by the fact that activity and emissions may shift from mode to mode (e.g., truck to rail), from mode to submode (e.g., rail to dray), or submode to submode (e.g., from switching locomotive to dray truck), to the extent that those shifts are important to the analysis.

It may also be desired to perform an assessment of the costs and benefits associated with the change. This can be as elegant or simple as is needed by the local process. Items which might be included in this assessment are:

- Public vs private costs
- Long range vs. short range costs
- Freight emissions benefits
- Congestion relief and secondary emissions benefits
- Avoided costs (wear, rehabilitation, new construction)
- Better service/reduced costs for providers, shippers, customers

The next section takes this procedure into the type of detail that is appropriate to its application by the typical user.

4.4 Application of Methodology

Following the cursory introduction to the 2-part/3-step freight emissions methodology in Section 4.3, this section describes the individual steps at a ***procedural*** level of detail. Where appropriate, look-up tables and charts and references to other sources are provided to accompany the application of the given step/procedure. In the next Chapter, the methodology is physically applied to specific problem examples, to illustrate how the techniques described below would be used in a typical analysis, and provide a sense of the relative impact of various strategies.

4.4.1. Part I: Assessment of Overall Freight and Air Quality Conditions

Step 1: Freight Contributions to Regional Air Quality

The purpose of this step is to develop an estimate of the baseline contribution of intercity freight operations to regional emissions. This contribution is not directly reported in regional emissions inventories. Sites that are challenged to attain or maintain air quality standards and suspect that freight may be an important component of the local emissions "equation" are urged to perform this assessment to determine the level of that contribution, its proportion in relation to activity levels and other sources, and in particular, its contribution to particular ***species*** of pollutants, such as NOx and PM. Such an assessment will help determine the relative emphasis which should be assigned to be applied to freight emissions planning and mitigation efforts.

Intercity freight emissions are included under two separate emission source categories in emissions inventories: Truck-based emissions are contained in the Mobile Source group, while Rail emissions are included within Off-Road Sources. Mobile Source emissions stem from motor vehicle operations on public roads and highways, and include passenger and light duty cars and trucks, motorcycles, and heavy duty vehicles; distinction is made between gasoline vs. diesel power because of their different emissions characteristics. The Off-Road Source category, however, contains other important ***transportation*** emissions sources, which includes not only railroads but aircraft, watercraft, recreational vehicles, lawn and garden equipment, and a wide range of construction, industrial and agricultural equipment.

Intercity Truck Emissions

Mobile Source emissions estimates are generally prepared through application of EPA's MOBILE emissions factor model (or EMFAC in California). The emissions factors used in these models are determined through drive-cycle testing procedures for different model years and eight different classes of vehicles (i.e., LDGV, LDDV, MC, LDGT1 & LDGT2, LDDT, HDGV, and HDDV). These rates are then usually adjusted at the application site to reflect local vehicle fleet composition and age, are then are applied in the MOBILE model to VMT to produce the regional emissions estimates. Trucks are found in the heavy-duty vehicle classes, either HDGV or HDDV, comprised of gas and diesel-powered vehicles (including buses), respectively, that have gross vehicle weights over 8,500 pounds. Despite this weight threshold, there is quite a variation in size, weight, age, condition and operating environment represented among the vehicles in these heavy-duty classes. At least three basic intra-class distinctions can be made among the heavy duty trucks:

- Large pickup trucks rated between 8,500 and 14,000 lbs, GVW.
- Straight trucks (i.e., no trailer) consisting of 2, 3, or 4-axle configurations and rated between 19,500 and 33,000 pounds GVW (although dump trucks included in this group can weigh out at 50,000 lbs or more).
- Combination trucks, which have a detachable power unit and trailer, may have 3 to 9 axles and are rated at anywhere between 33,000 and 80,000 lbs. GVW.

Experience suggests that vehicles used in the transport of intercity freight, either in long-haul intercity service or for local intermodal transfer movements (i.e., drayage) are generally combination trucks (power unit with detachable trailer), and are predominately diesel powered. This knowledge offers two factors that allow use of the MOBILE emissions inventory data more effectively in isolating intercity freight emissions.

Table 4.3 was prepared for this purpose using data compiled from the Truck Inventory and Use Survey (TIUS) and the Highway Performance Monitoring System (HPMS)[1]. The

[1] The combination truck VMT in Table 4.3 includes VMT of both tractor-trailer combinations and truck-trailer combinations and it includes all fuel types. Data from the 1992 Truck Inventory and Use Survey (TIUS) indicates that 85 percent of this VMT is contributed by combinations consisting of a tractor and one or more trailers. TIUS also indicates that 99.6 percent of the latter VMT and 89.8 percent of VMT by all combinations is contributed by diesel-powered vehicles. Of the VMT by combinations consisting of a tractor and one or more trailers, 75.5 percent is accumulated on trips of more than 100 miles - i.e., on trips that can be considered to be intercity in nature. The estimates in Table 4.3 were produced using a procedure developed by Cambridge Systematics for

(Footnote continued on next page...)

table presents an estimate of the percentage of Annual VMT by Heavy Duty Diesel Vehicles (HDDV) which is constituted of VMT from combination heavy duty trucks. A separate estimate is provided for the urbanized portion only of each US Air Quality nonattainment area.

Simply multiply the percentage in the last column of this table times the emissions totals for HDDV in the respective inventory to obtain an estimate of the emissions contributions of intercity truck.

Intercity Rail Emissions

In contrast to truck and Mobile Source emissions, estimating emissions due to intercity rail activity is somewhat more straightforward. In most cases, it should be possible to determine rail emissions for the given nonattainment area from the reported source information within the Off-Road Source category in the emissions inventory. These emissions are usually estimated by applying the guidance in EPA's AP-42 Standard Inventory Handbook.

Unlike truck, rail emissions are determined as a function of fuel consumption rather than VMT. Section 4.1 provided an overview of the method by which rail emissions are calculated, with Class I and Class II and III "line haul" emissions being determined separately in relation to respective fuel consumed, while emissions from "yard" operations are determined from the number of locomotives in service.

The estimate of rail emissions may or may not be separated according to freight vs. passenger operations. If not, the calculation of rail emissions will be an over-estimate to the extent of passenger rail operations in the respective nonattainment area. In order to isolate the contribution of rail freight specifically, it would be necessary to ascertain the fuel consumed by each type of operation, and separate out those emissions attributable to freight in proportion to its fuel consumption. Similarly, if local short-line rail freight is regarded as not reflective of intercity freight operations (and not covered by yard operations), as in the case of movement of coal to a local power plant, then this contribution also should be separated out based on some estimate of fuel consumed (or might be approximated through estimated ton-miles carried, which can be converted to fuel consumption). More guidance on the calculation of rail emissions is provided in Appendix A-3 and A-4.

EPA which uses sample-section data from FHWA's Highway Performance Monitoring System (HPMS) to estimate total VMT in the urbanized portion of each NA on roads other than rural minor collectors and functionally local roads; and also the portions of this VMT contributed by combination vehicles and by single-unit commercial vehicles. Areawide HPMS data was then used to extrapolate these results to cover rural minor collectors and functionally local roads, and also to distribute VMT of heavy-duty single-unit vehicles across four FHWA vehicle classes. Data from TIUS and EPA were then used to estimate the portion of VMT in each of these four classes that is contributed by diesel vehicles, and these results were summed to produce estimated VMT of other HDDVs.

Table 4.3 Combination Truck VMT as Part of Total HDDV in Non-Attainment Areas Urbanized Areas Only (in millions of vehicle-miles)

Non Attainment Area		Area Code	Total VMT	VMT All HDDV	VMT Combinations	Comb.% of all HDDV
State	**Name**					
Alabama	Birmingham	35	6174	409.0	310.65	**76.0**
Arizona	Phoenix	33	17666	971.0	636.22	**65.5**
	Tucson	73	4072	234.3	155.12	**66.2**
Arkansas	Memphis (TN, MS)	34	6808	246.1	162.69	**66.1**
	Texarkana (TX)	211	NA	NA	NA	**NA**
California	Fresno	80	10100	378.7	205.23	**54.2**
	Los Angeles	2	112837	4183.1	2516.44	**60.2**
	Oxnard-Ventura-Thousand Oaks	224	5594	203.9	114.87	**56.3**
	Riverside-San Bernardino	48	3944	151.9	77.53	**51.0**
	Sacramento	42	10703	402.5	242.52	**60.2**
	San Diego	23	20777	738.9	438.75	**59.4**
Colorado	Colorado Springs	153	2422	67.0	36.10	**53.9**
	Denver	24	13694	379.5	216.39	**57.0**
	Fort Collins	308	684	19.1	9.60	**50.2**
	Greeley	310	393	9.2	4.54	**49.3**
	Longmont	403	244	6.2	3.16	**50.8**
Connecticut	Hartford	47	13894	432.6	244.71	**56.6**
	Springfield-Chicopee-Holyoke (MA)	43	3915	106.0	45.26	**42.7**
Delaware	Dover	387	442	20.7	10.60	**51.3**
	Wilmington (NJ, MD)	63	3279	204.7	136.33	**66.6**
District of Columbia	Washington (MD, VA)	8	25583	1159.5	515.19	**44.4**
Illinois	Chicago-Northwestern (IN)	3	52746	3399.8	2747.06	**80.8**
	St. Louis (MO)	11	20023	1068.6	770.09	**72.1**

Table 4.3 Combination Truck VMT as Part of Total HDDV in Non-Attainment Areas Urbanized Areas Only (in millions of vehicle-miles) Cont'd

Non Attainment Area		Area Code	Total VMT	VMT All HDDV	VMT Combinations	Comb. % of all HDDV
State	**Name**					
Indiana	Elkhart-Goshen	325	894	51.3	34.82	**67.9**
	Evansville	114	1156	58.7	37.60	**64.0**
	Indianapolis	29	8643	737.8	574.01	**77.8**
	Louisville (KY)	31	7779	372.0	237.84	**63.9**
	South Bend (MI)	77	1775	105.1	71.9	**67.7**
Kansas	Kansas City (MO)	19	7965	373.0	252.49	**67.7**
Kentucky	Cincinnati (OH)	17	11588	630.3	449.94	**71.4**
	Huntington-Ashland (WV, OH)	105	902	53.4	35.67	**66.8**
	Lexington-Fayette	144	2289	90.6	51.62	**57.0**
Maine	Portland	145	14	0.4	0.20	**48.1**
	Portsmouth-DO-Rochester (NH)	283	1250	65.5	23.07	**35.2**
Maryland	Baltimore	12	16348	786.8	264.58	**33.6**
Massachusetts	Boston	7	35954	1081.4	512.93	**47.4**
	Providence-Pawtucket-Warwick (RI)	26	5888	236.1	147.32	**62.4**
Michigan	Battle Creek	267	656	40.5	22.99	**56.8**
	Benton Harbor	333	721	46.7	27.10	**58.0**
	Detroit	5	35368	2379.2	1432.56	**60.2**
	Flint	65	3483	226.8	133.38	**58.8**
	Grand Rapids	61	4603	290.9	167.87	**57.7**
	Jackson	190	773	49.7	28.82	**58.0**
	Kalamazoo	141	1589	96.5	54.29	**56.3**
	Lansing	102	2235	140.6	80.90	**57.5**
	Muskegon-Muskegon Hgts	162	791	44.7	23.60	**52.8**
	Saginaw	123	1593	98.1	56.04	**57.1**
	Toledo (OH)	44	3154	164.5	115.79	**70.4**
Minnesota	Minneapolis-St. Paul	13	18196	430.7	329.85	**76.6**

Table 4.3 Combination Truck VMT as Part of Total HDDV in Non-Attainment Areas Urbanized Areas Only (in millions of vehicle-miles) Cont'd

Non Attainment Area State	Name	Area Code	Total VMT	VMT All HDDV	VMT Combinations	Comb. % of all HDDV
New Hampshire	Manchester	165	1729	84.1	35.83	**42.6**
	Nashua	246	114	5.9	1.79	**30.3**
New Jersey	Allentown-Bethlehem-Easton (PA)	68	2694	91.8	58.15	**63.4**
	New York-Northeastern NJ (NY)	1	51763	2208.8	1364.37	**61.8**
	Philadelphia PA	4	18100	733.1	509.30	**69.5**
New Mexico	El Paso (TX, NM)	66	3514	153.5	116.98	**76.2**
New York	Albany-Schenectady-Troy	41	4233	187.6	117.71	**62.8**
	Buffalo	16	6376	268.8	162.84	**60.6**
	Poughkeepsie	270	2781	123.9	77.92	**62.9**
	Syracuse	56	2583	115.2	72.72	**63.1**
North Carolina	Charlotte	82	4719	442.8	352.85	**79.7**
	Greensboro	132	2992	276.5	218.79	**79.1**
	Raleigh	163	5338	496.0	393.57	**79.4**
	Winston-Salem	124	1912	177.6	140.05	**78.8**
Ohio	Canton	79	1621	72.5	47.58	**65.6**
	Cleveland	10	17286	961.4	705.77	**73.4**
	Columbus	30	8205	449.0	327.03	**72.8**
	Dayton	38	5733	291.4	203.77	**69.9**
	Parkersburg (WV)	273	326	13.4	6.55	**48.8**
	Sharon (PA)	290	259	7.9	4.67	**59.3**
	Youngstown-Warren	49	2224	97.4	63.27	**65.0**
Oregon	Portland (WA)	27	1599	88.4	55.76	**63.1**
Pennsylvania	Altoona	175	379	9.8	5.08	***52.0***
	Erie	95	750	24.3	15.11	***62.1***
	Harrisburg	83	3105	137.8	99.24	***72.0***
	Johnstown	159	443	11.0	5.57	***50.5***
	Lancaster	164	1403	38.6	21.19	***54.8***

Table 4.3 Combination Truck VMT as Part of Total HDDV in Non-Attainment Areas Urbanized Areas Only (in millions of vehicle-miles) Cont'd

Non Attainment Area		Area Code	Total VMT	VMT All HDDV	VMT Combinations	Comb. % of all HDDV
State	**Name**					
Pennsylvania	Pittsburgh	9	12957	523.8	363.54	*69.4*
	Reading	107	1222	33.8	18.55	*55.0*
	Scranton (081)--Wilkes-Barre	281	2293	97.4	69.11	*71.0*
	York	152	1287	58.1	42.17	72.6
Tennessee	Knoxville	98	2981	142.2	103.53	72.8
	Nashville-Davidson	54	6893	327.1	237.78	72.7
Texas	Abilene	166	516	20.6	15.37	74.7
	Amarillo	120	727	37.5	30.06	80.3
	Austin	90	153	6.2	4.67	74.7
	Beaumont	135	1803	76.6	57.50	75.1
	Brownsville	248	293	11.1	8.04	72.7
	Corpus Christi	96	1396	56.9	42.86	75.3
	Dallas-Fort Worth	282	28097	1249.7	961.92	77.0
	Harlingen-San Benito	201	441	16.7	12.20	73.0
	Houston	15	28187	1156.9	869.44	75.2
	Kileen	277	1024	43.9	33.35	75.9
	Laredo	205	242	12.6	10.16	80.5
	Longview	361	326	14.4	10.88	75.8
	Lubbock	122	702	29.1	21.82	75.0
	McAllen-Pharr-Edinburg	230	1403	51.8	37.37	72.2
	Odessa	174	675	28.3	21.31	75.3
	SanAngelo	208	285	9.3	6.41	68.8
	San Antonio	28	7	0.2	0.11	60.1
	Sherman-Denison	232	506	16.9	11.87	70.0
	Tyler	213	478	21.5	16.34	76.0
	Victoria	363	118	5.4	4.11	76.4
	Waco	140	1085	49.8	38.82	77.9
	Wichita Falls	151	465	20.4	15.63	76.6
Utah	Odgen	133	1938	86.7	62.39	72.0
	Provo-Orem	203	1608	74.8	54.43	72.7
	Salt Lake City	53	6017	276.0	200.78	72.7

Table 4.3 Combination Truck VMT as Part of Total HDDV in Non-Attainment Areas Urbanized Areas Only (in millions of vehicle-miles) Cont'd

Non Attainment Area		Area Code	Total VMT	VMT All HDDV	VMT Combinations	Comb. % of all HDDV
State	**Name**					
Virginia	Norfolk (036) - Virginia Beach - Newport News	405	8675	350.3	204.35	**58.3**
	Richmond	55	4869	204.0	119.69	**58.7**
West Virginia	Charleston	101	1984	140.6	99.63	**70.8**
Wisconsin	Milwaukee	14	10866	658.9	455.83	**69.2**
	Sheboygan	372	307	17.9	11.56	**64.4**

Source: 1993 HPMS Database
1993 Highway Statistics

Step 2: Freight System Profile

Constructing a working profile of a region's freight transportation system may seem like a superfluous exercise, since (1) most planners or transportation officials will assume that these features are fairly obvious, and (2) those operating, institutional or capital features that are imperfectly understood may be shrugged off as private sector activities or proprietary information that can't be affected by the public sector anyway.

The type of profile that is suggested here is merely a "working model" of the freight marketplace, or a structure that creates a similar "picture" for all those who eventually will be involved in the discussions related to freight activities and needs. The profile helps establish a common reference point for developing an understanding of the region's freight resources and a common starting point for identifying deficiencies and discussing enhancements or policy actions. In many, if not most, metropolitan areas where freight transportation has an important role in the local economy, the regional MPO or related organizations has probably produced such a profile as part of the regional planning process. Generally these plans will list infrastructure features, deficiencies and ongoing development plans and programs, and discuss future trends and needs.

The generic types of information that are likely to be of value in a freight profile are:

- Physical features of the system
- Types of commodities moved
- Role in regional, national, international transportation system
- Number of modes, interconnections
- General level of condition and capability of the system

Listed below are various questions which reflect the types of information that would be desirable to extract from a freight profile:

1. Is area a major <u>terminus</u> for freight activity, i.e. as a port or a hub?
    - If a port, does it serve a national, international, or regional market?
    - If a hub, what types of modal connections are dominant?
2. Is the area in the <u>pathway</u> of major goods movement by virtue of its infrastructure or its location in the national "grid"?
    - Is it a node in the mainstream of the nation's highway system?
    - Is it a gateway to a particular region or international destination?
3. Is the area itself a <u>generator</u> of freight activity, either as a producer of goods or a user?
    - Where are the shippers located relative to freight transportation resources?

4. What types of commodities are shipped into, out of or through the region?
   - What special requirements does the commodity base place on freight transportation, with regard to mode, types of service demanded, shipping patterns?
   - To what extent does modal capability/investment influence commodity or shipping patterns?
5. How does freight activity interact with other transportation activity, in terms of location, facility use, time of day, etc.?
6. What is composition of local freight industry?
   - Number Class I, II, III railroads serving area
   - Number Intercity Freight Trucking companies
   - Number local drayage operators
   - Number air cargo carriers serving area
   - Number ports and ownership/operation (public or private)
7. What is the nature and extent of the region's freight infrastructure, including:
   - Number and location of railroad facilities, track capacity and condition, rail yard capacity and condition.
   - Number of primary highway facilities, location, capacity lane miles, condition.
   - Number of air cargo airports, handling capacity, condition and technology
   - Port capacity, condition
   - Location of freight facilities relative to local goods production or use activities (i.e., industries, warehouses).
8. What is the nature and extent of intermodal connections?
   - Number of intermodal terminals, location, function, capacity and condition
   - Proximity of intermodal terminals to sources of freight activity, including ports, rail lines, major highways
   - Access to and connectivity between terminals and modes.

An example of a profile of this type is suggested by the write-ups in the Case Studies found in Appendix B. Section 5 in each of the three examples profiles the Nature of Regional Freight Operations for each area.

Development of a ***freight system profile*** causes a fresh look at the features and operating characteristics of a region's freight system, and as result, helps identify current or future problems and deficiencies. Again, an existing regional freight study or plan will probably have identified many of these features and deficiencies, reflecting current conditions or as might develop under future growth scenarios. The following is a categorization of the types of deficiencies or imperfections that may be of concern to a region with respect to freight-related emissions, efficiency of freight transportation service, impact of freight capacity and efficiency on the regional economy, or impact of freight transportation on other transportation activity and emissions:

1. ***Capacity limitations*** on major facilities, leading to suboptimal routing patterns, congestion, poor travel/shipping times, leading to negative economic consequences.
2. ***High rates of through traffic*** which affect local transportation efficiency and overall emissions because of timing or location on regional transportation system
3. ***Routing constraints*** which increase truck VMT through circuitous routing, geometric constraints at intersections/ramps, bridge clearance problems.
4. ***Restricted modal choices*** in shipping by truck vs. rail due to transit time disparities resulting from system capacity, connectivity or operational factors.
5. ***Poor intermodal connectivity and terminal access*** due to location of terminal facilities and connection with the primary transportation system, causing access and handling delays when accomplishing transfers.
6. ***Congestion and delay*** on major highway facilities due to overcrowding during peak-use periods, and also causing (or being affected by) major incidents and breakdowns.
7. ***Deficient port/intermodal capacity*** due to outdated technology or inefficient management.
8. ***Traffic conflicts*** between freight movements and passenger/commercial transportation, resulting in secondary impact on emissions from those modes.
9. Emissions resulting from ***disadvantageous operating conditions***.
10. Emissions resulting from ***inefficient management practices*** by freight providers, terminal operators, or shippers.
11. Emissions resulting from ***technological factors***.

Step 3: Freight Strategy Options

Using the problem concerns listed above as a general guide, the next question is "what actions are suitable for affecting these conditions?" Table 4.4. offers a guide to the types of actions which might be considered to address these concerns, across three categories of actions:

- Capital/Infrastructure Enhancements
- Transportation System Management (i.e., low capital) actions
- Policy and Regulatory Actions, including Pricing and Market-Based actions

The analyst or reviewer is advised to match up the deficiencies which were identified in the profile of Step 2 with those listed in the left hand column of the table. Then examine the suggestions for strategies which appear in the table under each of the three categories. Note that the problem concerns are not mutually exclusive, nor are the suggested strategies. The problems have a good deal of overlap with each other, as do the various strategies have applicability across more than one problem.

Table 4.4. Freight Strategy Options to Address Particular Types of Concerns

Type Deficiency or Concern	Capital Infrastructure Enhancements	Transportation System Management (Tsm) Actions	Policy or Regulatory Action
1. Capacity Limitations	• New general roadway capacity • Truck-only or truck bypass routes • High-tech ITS-type management systems • New/expanded ramps, intersections • New rail trackage • Double stack lines • Rail grade separations	• Designation of truck routes from among existing facilities • Traffic engineering, flow improvements • Ramp metering • Improved signal timing for trucks • Improved directional signing for trucks • Low-tech incident detection/management systems	• Road/facility pricing • Congestion pricing • Peak period truck restrictions
2. "Through Traffic" Conflicts	• New general roadway capacity • Truck bypass routes • Truck-only routes • Additional mainline rail track capacity • High-tech capacity management systems	• Designation of truck through or bypass routes • Better management of trains at rail yards • Shift through trains to other terminals • Improved directional signing	• Road pricing • Congestion pricing • Area/entry pricing
3. Routing Constraints	• Eliminate geometric constraints on roads, ramps, intersections • Eliminate clearance problems • Fill key missing rail or highway links	• Designate existing routes with fewest constraints • Clearly sign routes • Low-capital modifications to minor geometric or design flaws • Intersection design enhancements	
4. Restricted Modal Choices/Options	• Double-stack rail lines • Improved track quality/alignment to permit higher speeds • Improved rail line, system, yard management systems	• Improve access and connections to intermodal yards • Maximize ease of accessing and using rail/intermodal service • Better management of train assembly and shared usage of track	• Road pricing • Congestion pricing • Emissions fees • Investment credits for rail and intermodal facility enhancements • Motor fuel tax increases • Enforce/restrict truck size & weight limits

Table 4.4. Freight Strategy Options to Address Particular Types of Concerns (Continued)

Type Deficiency or Concern	Capital Infrastructure Enhancements	Transportation System Management (Tsm) Actions	Policy or Regulatory Action
5. **Intermodal Access and Connectivity**	• New or improved NHS connectors • Ramp extensions, modifications • Steel-wheel connections between yards • Rail/highway grade separations • Terminal relocation • Direct rail/port intermodal connections	• Designation of optimal access routes to terminals • Enhancement of access routes to maximize efficiency	• Incentives to develop new intermodal facilities in improved locations • Incentives for steel wheel intermodal transfer • Road or congestion pricing
6. **Congestion and Delay**	• New general rail or highway capacity • Priority truck corridors • Improved high-tech scheduling, information and signal systems • Separated grade crossings • Redesigned/capacity-enhanced intersections	• Traffic engineering/ flow improvements • Low-tech incident detection and management systems	• Road pricing • Congestion pricing • Peak-period truck restrictions • Incentives for shippers to ship off-peak
7. **Deficient Intermodal Capacity**	• New terminals • Expanded terminals • Modernization	• Programs to reduce delay at terminals • Improved scheduling & management at terminals • Better efforts to interconnect terminals	• Incentives to expand, enhance, modernize intermodal facilities • Incentives to locate new facilities in more desirable locations • Incentives for consolidation of terminals
8. **Freight/Passenger Traffic Conflicts**	• Truck-only routes • Truck bypass routes • Grade separations • Create "inland" terminals for distribution of goods outside region	• Designate truck only or bypass routes • Intersection or ramp redesign • Bottleneck alleviation	• Congestion pricing • Road pricing • Area/entry pricing • Truck roadway, area or time of day restrictions • Differential tolls for cars and trucks

Table 4.4. Freight Strategy Options to Address Particular Types of Concerns (Continued)

Type Deficiency or Concern	Capital Infrastructure Enhancements	Transportation System Management (Tsm) Actions	Policy or Regulatory Action
9. Unfavorable Emissions Operating Conditions	• High-tech (ITS) congestion/incident management system • Grade moderations • Alignments • Signal synchronization	• Reduce signal delay • Reduce intersection or ramp delay • Route trucks around bottlenecks/obstacle • Manage yard operations to reduce idling	• Truck restrictions from high traffic areas or times of day • Congestion pricing •
10. Inefficient Management Practices	• Improved scheduling technology	• Encourage substitution of steel wheel over truck drayage where possible • Reduce empty backhauls • Reduce delays at terminals	• Incentives for steel wheel intermodal transfer • Idling limitations at terminal areas • Peak period truck limitations • Truck restrictions from highly congested roadways
11. Technological Factors Affecting Emissions	• New equipment • Maintenance capabilities	• Improve equipment maintenance	• Increased emission standards for diesel • Enhanced I&M for truck • Alternative fuels incentives • New technology replacement incentives • Emissions fees • Fuel tax increases

It is suggested that the reviewer/analyst make a list of those **problems** or deficiencies which are of greatest concern, and assign a **priority** ranking to them. Then, as suggested in the figure below, list the strategies that might be of value in addressing those problems, next to the problem definition. Shape and define the strategy so that it is reflective of the local condition to which it would be applied. It is recommended that the list of strategies be kept as open and comprehensive as possible in the early exploratory phase. That is, an option should not be dismissed prematurely as unacceptable until its impact has at least been objectively assessed and compared with other strategies.

Priority	Problem/ Concern	Strategy(s)
1	Problem 1	Strategy x Strategy y
2	Problem 2	Strategy j Strategy k Strategy o
3	Problem 3	Strategy j Strategy k Strategy x
Etc. ↓	Etc. ↓	Etc. ↓

Having listed the strategies that address the identified problems, perform an initial synthesis and appraisal to identify those strategies that should be carried forward into analysis based on range of problems they impact, complementary with other strategies, and other factors. This review may also cause a reassessment of the priorities initially assigned to the problems, although any shaping or eliminations at this point in the process should be limited since no analysis to quantify the outcomes will have yet been done.

4.4.2. Part II: Emissions Impact Assessment

This is the more **analytic** part of the methodology. It provides for the quantitative assessment of the travel and emissions impacts of the wide range of actions that may directly or indirectly affect freight operations and efficiency. These may either be:

- Actions identified in Part I that are specifically intended to address a particular freight system deficiency, especially those which tangibly impact freight-related emissions.
- Other transportation system actions that stand to affect freight operations and emissions indirectly.

- Various external or exogenous events that are likely to have an impact on freight activity levels and emissions.

The procedures spelled out in this section will allow the user to methodically explore these strategies -- alone, or in typical "packages" -- and estimate their basic travel and emissions impacts.

It should be noted that there is a considerable degree of flexibility built into this methodology, due both to the wide range of needs and capabilities in the field, as well as the numerous uncertainties associated with forecasting intercity freight activity changes and emissions impacts. As earlier indicated, the study of freight issues and development of good data sources and sophisticated analytic tools has lagged substantially behind the interest and advancements in passenger transportation analysis. Thus, we are at a much more elementary stage in forecasting and analysis. Three important features have been adopted into the methodology to allow for this range of understanding, capability, and uncertainty:

- **Understanding:** The methodology employs a "deductive reasoning" approach to deal with the many aspects of freight transportation where relationships may not be well understood or for which models or empirical information have been developed. Each element of behavior is ***broken down*** to its elemental component, be it VMT on a particular facility at a particular speed and time of day, or ton-miles of rail shipment. Worksheets are used to perform the "accounting" that allows the problem and the analysis to be broken down to elements of an appropriate size that they can be dealt with.

- **Varied Capabilities:** The methodology may be ***scaled*** to the dimensions of the problem, the available tools and data, and the level of accuracy that is required. Clearly, some users will have higher quality data and planning tools available to them, and perhaps more staff expertise. Others, however, will be starting at a much more fundamental level, in terms of the issues, the strategies, and the analytic capabilities. Having a "scaleable" technique is also valuable for those analyses where a high level of detail may not be necessary or desired, such as in preliminary screening vs. detailed project planning or conformity determinations.

- **Uncertainty:** Many aspects of the forecasting process for freight carry major uncertainty for analysis efforts. Because freight activity derives from a different set of underlying factors, the decisions which affect the level and character of freight activity must account for prevailing market conditions, the preferences of shippers, and the role of service providers (freight operators). Thus, when a policy or strategy is proposed that would affect freight, how the market, the providers and the shippers will respond is not well known. To allow for this uncertainty, the methodology expects the user to obtain information from the local freight industry in creating an expectation as to how it would respond to the given action. The methodology aids the user in culling out the critical parameters that would likely be of interest to the freight community, to facilitate framing the choice options. This feedback is important in capturing realism into the forecasting methodology until and if more objective and transferable analytic methods can relate these relationships.

Step 1: Preparatory Work

This step, as pictured in Figure 4.12.A, entails three separate procedures that lay the foundation for the analysis which takes place in Step 2:

- Identification of the (1) **Initiatives**, i.e., the strategies, actions or events to be examined.
- Cross-referencing those actions or strategies with an (2) **Impact Translator** that indicates where the given strategy will have impact in the analysis hierarchy.
- Initiation of an (3) **Analysis Plan** to serve as a guide and "checklist" for the subsequent steps to be taken in the analysis.

Described below are guidelines and suggestions for what is accomplished in these respective procedures.

(1). Selection and Inventory of Initiatives

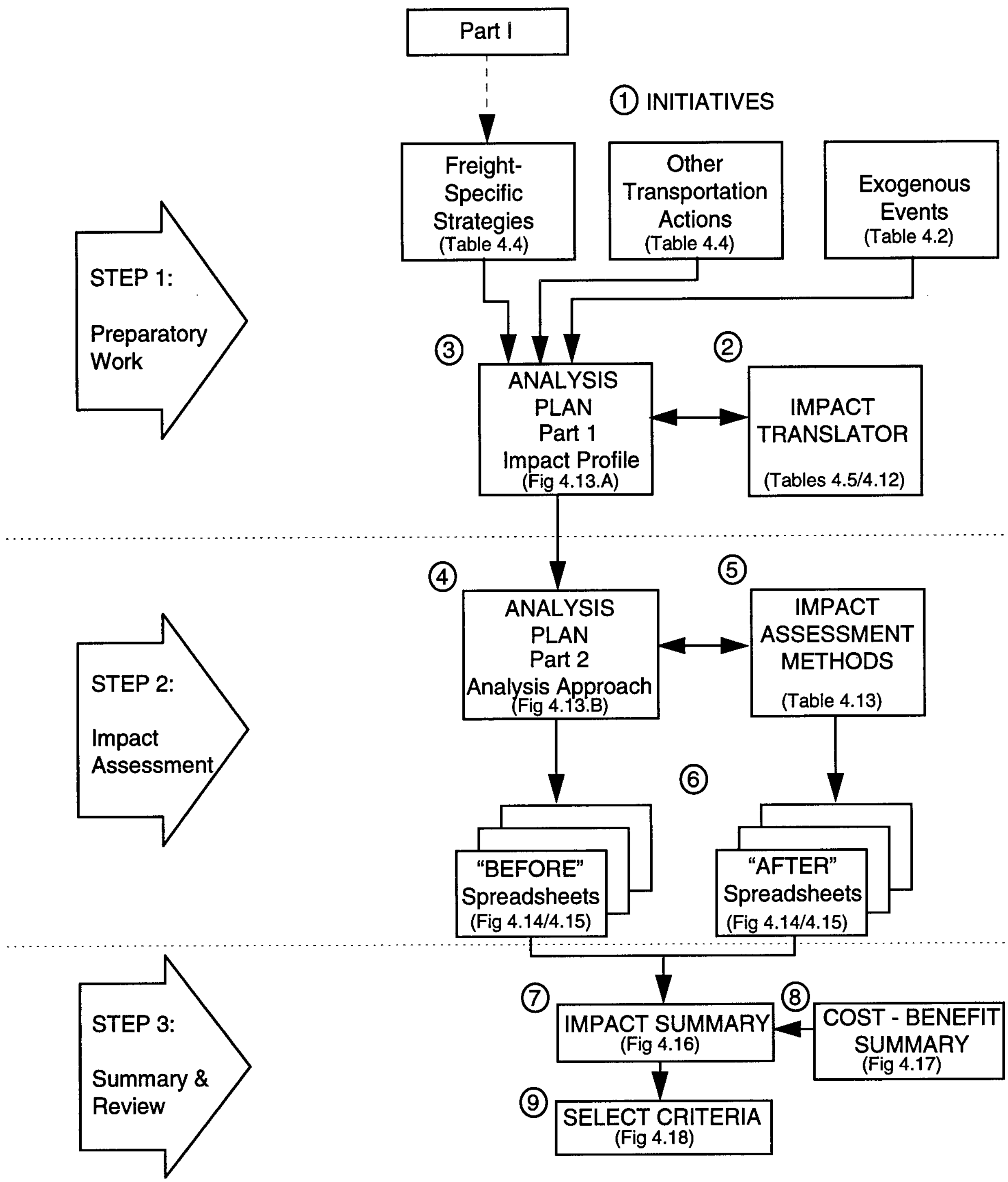
As indicated earlier, three general types of actions may raise analytic interest in connection with their impacts on freight transportation activity levels and patterns, efficiency, and emissions. These groups are:

- **Freight Strategies:** Actions specifically intended to alter the way in which freight transportation activity occurs, either to produce reductions in emissions or to improve the efficiency or effectiveness of freight service with likely emissions benefits.
- **Other Transportation Actions:** Actions to alter or improve the larger transportation system, which is likely to produce an effect on freight transportation activity levels, efficiency and emissions.
- **Exogenous Events:** Accounting for a variety of background factors that will impact freight demand or operations, transportation in general, or efforts in planning or policy making to affect air quality and emissions.

Freight Strategies: If the objective of the analysis is to identify and assess actions that ***directly impinge on freight operations and emissions***, it is expected that they will have been identified as part of the systematic review in Part I, Step 3. If the user is indeed attempting to address a freight transportation problem or deficiency directly, or wishes to pursue actions that will result in emissions reductions, the set of reference tables and identification procedures suggested in Part I, Step 3 are a recommended starting point. This does not preclude initiating the analyses here, however, with a given strategy that has been identified from some other process (e.g., suggested by decisionmakers, or by freight industry representatives), though wherever possible, a systematic process that identifies an unrestricted set of alternatives is recommended to ensure that intuition does not replace objectivity in searching out the most effective solutions.

Other Transportation Actions that might receive attention because of their indirect effect on freight and freight emissions include general capacity enhancements (or reductions), changes in access, new routing options that circumvent existing obstructions, pricing measures, changes in speed limits, etc. As will be demonstrated, the analyses for these strategies is the same as for the freight specific actions, requiring

Figure 4.12.A
Part II: Emissions Impact Assessment Procedure and Reference Guide



a methodical translation of the essential effects of the action on the freight transportation activity.

Exogenous Events are different in substance from the above "transportation actions" in that they correspond to the background forces in the economy, the population, or in policy and regulation that have an important impact on the conditions under which freight transportation is determined, and hence its volume, distribution and efficiency. These include the condition of the regional, national or international economy and location of markets and suppliers, trends in industrial and management practices, shifts in technology, and changes in regulation, policy and funding. In effect, while these measures are more abstract than the physical/direct transportation system actions described above, the analysis approach, again, is still essentially the same, requiring a breaking down of the essential features of the action or event as to its primary effects on the freight system, and consequently how it responds to those changes.

Lists of the various actions are presented in Tables 4.5 through 4.12, along with information on where in the analysis hierarchy that impacts might be expected, as a lead-in to the upcoming analysis. Review the tables to become familiar with their content, as they will become an important element in the next steps. Note that, while three categories of measures have been cited -- Freight Specific, Other Transportation, and External Events -- there are only two groups of tables. This is because the Freight Specific and the Other Transportation actions have been merged, since the manner in which their impacts are felt and assessed is fairly similar.

(2) Impact Translator

The important first step in conducting an analysis of any given Strategy, Action or Exogenous Event is to reduce its characteristics from terms that are "nominal" in describing the action to terms that are meaningful to analysis. For example, the improvement of a highway link's capacity through new construction or improved management only becomes relevant for analysis purposes when it can be related to the change it induces in transportation system performance, as experienced by its users in terms of changes in speed, travel time, cost and similar tangible factors upon which decisions are made. As discussed back in Section 4.2 (Figures 4.6. through 4.10.), the Analysis Hierarchy which underlies this methodology suggests three basic levels at which events may occur that have an eventual impact on the level and character of freight transportation, such as are essential in assessing overall activity levels, efficiency, and emissions production. These levels and their components, which appear as column headings in Tables 4.5 through 4.12, are:

- **Overall Freight Volume**, or the total volume of freight that is moving, by commodity with destinations either *into or out of the region, through the region,* or into the region to be *transferred to another mode* for travel back out.
- **Modal Activity Levels**, or the "Modal Split" of the given commodity by *truck* or *rail,* with distinction as to primary mode (i.e., the *Line-Haul* or long-distance carrier) or submode (i.e., the *Drayage or Yard* mode for local transfer and handling).

- **Emissions Precursors:** Freight activity variables that directly link to the production of emissions. The major precursors for **Truck Emissions** are *VMT and route, time of day, speed and acceleration profiles*, and the *emissions rate* of the technology itself. **Rail Emissions** are estimated from *energy use* in association with the *emissions rate* of the technology, though the *ton-miles* of freight movement is a primary determinant of energy use.

Tables 4.5 through 4.12 serve as an **Impact Translator**. The user will note the nomenclature of P, S, U or blank in each cell of the tables relating the given strategy, action or event to the range of potential impacts in the Analysis Hierarchy. The codes have the following meaning and purpose:

- **"P"** denotes a potential "Primary Impact" from the given strategy/action/event on the particular Impact Variable. This suggests that the effect of the action on this variable is very important, and should if at all possible be dealt with explicitly in the analysis.
- **"S"** denotes an expected "Secondary Impact" from the strategy/action/event, meaning that a measurable influence would be expected, but it would be through an indirect, or secondary, set of relationships. Again, though, the analysis should attempt to account for the impact of the action, if at all possible.
- **"U"** denotes a relationship where an impact may occur, but whether or not that impact is important enough to require analysis (or how the action will impact freight emissions) is uncertain. However, the analyst should be cautious about disregarding the potential impact of one of these actions out-of-hand, and should at least reflect on what effects it may induce, based on the particular circumstances of the given area.
- **"Blank"** suggests that no tangible or measurable effect would be expected between this particular action and freight/emissions, and probably need not be of concern in the analysis.

Table 4.5 Delineation of Impact Analyses for Freight Emissions Strategies
Group: Capital/Infrastructure Improvements

	Overall Volume			Modal Activity Levels				Truck Emissions Precursors				Rail Emissions Precursors		
Strategy	Regional Terminus	Through Region	Inter Modal	L.H. Truck	Dray Truck	L.H. Rail	Rail Yard	Time of Day	Route/ VMT	Speed/ Accl	Emis Rate	Ton-Miles	Energy Use	Emis Rate
New General Roadway Capacity	P	P	P	P	P	U	U	U	P	P	S	U	U	
Truck By-Pass Routes	U	P	U	P	U	U	U	U	P	P	S	U	U	
Grade Moderations	U	U	U	U					P	P	P	U	U	
Eliminate Physical Hwy. Constraints	S	S	S	P	P	U	U	U	P	P	S	U	U	
NHS System Connectors	S	S	S	U	S	U	S	U	P	P	S	U	U	
Ramp Extensions/ Modifications			S	P	P	U	U	S	P	P	P	U	U	
ITS Systems	S	S	S	P	P	U	U	U	P	P	S	U	U	

Impact Code: P = Primary Effect
S = Secondary Effect
U = Minor or Uncertain Effect

Table 4.5 Delineation of Impact Analyses for Freight Emissions Strategies
Group: Capital/Infrastructure Improvements (continued)

	Overall Volume			Modal Activity Levels				Truck Emissions Precursors				Rail Emissions Precursors		
Strategy	Regional Terminus	Through Region	Inter Modal	L.H. Truck	Dray Truck	L.H. Rail	Rail Yard	Time of Day	Route/ VMT	Speed/ Accl	Emis Rate	Ton-Miles	Energy Use	Emis Rate
RR Track Capacity Expansion/Upgrade	P	P	P	U	S	P	P	U	U			P	P	S
Double Stack RR Lines	P	P	P	U	S	P	P	U	U			P	P	S
Rail Priority Corridors	P	P	P	U	S	P	P	U	U			P	P	S
Short-Line/Belt Railways	S	S	P	U	S	P	P	U	U			P	P	S
ITS-Type Corridor or Yard Mgt. Sys.	P	P	P	U	S	P	P	U	U			P	P	S
Rail Yard/Switching Enhancements	P	P	P	U	U	S	P					S	P	S
New Intermodal Terminals	P	P	P	P	P	P	P	P	P	S	S	P	S	
Terminal Capacity Enhancements	P	P	P	P	P	P	P	S	S	S		P	S	
Terminal Relocation	S	S	P	P	P	P	P	U	P	S		P	S	
Terminal Consolidation	S	S	P	P	P	P	P	U	P	S		P	S	

Impact Code: P = Primary Effect
S = Secondary Effect
U = Minor or Uncertain Effect

Table 4.6 Delineation of Impact Analyses for Freight Emissions Strategies
Group: Low Capital/TSM/Management Improvements

	Overall Volume			Modal Activity Levels				Truck Emissions Precursors				Rail Emissions Precursors		
Strategy	Regional Terminus	Through Region	Inter Modal	L.H. Truck	Dray Truck	L.H. Rail	Rail Yard	Time of Day	Route/ VMT	Speed/ Accl	Emis Rate	Ton-Miles	Energy Use	Emis Rate
Designated Truck Routes	S	S	S	P	P	U	U	U	P	P	S	U		
Ramp Metering	U	U	U	S	S			S	P	P	P			
Incident Mgt. on Freeways	S	U	U	S	S			S	P	P	P			
Improved Signals on Arterials	U	U	U	U	U			S	P	P	S			
Traffic Engr. Flow Improvements	U	U	U	S	P			S	P	P	P			
Improved Signage			U						P	S				
Improved Scheduling	P	P	S			P	P					P	P	P
More Efficient Train Assembly	P	P	P			P	P					S	P	P
Terminal Efficiency Improvements	S	S	S					S			P*			
Improved Dray Scheduling			U		S	U		P	S	S	P*			
Longer Work Hours	S	S	S		P		P	P	S	S	S		S	

* Due to reduced Idling

Impact Code: P = Primary Effect
S = Secondary Effect
U = Minor or Uncertain Effect

Table 4.7 Delineation of Impact Analyses for Freight Emissions Strategies

Group: Regulatory/Pricing Actions

	Overall Volume			Modal Activity Levels				Truck Emissions Precursors				Rail Emissions Precursors		
Strategy	Regional Terminus	Through Region	Inter Modal	L.H. Truck	Dray Truck	L.H. Rail	Rail Yard	Time of Day	Route/ VMT	Speed/ Accl	Emis Rate	Ton-Miles	Energy Use	Emis Rate
Peak-Period Truck Restrictions	S	S	S	P	P			P	S	S	S			
Truck Facility or Area Restrictions	S	S	S	P	P			U	P	P	S			
Truck Size & Weight Limits	S	S	S	P	P				U	S	S			
Truck Emissions Fees	S	S	S	P	P						P			
Congestion Pricing	S	S	S	P	P			P	P	P	S			
Road Pricing	S	S	S	P	P			U	P	S	S			
Fuel Taxes, All	S	S	S	P	P	P	P	S	S	S	S	S	S	
Rail Emissions Fees	S	S	S			P	P		U	U	P	U	S	P
Incentives for Steel-Wheel Connection	U	U	S	S	P	S	P	U	S	S		P	P	
Incentives to Extend Terminal Oper. Hrs.	U	U	S	U	S	U	S	P	S	S		U	S	

Impact Code: P = Primary Effect
S = Secondary Effect
U = Minor or Uncertain Effect

Table 4.8 Delineation of Impact Analyses for Freight Emissions Strategies
Group: Modal Emissions Rates

	Overall Volume			Modal Activity Levels				Truck Emissions Precursors				Rail Emissions Precursors		
Strategy	Regional Terminus	Through Region	Inter Modal	L.H. Truck	Dray Truck	L.H. Rail	Rail Yard	Time of Day	Route/ VMT	Speed/ Accl	Emis Rate	Ton-Miles	Energy Use	Emis Rate
New/Higher Standards Truck	U	U	U	S	S	S	S				P			
New/Higher Standards Rail	U	U	U	S	S	S	S							P
Alternative Fuels Truck				U	U				U*		P			
Alternative Fuels Rail						U	U						S	P
Modified Fuels Truck				U	U						P			
Modified Fuels Rail						U	U						S	P
Enhanced I&M for Trucks				U	U						P			

* Possible Issue in Relation to Accessing Fuel

Impact Code: P = Primary Effect
S = Secondary Effect
U = Minor or Uncertain Effect

Table 4.9 Delineation of Analyses Issues for External Actions/Events Affecting Freight Emissions

<u>Group: Economic Trends and Conditions</u>

	Overall Volume			Modal Activity Levels				Truck Emissions Precursors				Rail Emissions Precursors		
Strategy	Regional Terminus	Through Region	Inter Modal	L.H. Truck	Dray Truck	L.H. Rail	Rail Yard	Time of Day	Route/ VMT	Speed/ Accl	Emis Rate	Ton-Miles	Energy Use	Emis Rate
Overall Economic Conditions	P	P	P	S	S	S	S	S	S	S		S	S	
Regional Economic Conditions	P	S	P	P	P	P	P	S	S	S		S	S	
Shift in National/ International Markets	P	P	P	P	P	P	P	S	P			S		
Shift in Regional Economic Base	P	S	P	P	P	P	P		S					
Change in Cost of Travel (to Providers)	S	S	S	P	P	P	P				S		S	S
Highway Congestion	P	P	S	P	P	S	S	P	P	P	S			

Impact Code: P = Primary Effect
S = Secondary Effect
U = Minor or Uncertain Effect

Table 4.10 Delineation of Analyses Issues for External Actions/Events Affecting Freight Emissions
<u>Group: Industry Trends & Conditions</u>

	Overall Volume			Modal Activity Levels				Truck Emissions Precursors				Rail Emissions Precursors		
Strategy	Regional Terminus	Through Region	Inter Modal	L.H. Truck	Dray Truck	L.H. Rail	Rail Yard	Time of Day	Route/ VMT	Speed/ Accl	Emis Rate	Ton-Miles	Energy Use	Emis Rate
Structure of Truck Industry	S	S	S	P	P	S	S		S			S		
Structure of Rail Industry	S	S	S	S	S	P	P		S			S		
Change in Shipper Time/Cost Preferences	S	S	S	P	P	P	P	S	S	S	S	S	S	S
Truck Industry Operating Practices	U	U	U	P	P	S	S	S	S	S	S	S		
Rail Industry Operative Practices	U	U	U	S	S	P	P					S	S	S
Changes in Labor Rules				S	S	S	S	P			S	P	S	
Changes in Management Practices			S	S	S	S	S	S	S	S	S	S	S	S

Impact Code: P = Primary Effect
S = Secondary Effect
U = Minor or Uncertain Effect

Table 4.11 Delineation of Analyses Issues for External Actions/Events Affecting Freight Emissions

Group: Technological Changes

	Overall Volume			Modal Activity Levels				Truck Emissions Precursors				Rail Emissions Precursors		
Strategy	Regional Terminus	Through Region	Inter Modal	L.H. Truck	Dray Truck	L.H. Rail	Rail Yard	Time of Day	Route /VMT	Speed/ Accl	Emis Rate	Ton-Miles	Energy Use	Emis Rate
New Emissions Tech. Truck	S	S	S	S	S					S	P			
New Emissions Tech. Rail	S	S	S			S	S						S	S
Change in Hauling/ Energy Effcy. Truck	S	S	S	P	P				U		S			
Change in Hauling/ Energy Effcy. Rail	S	S	S	S	S	P	P					P	P	S
Advanced Sched. & Mgt. Systems	S	S	S	S	S	S	S	P	S	S	S	P	P	S

Impact Code: P = Primary Effect
S = Secondary Effect
U = Minor or Uncertain Effect

Table 4.12 Delineation of Analyses Issues for External Actions/Events Affecting Freight Emissions

<u>Group: Policy/Regulatory Shifts</u>

	Overall Volume			Modal Activity Levels				Truck Emissions Precursors				Rail Emissions Precursors		
Strategy	Regional Terminus	Through Region	Inter Modal	L.H. Truck	Dray Truck	L.H. Rail	Rail Yard	Time of Day	Route/ VMT	Speed/ Accl	Emis Rate	Ton-Miles	Energy Use	Emis Rate
Changes in Air Quality Regulations	U	U	U	S	S	S	S	S	S	S	P	S	P	P
Change in Highway Funding Programs	P	P	S	S	S	S	S	U	P	P	S	S		
Change in Truck Safety Regulations	U	U	U	P	P	S	S	U	P	U	U	S		
Change in Rail Safety Regulations	U	U	U	S	S	P	P					P	P	S
Regulation of Truck Ship Fees	P	P	P	P	P	P	P	S	P			S	S	
Regulation of Rail Ship Fees	P	P	P	P	P	P	P		P			P	P	S
Change in Truck Size/ Weight Rules	P	P	P	P	P	P	P		P		S	P	S	

Impact Code: P = Primary Effect
S = Secondary Effect
U = Minor or Uncertain Effect

(3) Analysis Plan, Part I: Impact Profile

Figure 4.13 offers a form to guide this task. It is suggested that one of these forms be completed for each strategy or action that will eventually be analyzed. The top of the form provides for a basic description of the Problem and Setting which is being addressed, the Strategy, Action or Event which is to be tested, and a summary of the Overall Expected Impact, i.e., what the analyst anticipates might happen through the application of this strategy.

Following the description, the body of the form systematically identifies each step in the hierarchy where an impact could occur. These steps are pictured in the same order as they are found in the **Impact Translator**, Tables 4.5 through 4.12, namely:

- Overall Freight Volume:
  - Goods that have a Regional Origin or Destination
  - Goods that are traveling Through the Region
  - Goods that are undergoing Intermodal Transfer
- Modal Activity Levels:
  - Line-Haul Intercity Truck
  - Drayage Truck
  - Line-Haul Rail
  - Rail Yard/Switching Operations
- Rail Emissions Precursors:
  - Ton-Miles of Rail Goods Movement
  - Rail Energy Consumption
  - Rail Emissions Rates
- Truck Emissions Precursors:
  - Time of Day
  - Route/VMT
  - Speed/Acceleration Profile/Events and Idling
  - Truck Emissions Rates

Also listed at the end of the form is a separate category for accommodating Secondary Emissions, or emissions from other (non-freight) transportation that are either affected by current freight operations or would be affected by strategy-induced changes.

The small box in the center column of the Analysis Plan form provides for an Impact Code. This code is taken from the **Impact Translator** Tables (4.5 through 4.12) and denotes whether the selected strategy is likely to have a Primary (P), Secondary (S), Uncertain (U), or no (blank) impact on that particular step. Locate a strategy or event in the Tables that is similar to the one under consideration, and enter the letter in the Impact Code box of Figure 4.13. This will help guide the analyst in where to direct the greatest effort in the subsequent analysis.

Figure 4.13. Analysis Plan

Problem/Setting:	
Test Strategy, Action or Event:	
Summary of Overall Expected Impact:	

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Overall Volume	Regional Origin or Destination			
	Through Trips			
	Intermodal Trips			
Modal Activity Levels	Line-Haul Truck			
	Drayage Truck			
	Line-Haul Rail			
	Rail Yard/ Switching			

Figure 4.13. Analysis Plan (Continued)

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Rail Emissions Precursors	Ton-Miles			
	Energy Consumption			
	Emissions Rate			
Truck Emissions Precursors	Time of Day			
	Route/VMT			
	Speed/Accl & Idling			
	Emissions Rate			
Secondary Emissions				

The next column in the Analysis Plan form provides for a description of the Anticipated Impact that is expected from the strategy at that level, effectively explaining why the strategy/event is accorded a P, S, U or Blank Impact Code for that level. Once the potential impacts have been sketched out, the last column asks the user to specify the Proposed Analysis which will be conducted to quantify these impacts. This Proposed Analysis is discussed further in Step 2, where analytic approaches are reviewed and selected in relation to the given strategy and its impact "priority" (Impact Code).

Figure 4.13.A shows how an Analysis Plan might be developed for a typical strategy. The example used is an "NHS Connector", a set of strategic improvements to the access between the main highway system and a given intermodal facility. Commonly, local access to and between rail intermodal yards or ports is by drayage truck, and occurs over local secondary roads and streets which were not designed for that purpose. Hence, connections to the main highway system may be at distant, sub-optimal locations, may not involve smooth ramp transitions with mainline traffic, and may involve travel on crowded, capacity-restricted local streets with intersection and parking conflicts, turning restrictions, and poor flow characteristics. These deficiencies may result in added VMT due to circuitous routing, high rates of emissions resulting from suboptimal flow conditions, and secondary congestion and emissions impacts on other traffic.

This strategy is detailed in Figure 4.13.A. The top of the form describes the problem setting and the problem, describes the strategy, and then offers an overall summary of the way in which this strategy might be expected to change conditions and affect emissions. The next step is then to find the NHS Connector strategy in the Impact Translator table set, in this case the fifth strategy entry in Table 4.5 as a Capital/Infrastructure Improvement. Taking guidance from Table 4.5, the Impact Codes for the strategy on each of the dimensions or elements in the hierarchy are reviewed and copied into the Figure 4.13.A worksheet. Then, based on the perspectives that have been presented in this report and this chapter, the user attempts to write a brief description of the Anticipated Impact that would be expected at that particular level. The Impact Codes should signal to the analyst what level of priority to place on the respective element in analysis: If it is a Primary effect, then the very best efforts should be directed at the analysis of that element. If it is a Secondary effect, then the analyst should be very *wary* of what level and type of impact could occur, since the effect could be counter-productive. A reasonable analysis should still be planned. If the suggested Impact Code is U, then its effects are either minor, or at best <u>uncertain</u>. If the latter, the analyst should again be careful to ensure that the effect is not one that has a potential major impact on the overall outcome.

Later, in Step 2, it will be shown how this profile is transformed into a complete Analysis Plan by linking the Anticipated Impacts with the Proposed Analysis method.

Figure 4.13.A: Example Analysis Plan

Problem/Setting:	Poor access to rail intermodal terminal XYZ from NHS highway system. Significant VMT over secondary roads and local streets.
Test Strategy, Action or Event:	Implement NHS connector to terminal from State Highway ABC, involving widening, easing of geometric and vertical clearance barriers, improved signalization.
Summary of Overall Expected Impact:	Truck emissions to decrease based on reduced VMT, improved operating conditions. Secondary benefits possible due to reduced conflict with other traffic. Issues as to whether improved access generates additional truck traffic & emissions.

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Overall Volume	Regional Origin or Destination	S	Improved access may stimulate volume of goods entering or leaving region, but major inducements not expected.	
	Through Trips	S	Improved access could increase the volume of goods which are trans-shipped through the region.	
	Intermodal Trips	S	Improved access to a given terminal could increase the volume of activity to that terminal, either absolute or diverted from other terminals.	
Modal Activity Levels	Line-Haul Truck	U	Unlikely to affect level of activity of line-haul intercity truck operations.	
	Drayage Truck	S	By improving access, may increase the volume of goods transported to yard by truck	
	Line-Haul Rail	U	Unlikely to affect level of activity of line-haul rail operations.	
	Rail Yard/ Switching	S	Improving access for dray truck may reduce incentives for steel-wheel intermodal transfers.	

Figure 4.13.A: Example Analysis Plan (Continued)

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Rail Emissions Precursors	Ton-Miles	U	No major effect expected unless regional activity level increases.	
	Energy Consumption	U	No major effect expected unless regional activity level increases.	
	Emissions Rate		No effect expected.	
Truck Emissions Precursors	Time of Day	U	Unlikely to shift time of day truck trips unless improvements increase capacity and induce shift of VMT back into peak periods.	
	Route/ VMT	P	Major effect would be to shift routing of dray trips, and possibly reducing VMT with improved routing (could also increase VMT).	
	Speed/Accl & Idling	P	Speeds may improve and smoother flow (less stops & starts & idling time) would reduce emissions rates.	
	Emissions Rate	S	Emissions rates would change if speeds and flow conditions changed above.	
Secondary Emissions		S	Dedicated route for trucks may reduce conflicts and other traffic, resulting in smoother flow and higher average speeds, with reduced emissions.	

Step 2: Impact Assessment

Having identified the candidate strategies, actions or events in Step 1 to be examined, and initiating the evaluation with development of the Impact Profile, this step provides for the actual analysis. Again, there are subcomponents to this Step, which, as pictured in Figure 4.12.A are:

(4) Development of **Part 2 of the Analysis Plan**, which details the **Analytic Approach**

(5) Identification of the relevant **Impact Assessment Methods**

(6) Development of a system of **"Before" and "After" Spreadsheets**

These are discussed individually below:

(4) Analysis Plan/Analytic Approach

As discussed above, the Analysis Plan captured in the worksheet form in Figure 4.13 is developed in two parts. The first part, developed under Step 1 (3), provided a profile of the Anticipated Impact for each level of the hierarchy. In this Step 2 (4), the same worksheet form is now used in conjunction with review of the available analytic tools and data, and the noted priorities for the analysis, to develop an actual approach for conducting the analysis.

The last column in the Analysis Plan worksheet (Figure 4.13) provides for a description of the Proposed Analysis approach. Figure 4.13.B later shows how the Anticipated Impact information compiled on the NHS Connector example is used along with the additional guidance information provided in the following steps to specify a Proposed Analysis approach for the same strategy.

(5) Impact Assessment Methods

The options for assessing freight activity and emissions impacts are as varied as there are strategies, regulatory/planning requirements, data resources, modeling tolls, and level of interest. As indicated earlier, given the state of flux the development of freight forecasting tools, this methodology has been designed to be flexible enough to address a wide range of needs and circumstances. Listed below are methods and concepts that may be used for conducting freight transportation-related analyses. By no means is this expected to be the complete list of analytic options that exist, and users are encouraged to refine and improvise on these methods to serve their particular analysis needs.

In general, a classification system of methods is suggested that reflects an increasing gradient of sophistication, accuracy and input effort, according to the following scale:

Level A: Judgment and Hypothesis Testing:

This is the most elementary and potentially least accurate method of estimating changes and impacts, though for certain applications it may be a very acceptable alternative. To infer what change may occur in travel activity levels or patterns as a result of a change in system operations, policy or market conditions, the analyst can do one of two things:

- **Expert Opinion:** The opinion or judgment of a specialist in the particular area, such as an industry representative, a shipper, or a freight operator is often a valid source for gauging an impact. It is important to supply this specialist with the important facts and conditions that effectively and objectively describe the proposed action. Also, care should be taken to minimize the effects of "personal stake" or bias in the proposal which the expert is being asked to comment upon. Where possible, such biases and ranges of experience should be buffered by using a group of specialists to get a "balanced" opinion; such a body may exist within the Freight Planning or Advisory Committees which have been established by many MPOs under the intermodal provisions of ISTEA.
- **Hypothesis Testing:** When the actual outcome of an action is difficult to predict with existing data, tools or knowledge, a commonly-used approach is to make an informed judgment about the "range" of outcomes that the particular action can induce, and then bracket the uncertainty of the conclusions by portraying the sensitivity of the final result to these different preceding events.

Level B: Sketch Planning Using Secondary Data:

A common way of performing a reasonably structured and comprehensive analysis when knowledge, data or tools are deficient is to employ "Sketch Planning" methods. This technique is often used for first-stage analysis, or when a quick response is required. In essence, the analyst identifies the major variables and parameters which define the problem setting and the strategy or action to be tested. He then makes various stated assumptions about the range of these elements that best contain the given test. Frequently, among the variables that are involved in the test, insights or relationships can be drawn from empirical studies, reference guides, or various secondary data sources Existing data sources are described in Chapter 3. Sometimes models can be used to generate estimates of the given effect, once it has been "isolated" from other factors and influences. A sketch planning analysis may be a perfectly acceptable option for screening or preliminary analysis. It may even serve as the basis for development of a more sophisticated analysis tool/procedure if new data and statistical analyses are applied to formalize the relationships. [In many respects, this Freight Emissions methodology itself is such a sketch planning approach.]

- **Sample Shipment Analysis:** A technique which has particular value in sketch planning applications for freight is to study a representative freight movement, or shipment, in some detail, and then extrapolate broader policy implications from that case study. Often, the number of variables associated with a freight movement can be overwhelming, considering commodity, mode and type of vehicle, origin-destination, load factors, route alternatives and choices, and speed/flow conditions. The analyst picks a particular trip that is believed to be representative of the movement in question, and then, using the assistance of maps and other secondary data, describes the routing, speed, VMT and other salient characteristics of that trip. Selective original data may be obtained to sharpen this trip profile, such as observation of a given trip, travel time runs, or observation of flow impediments and conflicts. The sample trip is then used as the basis for investigating changes in response to a policy or system action. The accuracy and realism of this approach increases with the number of **Sample Shipments** that are used to represent the particular problem situation.

Level C: Adaptation of Existing Models:

While the modeling of freight transportation, and intercity freight in particular, is acknowledged to be behind that of passenger transportation, there are existing modeling tools that may be of meaningful use. These tools may be special-purpose freight forecasting procedures which have been developed for other areas or applications. However, local planning tools may also be of some use. General options are:

- **Freight Forecasting Tools**: A number of industry and public research studies have produced models and procedures to estimate freight transportation response to policy or system changes, or to changes in underlying economic or market conditions. Relevant tools or studies researched by this project and are summarized in Chapter 3 and in Appendix A. These tools or approaches may prove to be relevant and can be adapted to address a given site's particular problem.
- **Local Modeling Tools:** While the conventional 4-step regional transportation planning process is not particularly suited to analysis of freight, it can still serve an important supporting role in relation to traffic assignment and perhaps even activity levels and distribution (other techniques are under development to aid in the development of freight trip tables, per se). Traffic microsimulation tools are gaining increased use in estimating flow and speed conditions more accurately for input to emissions.

Level D: Local Case Studies, Data Collection, Model Development:

For analyses which require the highest levels of accuracy and specificity, particularly in relation to regulatory determinations, financing issues, or decisions which may be politically controversial, the analysis effort will probably want access to the best tools and data possible in order to maximize confidence in the findings. For this there is no substitute for intensified local analysis involving one or more of the following strategies:

- **Case Studies:** Given the luxury of time, a reliable approach would be to compile local information on the particular market segment and/or strategy by monitoring and analyzing the changes that occur in a real life episode. For such a test to be valid, however, careful attention must be given to the design of the monitoring and data collection. Before and after measurements should be taken to detect changes, with sufficient time between measurements to allow for stabilization to occur. It is also important to control for important background events and mitigating circumstances, such as economic conditions, price levels, commodity or market shifts, new policies or regulations, new infrastructure or capacity modifications, and factors relating to spatial and temporal setting.
- **Data Collection:** Since the desired data on freight activity levels and specific conditions around a particular problem/applications site are not likely to be available, the quality of an analysis is likely to be improved by the collection of current and statistically representative data. Trip data on goods movement is generally quite

limited, including origin-destination of shipments, intermodal transfers, commodity, vehicle configurations, facilities/routes, and time of day or day of week. An initial analysis of a strategy may make exceptions for the existence or quality of such data, but for important strategies that require a higher level of accuracy and confidence, obtaining some case-specific data may be absolutely necessary. Sources for these data might range from regional truck O-D surveys to commodity surveys, to traffic facility/corridor studies, to site activity and use surveys (e.g., at a terminal, port or yard).

- **New/Specialized Models:** If the particular problem or concern is especially complex, and/or it appears likely to be a recurrent issue, the analysis agency may be advised to develop specialized statistical modeling tools that integrate with or operate separately from the current 4-step model. This particular Freight Emissions methodology may itself be transformed into a computer software routine, which will allow for consideration of a wider range of variables, account for interactions among modes and strategies, and provide a basis for longer-term enhancement with more sophisticated decision modules.

Which technique the analyst uses depends greatly on several factors: the strategy to be analyzed; the scale of the application (site, corridor, region, intercity/interstate); available data; available modeling tools; level of expertise in freight issues; and perhaps most importantly, the level of accuracy necessary in the results. ***The important perspective to gain is that the typical freight "problem" has a hierarchy of activity levels and relationships that influence "bottom-line" emissions (consistent with the framework), and that analysis at each of these levels may be an independent decision based on tools, data and requirements of the strategy (i.e., whether that level or factor is of Primary or Secondary importance).***

This range and independence of options is highlighted in the schematic figure on the following page. Along the left column are each of the dimensions in the hierarchy where impact could occur, from Volume Levels though Secondary Emissions, and along the top are the four levels of analysis, from Levels A through D. In a given strategy analysis, then, the analyst considers the impact importance of each of the dimensions in the freight hierarchy (i.e., its contribution to the final answer), and then assesses and selects the best available/most suitable analysis methodology at that step. In other words, it could easily happen that only Level A or Level B analysis was used for evaluating the impact of the example NHS Connector strategy on Freight Volume Levels, Modal Activity Levels, and Rail Emissions Precursors -- since these are expected to be minor effects -- but might advocate using more rigorous Level B methods or pushing to Level C for the analysis of the Truck Emissions Precursors and possibly the Secondary Emissions effects.

Alignment of Analysis Options with Freight Activity Issues in Analysis Hierarchy

Analysis Hierarchy	Level A: Judgment	Level B: Sketch Plan	Level C: Exist. Models	Level D: New Methods
Freight Activity Levels				
1. Regional Source 2. Through Travel 3. Intermodal				
Modal Activity Levels				
1. Line-Haul Truck 2. Drayage Truck 3. Line-Haul Rail 4. Yard Locomotive				
Rail Emis. Precursors				
1. Ton-Miles 2. Energy Use 3. Emissions Rate				
Truck Emis. Precursors				
1. Time of Day 2. Route/VMT 3. Speed, Accel 4. Emissions Rates				
Secondary Emissions				
1. Time of Day 2. Route, VMT 3. Speed/Delay 4. Emissions Rates				

Tables 4.13.A through 4.13.E provide the ***detailed*** guidance implied by the diagram above, as to what particular options exist or are suggested for each impact area (and subarea) and each Level of Analysis. The way this key should be used is in conjunction with preparing Part 2 of the Analysis Plan, which outlines the Analysis Approach. This is discussed as a procedure below in the section on Analysis Approach development.

The following is a general description of the reference Tables 4.13.A through 4.13.E, their content and use:

Freight Volume and Orientation: Table 4.13.A suggests analysis options for questions related to freight volume levels and the orientation of those flows -- to or from a Regional Source, pure Through Movements, and movements which are undergoing Intermodal Transfer. Options for analysis are suggested for each of the four levels, which are broadly summarized below. The reader will note that each cell in this table suggests a slightly different approach depending upon whether the particular change is **Strategy Induced**, that is, where a program, policy or project causes changes in operating conditions, or is based on **Time Trend,** where the change is one of evolution over time in relation to economic growth, changes in demographics, technology, etc. Clearly, long-term analysis scenarios could include both Strategy Induced and Time Trend types of influences.

Level A: Judgment -- Changes in freight volume by commodity or orientation may be estimated using the judgment of industry and freight experts. This may be made more credible by associating the estimates with other evidence, such as economic trends, freight trends, or similar examples from other areas. The use of ranges to bracket uncertainty regarding the degree of change may also be an acceptable first stage analysis strategy.

Level B: Sketch Planning -- The realism of a simple analysis can be increased by paying more careful attention to the details or factors which influence the outcome, and attempting to control for those factors as carefully as possible. In this case, an estimate of the possible change in volume, even if it ultimately involves a high degree of *judgment,* may be made more accurate by applying the following procedures or strategies:

- For strategy induced changes, carefully ascertain what effect the particular policy or improvement will have on freight operations, in terms of objective travel time, cost, quality of service, or flexibility to make route, time of day, or loading decisions. This will make the circumstances to which the "expert" is being asked to make a judgment on more tangible and realistic.
- Define the context of the problem as clearly as possible, with regard to type of commodity, routes used, types of carriers, modal options, market locations, shipper requirements, etc.
- For applications that have complex or uncertain choices (and are of a manageable spatial scale), use of the **Sample Shipment** technique can be quite valuable at delineating the characteristics and conditions of the given trip, and for enumerating the alternatives.
- For Time Trend induced changes, all the above apply, but tie-in of estimates of freight activity to economic forecasts should be more specifically linked to commodity forecasts, regional and national economic trends, technology factors, industry trends, etc.

Level C: Existing Models -- An estimate of changes in freight demand and activity level might be accomplished through a number of economic activity models or indices. Using methods presented in Chapter 3, Section 3.2.3, changes in economic activity can then be converted to changes in freight flows by modifying the truck trip tables to reflect the new level or distribution of activity. This approach would be an option in the case of long term trends. It may also be useful for strategy-induced changes if the economic activity levels in the input/output model are sensitive to the level of service provided by the transportation system. Modeling changes in volume for Through Traffic would require use of a higher-resolution economic flow model that extends beyond the region to the state, national or international level. Estimating changes in Intermodal Traffic would combine both of the above techniques, since both internal and external economic activity levels are determinants.

Level D: New Data & Models -- It would be a challenging endeavor for a regional agency to undertake development of a new modeling procedure for generating truck trips and travel flows. A good start in this direction, however, would be to develop a current and comprehensive freight database. An Origin-Destination truck use survey would provide valuable information on commodity flow, intercity vs. local trips, geographic orientation, trip rates relative to economic activity levels, and characteristics specific to the vehicle. More conventional traffic flow studies with vehicle classification components would provide valuable information on truck volumes, ratios and speeds on particular routes at particular times. Relating this information to concurrent economic or transportation system conditions (and ideally maintaining monitoring over time) could produce valuable relationships for either simple or sophisticated analytic tools.

Freight Modal Activity Levels:

Table 4.13.B identifies analysis options for issues related to Modal Activity, specifically the split between truck and rail for intercity movements. Modes represented in the table are Line-Haul Truck and Rail, and Drayage Truck and Locomotive Yard/Switching operations. An overview of suggested analyses techniques by Level is as follows:

Level A: Judgment -- Changes in use rates of rail vs. truck, either in response to a change in service conditions or over time, is a fairly complex phenomena to model. Many factors can influence the outcome, including the type of commodity and the importance of time or cost in its shipment; the final demand for the commodity itself; and competition between alternatives. Given this uncertainty, soliciting the opinion of freight or industry experts may well produce the most reasonable estimates. Again, uncertainty in the response can be offset somewhat by also analyzing results under a range of possible outcomes.

Level B: Sketch Planning -- Again, estimates of activity change where data, information or tools are limited can be made through sketch planning methods.. Judgments of experts or assumptions about ranges of outcomes can be made more defensible if the components of the analysis have been broken down and approached systematically according to available knowledge. Elasticity methods such as presented in Section 3.2.4 can be used to estimate these changes. In the case of mode shifts, accuracy in estimating changes in response to a policy or system change can be enhanced by making it very clear how the given policy or project will affect freight service, and then obtaining judgments about potential changes based on this specific context. Clearly, the use of the "Sample Shipment" technique can be quite helpful in breaking out the essential details of the system/policy change so that an estimate of the mode effect can be made.

Level C: Existing Models -- There are existing statistical models which attempt to forecast the shift in activity between rail and truck in intercity movements. The models of the Association of American Railroads and that developed for the Federal Railroad Administration by TransMode may both have applicability for intercity line-haul situations. As to the impact within a metropolitan area, the intercity line haul changes would need to be converted into changes in the regional heavy truck trips tables, using factoring procedures. For drayage truck, models do not exist. Estimates of net shifting from truck to intermodal rail could be used to estimate changes in dray truck activity levels. For situations where line haul mode balances were not being affected, such as with improved NHS connectors, or where rail inter-terminal connections were developed, the change in dray trips would have to be estimated from judgment based on the specific circumstances. Changes in locomotive yard operations could also be proportioned to increases in intermodal rail activity, but should also make use of expert judgment to estimate impact.

Level D: New Data & Models -- Development of site specific models for analyzing freight mode shifts is probably not realistic. Again, however, obtaining good local data on freight travel characteristics is a valuable contribution to the ability to form more reliable relationships. Case studies which monitor changes in behavior of either line haul or dray/switching activity related to changes in policy or the system can also serve as a basis for estimating changes more reliably.

Changes in Rail Emissions Precursors:

Table 4.13 C provides the following guidance in relation to the rail emissions precursors of Ton-Miles of activity, Energy Consumption, and Emissions rates:

Level A: Judgment -- Levels of rail service in ton-miles are based on economic conditions and rail/truck competition as addressed above (these techniques and estimates should be used as a starting point).

Changes in rail energy consumption rates could occur in response to factors of fuel cost, competition, new technology or fuels, or improved operation and maintenance. Emissions rates, also, are affected by policy requirements and standards, economic conditions and competition, and also the efficiency of fuel used. Use of industry trend data; implementation schedules for federal or state fuel economy or emissions standards; or judgment of experts are available to help guide these estimates.

Level B: Sketch Planning -- Again, for changes in ton-miles of rail activity, use results from Rail Volume and Activity estimates from prior steps.

For help on how fuel use rates or emissions change with market, investment or policy conditions, consult empirical studies such as the Canadian Railroad or the Abacus studies described in Chapter 3. Temper these empirical data with judgment based on similarities/differences with local situation.

Level C: Existing Models -- For changes in overall rail ton-miles, use estimates from prior step.

For changes in rail energy consumption or emissions rates, adapt and use relationships found in studies such as the Canadian Railroad or Jack Faucett reports.

Level D: New Data & Models -- Compile local data on trends in rail activity levels, age and condition of equipment, and changes which may occur over time or in parallel with changes in policy, economic or system performance factors. Case studies where conditions are controlled in measurement of response to a change may also be valuable. Specific models may be developed from these local data and case studies.

Changes in Truck Emissions Precursors:

Table 4.13 D provides the following guidance in relation to the truck emissions precursors of Time of Day, Route Choice/VMT, Speed/Acceleration Events and Idling, and Truck Emissions Rates. Each of these precursors is quite different in how it is determined:

Level A: Judgment -- The time of day at which a freight trip is made depends on several factors, most particularly of which is the urgency of timely delivery for particular commodity shipments. For through trucks and for straight line-haul trucks, time of day may not be a realistic option. Congestion during peak travel periods may already be the biggest factor influencing this choice. A first approximation as to how this might change would be to ask industry experts -- both shippers and carriers.

Route Choice may be limited by available options. Experts can also be asked to suggest how changes might occur under different proposed circumstances.

Not much can be done about estimating speed without at least some degree of data work (model or collection). However, idling emissions are an important concern with freight, and estimates can be made of how this might change under different inducements.

Truck emissions rates are affected mainly by age and turnover, but also by technology shifts induced by fuel and emissions policies and standards. Projected fleet composition is probably a good starting point; ask carrier, technology and regulatory specialists how rates might change under different inducements.

Level B: Sketch Planning -- This analysis is made a grade up from the rough judgments in Level A by being much more specific as to the context of the proposed inducement (where, how) and the effect it would have on service and flexibility for particular trips. Sample Shipment technique may be helpful in posing specific options to experts.

Level C: Existing Models -- Existing analytic tools primarily consist of the 4-step model, and its assignment and speed estimation routines. The use of the 4-step model for evaluating time of day changes would be limited to peak and off-peak conditions in only the most advanced models; peak and off-peak heavy truck trip tables would have to be re-allocated based on expected shifts, and a new assignment performed. While the traffic assignment routine in conventional models is not particularly suited to truck travel, it may be the only alternative to evaluate the system-wide shift of truck (and other) vehicle trips under a change in conditions. Judgment and reasoning should be applied to the results, however, to ensure that they are reasonable. While no 4-step model traffic assignment routine is good in predicting speeds resulting from a new traffic loading, it can be used as a first approximation of how speeds might change to reflect volume/capacity changes; traffic microsimulation tools can be used to provide a more intensive and accurate estimate of speed and delay conditions under constrained flow conditions. Emissions rates are provided by emissions factor models, like MOBILE or EMFAC. To improve the accuracy of these models, the emissions rates can be factored to reflect variations in speed or composition of the local vehicle fleet.

Level D: New Data & Models -- Again, obtaining new and comprehensive freight and truck activity data is one of the best investments in developing a higher-level freight analysis capability. It is also possible, either through observing changes in choice by carriers (or shipper preferences) in case studies, or gaining insight through stated preference surveys[2], to construct analytic relationships that will help predict the response of truck carriers to changes in time of day, route, idling, fuel consumption, or emissions rate relative to particular policy, program or market conditions.

Secondary Emissions:

Table 4.13 E provides the following guidance in relation to the analysis of the determinants of Secondary Emissions induced by freight operations on other traffic. The precursors of interest in this area are also Time of Day, Route Choice/VMT, Speed/Delay, and Emissions Rates:

Level A: Judgment -- The response of non-freight highway users to changes in travel/system performance conditions at different times of day or on different routes is somewhat more studied and predictable than with heavy truck. However, time of day flexibility and shifts for passenger travel is still not well understood and is handled crudely (with factors) in conventional models. Route choice also is more a mechanical assignment than a process of traveler "choice" in relation to factors such as level of service, cost, etc. For simple, first generation analyses, travelers might be asked as to how they might react to certain changes in conditions caused by different freight actions. Alternatively, for simple first-stage analyses, it might be advisable to simply not assume any change in non-freight travel and emissions.

Level B: Sketch Planning -- A sketch planning approach to this same analysis would attempt to define the change in level of service that would occur on the transportation system (perhaps sample "Sample Shipment" links only), calculate a new V/C ratio, and estimate the speed change for non-truck traffic which remains. Associate this VMT with a new emissions rate.

Level C: Existing Models -- Again assuming that non-freight traffic will not change its time of day patterns, run a new assignment with the truck trips removed from affected facilities. Determine the change in V/C and speeds, and relate to new emissions rate. Traffic microsimulation models can be used for complex cases of constrained flow to obtain more detailed estimates of speed and delay.

Level D: New Data & Models -- To do an effective job in forecasting the real effect on secondary emissions, travel survey data would be needed to obtain relationships on time of day choice and selective route choice for passenger/non-freight travelers. A choice model or set of relationships (from revealed or stated preference methods) could then be developed to help predict the shifts in time of day and route for non-freight traffic. A new assignment would be run for the various time periods, new speeds calculated, and new emissions rates applied.

[2] David A. Hensher, P. Truong, and P.O. Barnard, "The Role of Stated Preference Method Studies of travel Choice," *Journal of Transport Economics and Policy*, January 1988.

Table 4.13.A. Impact Assessment Methods by Level of Complexity vs. Analysis Impact Area: Freight Volume & Orientation

Impact Area Within Analysis Hierarchy	Level A: Judgment	Level B: Sketch Planning	Level C: Existing Models	Level D: New Data & Models
Overall Volume Into/Out of Area	Strategy induced change Opinions of experts Pick high/medium/low outcome ranges Time trend change Opinions of experts Pick high/medium/low ranges which reflect regional economic forecasts	Strategy induced change Carefully define strategy effects on service levels & cost; ask experts to estimate change, or pick ranges Time trend change Project off past trends in freight activity relative to level of economic output, link to regional growth forecasts.	Strategy induced change Use economic activity models to estimate activity change Modify freight trip tables in 4-step model to show higher activity levels Time trend change Use economic activity models to estimate activity change; Modify freight trip tables in proportion to higher activity levels	Strategy induced change Collect data on changes in travel levels to changes in service time & cost. Develop model procedure which links activity level to strategy Time trend change As above, but model links freight activity levels to both economic activity and transportation system performance levels
Through Traffic Movements	Strategy induced Opinions of experts Select outcome ranges Time trend Opinions of experts Pick H/M/L scenarios based on national trends	Strategy induced: Unit trip to estimate change in service/cost; ask experts or pick ranges Time Trend Combine freight trip rates with national growth forecasts	Strategy induced Factor external--external truck trips in regional trip table by changes in service Time trend Factor external-external truck trips in regional trip table to reflect national growth trends	Strategy induced Collect data on through truck trips, link to changes in service, build adjustment into 4-step model Time trend As above, but link to changes in both economic activity and system performance
Intermodal Traffic	Opinions of experts Pick H/M/L scenarios	Project based on trends in goods which are shipped by intermodal		Collect data on terminal traffic relative to trans. & economic conditions; build relationship

Table 4.13.B. Impact Assessment Methods by Level of Complexity vs. Analysis Impact Area: Modal Activity Levels

Impact Area Within Analysis Hierarchy	Level A: Judgment	Level B: Sketch Planning	Level C: Existing Models	Level D: New Data & Models
Line -Haul Truck	Ask experts or pick ranges	Compare service levels & cost for selected trip movements with rail; use elasticities; consult empirical studies, ask experts, or make judgments about amount of diversion	Compare truck with rail service in similar markets. Use AAR or FRA model to estimate degree of diversion. Modify existing truck trip tables and run new assignment	Obtain data on intercity truck use from surveys; Build models to relate line-haul truck response to service or policy changes Link back to 4-step model
Drayage Truck	Ask experts or pick ranges	Estimate change in service conditions; ask experts or make judgments about degree of change	Attempt to factor dray truck out of regional trip tables. Adjust trips to reflect strategy induced changes.	Obtain data on dray truck operations, factors affecting service and use; Build model to relate response, link back to 4-step model
Line-Haul Rail	Ask experts or pick ranges	Compare service levels & cost for selected movements with truck; use elasticities; consult empirical studies ask experts or make judgments about amount of diversion	Compare truck with rail service in similar markets. Use AAR or FRA model to estimate modal diversion. Use conversion factor to relate rail ton-miles and truck VMT	
Rail Yard/Switching Operations	Ask experts or pick ranges	Ask industry experts and/or tie to level of rail/intermodal activity	Adjust based on results of line-haul modal diversion analysis and inputs from industry	

Table 4.13.C. Impact Assessment Methods by Level of Complexity vs. Analysis Impact Area:
Rail Emissions Precursors

Impact Area Within Analysis Hierarchy	Level A: Judgment	Level B: Sketch Planning	Level C: Existing Models	Level D: New Data & Models
Ton-Miles of Rail Goods Movement	Strategy induced Ask experts or select ranges Time Trend Ask experts or select ranges based on economic trends for given commodities	Strategy induced Specify strategy impact on rail/truck service conditions for particular commodities, markets. Ask experts to estimate changes Time Trend Synthesize information on level of economic activity for selected commodities , location of markets, and trends in use of rail	Strategy induced Apply AAR or FRA model to estimate modal diversion; adjust for rail/truck ton-mile rates. Time Trend Project level of economic activity by commodity, estimate rail share based on current AAR or FRA model , tempered by industry knowledge	Strategy induced Conduct local monitoring and data collection to trace & analyze changes in rail ton-miles based on competition, economy, investment, policy conditions. Develop improved local model Time Trend As above, but focus on change overt time and contributing factors
Rail Energy Consumption	Strategy induced Ask industry experts Time Trend Consult published studies on industry trends (see text)	Strategy induced Consult empirical data on changes in energy use under changes in fuel price or availability, or competition Time Trend As above	Strategy induced Ascertain sensitivity of fuel rate to economic or policy conditions; apply change to rail activity level estimated above Time Trend Use above rail activity levels, associate with anticipated energy consumption rates	Strategy induced Collect data to track over time, relate to endogenous & exogenous conditions Time Trend As above, but focus also on changes over time and contributing factors.

Table 4.13.C. Impact Assessment Methods by Level of Complexity vs. Analysis Impact Area: Rail Emissions Precursors (continued)

Impact Area Within Analysis Hierarchy	Level A: Judgment	Level B: Sketch Planning	Level C: Existing Models	Level D: New Data & Models
Rail Emissions Rates	Strategy induced Ask industry experts Time Trend Consult published studies on industry trends (see text)	Strategy induced Assemble statistics on composition of fleet, & emissions rates; ask experts about how might change Time Trend Consult published technology studies, relate to own fleet composition	Strategy induced Follow through from estimate of ton-miles and fuel use above; ask experts how emissions rate might change as a response to conditions Time Trend Follow through on ton-miles/fuel use above, estimate also time trend change in emissions rate	Strategy induced As above. but also track changes in emissions rates in response to market conditions or policy initiatives Time Trend As above, but direct focus to changes over time in emissions rates

Table 4.13.D. Impact Assessment Methods by Level of Complexity vs. Analysis Impact Area: <u>Truck Emissions Precursors</u>

Impact Area Within Analysis Hierarchy	Level A: Judgment	Level B: Sketch Planning	Level C: Existing Models	Level D: New Data & Models
Time of Day	Ask shippers and freight haulers Make judgments based on traffic trends	Determine heavy truck ratios on given facility(s) at different times of day; Estimate time shift due to policy or system change (ask haulers for opinions)	Use 4-step model to reallocate truck trips by peak/off-peak period (using judgment)	Collect data on truck trips by time of day. Develop revealed or stated-preference model to reflect time changes in response to policy actions or conditions.
Route Choice, VMT	Ask freight haulers about how would change in response to policy or system changes	Using unit trip type analysis, sketch current typical trips, estimate change in route and VMT based on conditions and response of freight haulers. Calculate VMT change	Rerun assignment procedure with new time of day truck trips, and with information on how route choice would change.	As above, collect data on truck movements by route; Determine importance of policy or system factors in route choice. Develop revealed or stated pref. model on response
Speed/Accel. Events & Idling	Speed a given Ask freight haulers and/ or terminal operators as to how idling would change under different policy or system changes	Using analysis results above, estimate change in V/C ratio for affected facilities. Ascertain change in average speed/delay.	From new assignment, estimate change in speed, delay consider use of traffic microsimulation models to improve speed/delay	Obtain more detailed information on speed, acceleration cycles and idling. Enhance micro-simul models to reflect these findings
Truck Emissions Rates	Ask technology experts, consult sources about trends Ask freight haulers how would respond to policy requirement	Relate speed change to different emissions rate (emissions tables)	Relate speed change to different emissions rate (emissions tables)	Collect data on characteristics of trucks on system, related emissions factors more closely to vehicle type and speed/accel

Table 4.13.E. Impact Assessment Methods by Level of Complexity vs. Analysis Impact Area: Secondary Emissions from Mixed Traffic

Impact Area Within Analysis Hierarchy	Level A: Judgment	Level B: Sketch Planning	Level C: Existing Models	Level D: New Data & Models
Time of Day	Ask motorists how might shift time of day if conditions changed Make assumptions based on freight travel shifts, change in facility use/congestion	Determine heavy truck ratios on target facilities by time of day. Estimate change in non-truck level of service assuming no time of day switching	Re-run traffic assignment assuming truck ratios in peak/off-peak change Do not shift non-truck traffic to different time period	Collect data on travel distribution by time of day, and factors which affect time of day choice. Develop improved models to predict time shifts
Route Choice, VMT	Ask motorists how might shift route based on changes in freight traffic; compute change in VMT		Re-run traffic assignment with change in truck ratios (and by time of day) to determine shifts in route and VMT for regular traffic	Collect data on factors relating to choice of route, and use to enhance trip assignment routines
Speed/Delay		Calculate new V/C ratio for facilities where truck ratio has changed, compute change in speed	Determine change in speed for regular traffic due to re-assignment and different V/C relationships Consider use of traffic microsimulation tools to improve estimate of speed and delay	Use microsimulation to get better estimates of speed/acceleration events relative to traffic congestion levels.
Emissions Rates	Consult references on change in vehicle emissions rates relative to speed levels (see text)	In relation to above, determine emission rate for non-truck vehicles based on different speed	Relate revised speeds to revised emissions rates	Tie emissions rates to speeds and vehicle characteristics

(4) *Analysis Plan, Part 2: Analytic Approach*

Introduced earlier in Step 1 as a form and procedure which helps guide the analysis with a description of the Anticipated Impact, the information in the Analysis Plan is now expanded to describe the Proposed Analysis approach which will be attempted. Progressing to this step is now possible given the layout and previous discussion of analysis options in (5) above.

The example is again used to illustrate how this task would be performed. Where Figure 4.13.A. earlier illustrated how the Anticipated Impact profile might look for the NHS Connector example, Figure 4.13.B. now uses the same form to indicate what Proposed Analysis approach will be used for this strategy, in light of the options described in the previous section.

Because this is but a single project aimed at improving access to a single terminal, the proposed NHS Connector is not seen as having sufficient impact on overall market conditions that it would affect the overall level of activity in the region or the balance between modes. It could affect the *relative advantage* of the particular railroad to whose terminal the access was improved, but this might result more in a shift in the distribution of traffic than a general increase. Much depends on the level of the resulting access improvement.

As a result of this rather limited impact expectation, and the fact that this is a fairly tangible physical modification to the transportation system, a Level A "Judgment" type of analysis would be expected to be adequate for virtually all of the impact areas in the hierarchy except the Route Choice/VMT and the Speed dimensions. For these two impacts, a Level B Sketch Planning approach would be attempted, where the details of the particular route modifications would be carefully delineated, and estimates made of how the changes would reconfigure traffic patterns. For instances where the access improvement was not "simple", and numerous route choices (for truck and other traffic) were available, a Level C assignment might be advisable where a new subarea assignment would be performed to determine the change in route paths.

For all of the other dimensions of the problem, namely volume levels, line-haul mode shares, and impacts on other traffic, a Level A analysis appears warranted. However, the nature of this methodology is to stress that the analyst be objective and systematic at thinking through the potential impacts, via this Analysis Plan exercise, and before assuming that a given area of potential impact in the hierarchy is not important, to think about the impacts which could occur, and if in doubt (or just out of good method) to ask one or more industry specialists for insight into what could happen, and how large the action's effects would have to be before a change were induced. If the expert believes that the project is big enough to be likely to cause an impact at one of these "Secondary" levels, then it would be advisable to increase the intensity of the analysis to a higher level, i.e., Level or above.

Figure 4.13.B: Example Analysis Plan with Proposed Analysis

Problem/Setting:	Poor access to rail intermodal terminal XYZ from NHS highway system. Significant VMT over secondary roads and local streets.
Test Strategy, Action or Event:	Implement NHS connector to terminal from State Highway ABC, involving widening, easing of geometric and vertical clearance barriers, improved signalization.
Summary of Overall Expected Impact:	Truck emissions to decrease based on reduced VMT, improved operating conditions. Secondary benefits possible due to reduced conflict with other traffic. Issues as to whether improved access generates additional truck traffic & emissions.

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Overall Volume	Regional Origin or Destination	S	Improved access may stimulate volume of goods entering or leaving region, but major inducements not expected.	**Level A**: Single NHS connector not expected to affect overall regional freight volumes. Consult freight carrier to be sure.
	Through Trips	S	Improved access could increase the volume of goods which are trans-shipped through the region.	**Level A**: Single NHS connector not expected to affect overall volume of through movements. Consult carrier representative to confirm.
	Intermodal Trips	S	Improved access to a given terminal could increase the volume of activity to that terminal, either absolute or diverted from other terminals.	**Level A**: Improved access may increased traffic to that terminal. Ask affected and unaffected terminal operators for opinions.
Modal Activity Levels	Line-Haul Truck	U	Unlikely to affect level of activity of line-haul intercity truck operations.	**Level A**: No analysis necessary. Check with industry representative to confirm.
	Drayage Truck	S	By improving access, may increase the volume of goods transported to yard by truck	**Level B**: Estimate time savings using Sample Shipment. Get carrier and terminal estimate of traffic impact.
	Line-Haul Rail	U	Unlikely to affect level of activity of line-haul rail operations.	**Level A**: Impact not expected. Could increase traffic levels to railroad serving that terminal. Obtain assessment of rail expert.
	Rail Yard/ Switching	S	Improving access for dray truck may reduce incentives for steel-wheel intermodal transfers.	**Level A**: Impact not expected, obtain assessment of rail industry representative.

Figure 4.13.B: Example Analysis Plan with Proposed Analysis (Continued)

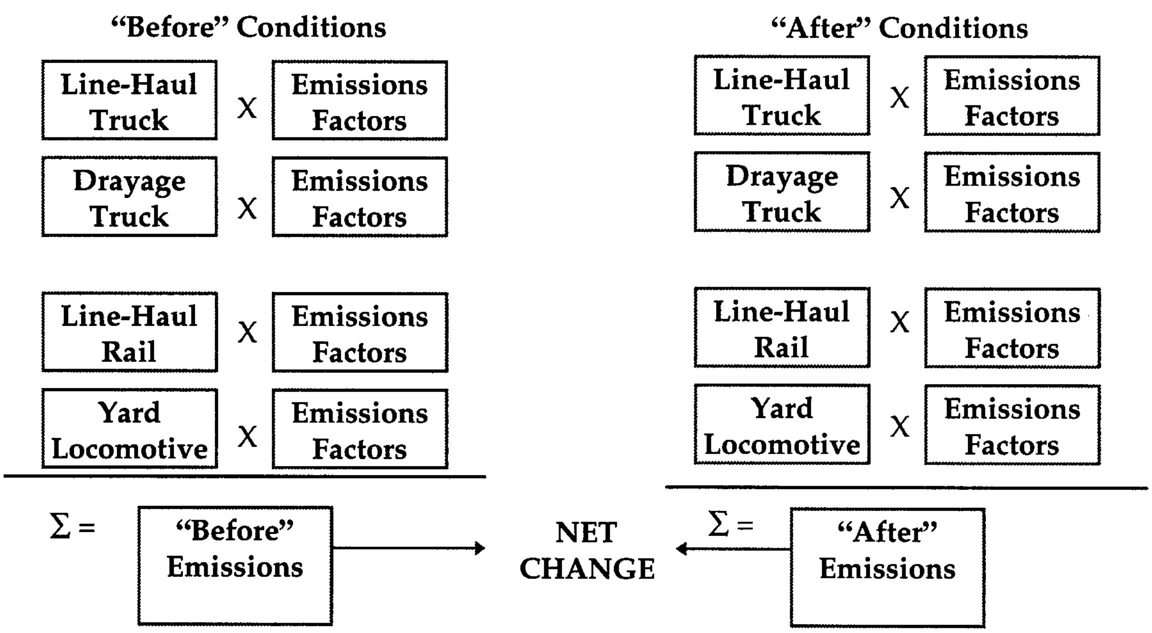
Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Rail Emissions Precursors	Ton-Miles	U	No major effect expected unless regional activity level increases.	**Level A**: Consult rail industry representative to determine whether rail traffic would be expected to increase.
	Energy Consumption	U	No major effect expected unless regional activity level increases.	**Level A**: If rail traffic level changes, calculate increase in fuel use based on change in Ton-miles.
	Emissions Rate		No effect expected.	No analysis necessary.
Truck Emissions Precursors	Time of Day	U	Unlikely to shift time of day truck trips unless improvements increase capacity and induce shift of VMT back into peak periods.	**Level A**: Estimate change in traffic conditions in peak periods if strategy increases capacity. Check with dray operators to see if it would change.
	Route/ VMT	P	Major effect would be to shift routing of dray trips, and possibly reducing VMT with improved routing (could also increase VMT).	**Level B**: Using Sample Shipment approach, sketch before & after route options, determine difference in VMT. Confirm assumptions with carriers.
	Speed/Accl & Idling	P	Speeds may improve and smoother flow (less stops & starts & idling time) would reduce emissions rates.	**Level B**: Calculate traffic volumes on affected links before and after. Estimate speed change based on different V/C ratios.
	Emissions Rate	S	Emissions rates would change if speeds and flow conditions changed above.	**Level A**: If speed change, multiply new VMTs by emissions rate for respective new speed.
Secondary Emissions		S	Dedicated route for trucks may reduce conflicts and other traffic, resulting in smoother flow and higher average speeds, with reduced emissions.	**Level A**: Assume non-freight traffic will not switch route but benefit from improved speeds. Correct emissions rate to reflect change. If major change in level of service due to project, consider Level C analysis with traffic assignment.

Using this completed Analysis Plan as a working guide, the analyst can keep the multiple dimensions and questions in mind, and thereby be methodical in considering options and accomplishing specific analysis tasks. Because the Analysis Plan is a device to help the analyst, it goes without saying that it should be used as a flexible *working guide*. As the analyst gets further along in the analysis, and new findings or insights become available, modification and enhancement of the plan to customize it to the particular problem is strongly encouraged.

(6) "Before" and "After" Analysis Spreadsheets

Where the Analysis Plan is the essential "blueprint" for planning and guiding the analysis, the **Analysis Spreadsheets** are the essential "tool" for conducting the actual analysis. As illustrated in the diagram below, the procedure is fairly straightforward. The analyst supplies information to a worksheet table which inventories the important elements that describe current conditions for the selected problem setting, and constitute the transportation inputs to the emissions calculations. This is done for Truck and for Rail in separate spreadsheets, which are then further separated into Line-Haul vs. Dray Truck, and Line-Haul vs. Yard Locomotive. These transportation activity spreadsheets are then mated with a second set of spreadsheets that contain emissions factors. The product of the two spreadsheets produces the estimated baseline emissions for each mode and for the problem setting as a whole. The process is then repeated to evaluate a strategy, action or event, constituting "After" conditions. A revised set of spreadsheets is developed to reflect the change in overall volume, mode (and sub-mode), facility/type, volume/capacity, and speed. As illustrated below, comparing the two sets of spreadsheets reveals the change in emissions attributable to the candidate strategy or event.

Analysis Spreadsheet Procedure



Truck Emissions Transportation Inputs:

Figures 4.14., parts A and B, illustrate the spreadsheets (worksheets) which are used for compiling truck-based transportation inputs and calculating resulting truck-based emissions. A description of each of the data fields for the transportation activity spreadsheet, Figure 4.14.B, is presented below, along with an explanation of the general procedure for supplying the necessary data and performing the required analysis.

Descriptive Data: At the top of each form note the provision for descriptive information on the problem setting and the test parameters. When completing this portion, offer a short description of the problem setting, sufficient only to identify and distinguish this test from the others. A scenario numbering convention may be useful where multiple problems or tests are anticipated. Indicate then whether this spreadsheet represents Existing or Improved Conditions, where "improved" implies the "after" condition produced by any tested strategy, action or event. Note, as appropriate, whether the Truck Mode in this table reflects line haul or dray truck operations (as they have different emissions rates). The space for "Environment" is a general purpose category to basically distinguish among important sub-markets or stratifications in describing the setting. These stratifications will be described below, but would, for example, include dimensions such as: different time of day periods for the same problem setting, portions of the transportation network which are "outside" the given analysis area, or different forecast year time frames.

Number of Truck Trips: Enter here the number of vehicle trips which are currently made in service of this particular problem setting. For analyses which are investigating annual rates of emission production or reduction, annual trips would probably be the appropriate time frame convention. However, if another time frame is more appropriate, such as average weekday, then use that convention, remembering to maintain these same units in the final definition of emissions. As described in the next item below, its is important to be able to report these trips by roadway segment. Trips should generally be reported as one-way, since they will be associated with volume conditions and capacity on roadway segments by direction. For those analyses where information on truck movements is not known, the analyst may consider adopting the Sample Shipment approach, where one or more hypothetical "single" truck trips may be used to represent how the universe of trips would behave.

Mileage by Functional Class and Segment: Identify each roadway in the scope of the study/problem area that is carrying truck traffic related to the problem/subject site. It is advised that these facilities be designated by functional class at a minimum (i.e., freeway, major arterial, etc.), but if possible also by specific named facility and specified segment. For each entry, supply the corresponding segment length in miles.

Empty Backhaul Ratio: In many cases, the basis for estimating the number of truck trips will be in terms of containers or cargo loads. Thus, a certain proportion of trips may be "empty" trucks traveling back to the original site or another location for the next load or to enter/leave service for the day. The proportion of truck trips which are empties is represented by the Empty Backhaul Ratio. Since these empty trucks also generate VMT and emissions, it is important that they be accounted for if the source data report only cargo movements. Enter in the provided column the ratio which is

Figure 4.14.A. Analysis Spreadsheet
Truck Transportation Inputs

Problem Setting Description: ____________________

Condition: ☐ **Existing** ☐ **Improved (Describe)** ____________________

Truck Mode: ____________ **Environment:** ____________ **Sheet:** ___ **of** ___

Number Truck Trips	Mileage by Functional Class & Segment	Empty Backhaul Ratio	Effective Daily VMT	Roadway Volume	Heavy Truck Percent.	Roadway Capacity	Average Speed	Accel/Decel Adjustment Factor
	Freeway 1:							
	Freeway 2:							
	Freeway 3:							
	Maj. Art. 1:							
	Maj. Art 2:							
	Maj. Art. 3:							
	Min. Art 1:							
	Min. Art 2:							
	Min. Art 3							
	Collector 1:							
	Collector 2:							
	Collector 3:							
	Local Road 1:							
	Local Road 2:							
	Local Road 3:							

	Number Trucks Affected	Total Minues of Idling
Terminal Idling		

Figure 4.14.B. Analysis Spreadsheet
Truck Emissions Estimation

Problem Setting Description: ____________________

Condition: ☐ Existing ☐ Improved (Describe) ____________________

Truck Mode: ____________ **Environment:** ____________ **Sheet:** ___ **of** ___

Daily Mileage by Functional Class & Segment	VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Running Emissions										
Freeway 1:										
Freeway 2:										
Freeway 3:										
Maj. Art. 1:										
Maj. Art 2:										
Maj. Art. 3:										
Min. Art 1:										
Min. Art 2:										
Min. Art 3										
Collector 1:										
Collector 2:										
Collector 3:										
Local Road 1:										
Local Road 2:										
Local Road 3:										
Idling Emissions										
Idling Hours										
Idling Emissions										
Total Emissions										

appropriate to the named segment, and the direction, since the backhaul rate may be much greater in one direction than another.

Effective Daily VMT: To ascertain total truck VMT, multiply the Segment Mileage times the Number of Truck Trips and the Empty Backhaul Ratio where applicable. Note that VMT is calculated on a daily basis, for the reason that a subsequent step calculates Speed as a function of Volume to Capacity relationships, which must be on a daily/hourly basis. A conversion from annual trips to daily may be performed using a factor of 261 days/year, if it is assumed that the truck operations are only weekday.

Roadway Volume: From traffic volume counts, model outputs or other source, indicate the traffic volume for each roadway segment/direction identified in the second column. Since the purpose of this data item is primarily to assist in the estimation of volume/capacity loadings and the corresponding speeds, this reported volume should be for those hours where speeds are constrained by congestion. Thus, peak hour (or hours) is more meaningful than AADT.

Heavy Truck Percent: Enter the percentage of trips on each segment which are made up of heavy (combination) trucks that will be influenced by the strategy, action or event. In some instances, it will only be a fraction of the heavy truck percentage measured in volume counts because of the specialized application of the strategy, e.g., changes to one NHS/intermodal terminal connector.

Roadway Capacity: Enter here the design capacity of the named roadway segment, corresponding to the traffic volume definition provided above.

Average Speed: Calculate the Volume to Capacity Ratio for each segment. Consult Figure 4.15. to estimate the equivalent average travel speed, using the appropriate curves for either signalized or unsignalized facilities. Alternatively (perhaps more accurately), the following BPR equation may be used:

Freeway Speed Equation

$S = S_{ff} / \ 1 + a\,(V/C)^K$, where

$a = 1$

$K = 4$

Arterial Speed Equation [3]

For $V/C <= 0.8$

$$D = (68.6 + 297.7\ V/C)\ (1 - e^{-n/24.4})$$

$$A = 297.7p\ V/C\ (1 - e^{-n/24.4})$$

For $V/C >= 0.8$

$$D = (68.6 + 297.7\ V/C)\ (1 - e^{-n/24.4}) + 1500\ (V/C - 0.8)^4$$

$$A = 297.7\ p\ V/C\ (1 - e^{-n/24.4}) + 6000\ (V/C)\ (V/C - 0.8)^3$$

The Arterial Speed Equation has been converted to tables 4.14 - 4.17.

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[3] Roadway Usage Patterns: Urban Case Study; Final Report June 9, 1994, Cambridge Systematics, Inc. and SAIC

Figure 4.15. Freeway Speed Estimates Under Various V/C Ratios

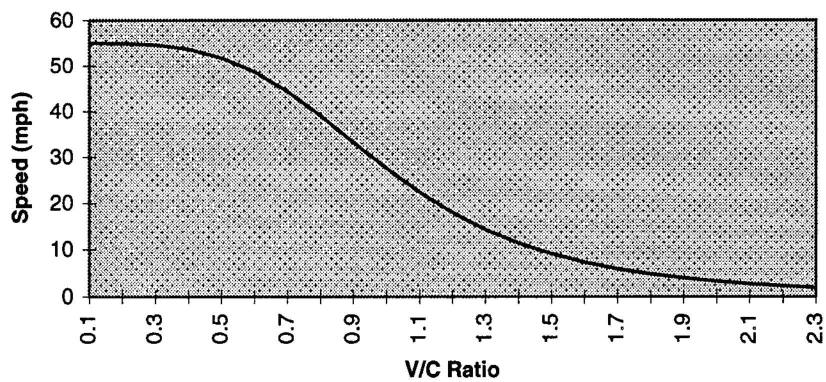

Table 4.14 Speed Estimates for Signalized Arterials: Feeflow Speed = 30

	Number of Signals per Mile									
V/C	1	2	3	4	5	6	7	8	9	10
0.1	26.82	24.35	22.36	20.74	19.39	18.26	17.28	16.44	15.70	15.06
0.2	25.99	23.03	20.76	18.97	17.52	16.32	15.32	14.46	13.72	13.09
0.3	25.21	21.85	19.38	17.48	15.98	14.76	13.75	12.91	12.19	11.57
0.4	24.47	20.79	18.17	16.20	14.68	13.47	12.48	11.66	10.96	10.37
0.5	23.77	19.82	17.10	15.10	13.58	12.39	11.42	10.62	9.96	9.39
0.6	23.12	18.94	16.15	14.14	12.64	11.46	10.53	9.76	9.12	8.59
0.7	22.49	18.14	15.30	13.30	11.81	10.67	9.76	9.03	8.42	7.91
0.8	21.91	17.40	14.53	12.54	11.09	9.98	9.10	8.40	7.81	7.33
0.9	21.28	16.68	13.81	11.85	10.43	9.36	8.52	7.84	7.28	6.82
1	19.82	15.49	12.80	10.97	9.65	8.65	7.87	7.24	6.72	6.29
1.1	16.29	13.05	10.95	9.49	8.41	7.59	6.93	6.40	5.96	5.60
1.2	11.26	9.50	8.26	7.35	6.64	6.08	5.62	5.24	4.92	4.65
1.3	6.88	6.14	5.56	5.10	4.73	4.42	4.15	3.93	3.74	3.57
1.4	4.04	3.76	3.52	3.32	3.15	3.00	2.87	2.75	2.65	2.56
1.5	2.41	2.30	2.21	2.12	2.05	1.98	1.92	1.86	1.81	1.76

Table 4.15 Speed Estimates for Signalized Arterials: Feeflow Speed = 35

V/C	Number of Signals per Mile									
	1	2	3	4	5	6	7	8	9	10
0.1	30.75	27.54	25.03	23.02	21.37	19.99	18.83	17.83	16.97	16.22
0.2	29.66	25.87	23.04	20.86	19.12	17.70	16.52	15.53	14.68	13.96
0.3	28.64	24.39	21.35	19.07	17.29	15.87	14.72	13.75	12.94	12.24
0.4	27.69	23.07	19.89	17.56	15.79	14.39	13.27	12.34	11.57	10.91
0.5	26.81	21.89	18.61	16.27	14.52	13.16	12.08	11.19	10.45	9.83
0.6	25.97	20.82	17.49	15.16	13.44	12.13	11.08	10.24	9.54	8.95
0.7	25.19	19.85	16.50	14.19	12.52	11.24	10.24	9.43	8.77	8.22
0.8	24.46	18.97	15.61	13.34	11.71	10.48	9.52	8.75	8.12	7.59
0.9	23.68	18.11	14.78	12.56	10.98	9.80	8.88	8.14	7.55	7.05
1	21.89	16.72	13.63	11.58	10.12	9.02	8.17	7.50	6.95	6.49
1.1	17.66	13.91	11.55	9.94	8.76	7.87	7.17	6.60	6.14	5.75
1.2	11.89	9.95	8.60	7.61	6.86	6.26	5.77	5.38	5.04	4.76
1.3	7.11	6.32	5.71	5.23	4.84	4.51	4.24	4.01	3.80	3.63
1.4	4.12	3.83	3.58	3.37	3.20	3.04	2.91	2.79	2.68	2.59
1.5	2.44	2.33	2.23	2.14	2.07	2.00	1.93	1.88	1.83	1.78

Table 4.16 Speed Estimates for Signalized Arterials: Feeflow Speed = 40

V/C	Number of Signals per Mile									
	1	2	3	4	5	6	7	8	9	10
0.1	34.54	30.54	27.49	25.08	23.13	21.53	20.19	19.05	18.07	17.22
0.2	33.17	28.50	25.11	22.54	20.52	18.89	17.56	16.44	15.50	14.69
0.3	31.91	26.72	23.11	20.46	18.43	16.83	15.53	14.46	13.57	12.80
0.4	30.73	25.14	21.41	18.73	16.73	15.17	13.93	12.91	12.06	11.35
0.5	29.65	23.75	19.94	17.28	15.32	13.81	12.62	11.66	10.86	10.19
0.6	28.63	22.49	18.66	16.03	14.12	12.68	11.54	10.63	9.88	9.25
0.7	27.68	21.37	17.53	14.95	13.10	11.71	10.63	9.76	9.05	8.46
0.8	26.80	20.35	16.53	14.01	12.22	10.88	9.85	9.03	8.36	7.80
0.9	25.86	19.37	15.60	13.15	11.43	10.15	9.17	8.39	7.75	7.23
1	23.75	17.79	14.33	12.08	10.50	9.32	8.42	7.70	7.12	6.64
1.1	18.85	14.64	12.05	10.31	9.05	8.10	7.36	6.76	6.28	5.87
1.2	12.42	10.32	8.88	7.83	7.03	6.40	5.90	5.48	5.13	4.84
1.3	7.30	6.47	5.83	5.33	4.92	4.59	4.30	4.06	3.86	3.68
1.4	4.19	3.88	3.63	3.42	3.23	3.07	2.94	2.82	2.71	2.61
1.5	2.46	2.35	2.25	2.16	2.08	2.01	1.95	1.89	1.84	1.79

Table 4.17 Speed Estimates for Signalized Arterials: Feeflow Speed = 45

V/C	Number of Signals per Mile 1	2	3	4	5	6	7	8	9	10
0.1	38.21	33.37	29.76	26.96	24.72	22.90	21.39	20.11	19.02	18.08
0.2	36.54	30.95	26.99	24.04	21.76	19.94	18.46	17.23	16.19	15.31
0.3	35.01	28.86	24.70	21.69	19.42	17.65	16.23	15.07	14.10	13.28
0.4	33.60	27.03	22.76	19.76	17.54	15.84	14.49	13.39	12.48	11.72
0.5	32.31	25.42	21.11	18.15	16.00	14.36	13.08	12.05	11.20	10.49
0.6	31.10	23.99	19.68	16.78	14.70	13.14	11.92	10.95	10.15	9.49
0.7	29.99	22.72	18.43	15.60	13.60	12.11	10.95	10.03	9.29	8.67
0.8	28.95	21.57	17.33	14.58	12.65	11.22	10.13	9.26	8.56	7.98
0.9	27.87	20.47	16.31	13.65	11.80	10.45	9.41	8.59	7.93	7.38
1	25.43	18.71	14.93	12.50	10.81	9.57	8.62	7.87	7.27	6.77
1.1	19.89	15.26	12.47	10.61	9.28	8.28	7.51	6.89	6.39	5.97
1.2	12.87	10.62	9.10	8.00	7.17	6.52	5.99	5.57	5.21	4.91
1.3	7.45	6.59	5.93	5.41	4.99	4.64	4.36	4.11	3.90	3.72
1.4	4.24	3.92	3.67	3.45	3.26	3.10	2.96	2.84	2.73	2.63
1.5	2.48	2.36	2.26	2.17	2.09	2.02	1.96	1.90	1.85	1.80

Calculation of Average Speed [4]
$S = 1/\ (1/S_{ff} + d/100)$

Definition of Variables

- S is average speed(mph)
- S_{ff} is free-flow speed (MPH)
- d is delay due to congestion and traffic control devices experienced by case study vehicles (hours per 1,000 vehicle miles)
- V is Volume (Vehicles per hour)
- C is capacity (vehicles per hour)
- n is the number of signals per mile
- p is passenger car equivalents for case study truck
- A is the added delay to other vehicles caused by the case study vehicle (hours per 1,000 case study vehicle miles)

Acceleration/Deceleration Adjustment Factor: Currently, nothing is entered in this space because there is no technique which accurately relates acceleration or deceleration events to speed and emissions. Acceleration/deceleration cycles, such as occur at ramps and interchanges, on signalized roadways, and in congested traffic conditions, obviously have major impacts on fuel consumption and emissions, especially for heavily loaded freight vehicles. Currently, the allowance for these events is built into the emissions factor through drive cycle relationships, (i.e., how many of these would occur on a "typical trip", and how would that figure into the total trip emissions). "Modal" emissions models may at some future time produce emissions

[4] Roadway Usage Patterns: Urban Case Study; Final Report June 9, 1994, Cambridge Systematics, Inc. and SAIC

estimates for these individual events. An interim technique that may be considered is to estimate the energy consumption that a truck of a particular horsepower rating, gearing and load would require to accelerate over a certain distance and speed range, say as in accelerating on a freeway ramp, and from this fuel consumption estimate the additional emissions that would result. At present, the analyst may simply want to record the number and extent of acceleration/deceleration events that occur with the given analysis subsystem, and make a qualitative judgment as to the change brought about by one of the candidate strategies.

Minutes of Idling: In the final column of Figure 4.14.A, there is an allowance for recording the total idling time that occurs in relation with the trips, typically as would occur in staging events at terminal sites. These idling emissions can be substantial, and can be mitigated through improved terminal management practices or traffic flow improvements. Enter the total number of minutes of idling which occur in conjunction with the particular facility segment, or overall for terminal operations in the space at the bottom of the table.

Truck Emissions Spreadsheet:

Figure 4.14.B is the companion spreadsheet to 4.14.A. It specifically provides for the estimation of truck-based emissions by drawing upon the inputs from 4.14.A and matching them with appropriate emissions factors from provided reference tables. The major features of the table are presented below:

Daily VMT by Functional Class and Segment: Since VMT is the prime determinant of emissions, bring forward from Figure 4.14.A the VMT totals by segment for each listed segment.

VOC, NOx, CO, SO_2, and PM-10 Emissions Factors: For each pollutant, the table provides space for calculation of emissions of each pollutant species relative to the truck activity levels (VMT by roadway segment) delineated in the first column. Refer to the table in Exhibit 4.1 to obtain the relevant emissions factors. Note that in Exhibit 4.1 the emissions factors differ based on (1) whether the vehicle is a Line Haul or Drayage operation, and (2) for what year the forecast is being made. The emissions rates shown are composites of forecast fleet distributions (heavy-duty vehicles classes 7, 8A and 8B). In general, line-haul fleets are newer and show somewhat lower emissions rates. Also, over time, improvements in technology and replacement of older vehicles in the fleets will result in lower composite emissions rates. Enter the appropriate emissions rate for each pollutant for each roadway segment that VMT have been reported for.

There are a number of variables that will cause these rates to vary from those shown in Exhibit 4.1, and adjustments may be necessary (and advisable) to make the emissions rates more reflective of conditions -- *either starting conditions, or as part of an intended change under a policy scenario.:*

<u>Age of Fleet:</u> It may be that the local fleet is comprised of a comparatively newer or older mix of vehicles than that represented in Exhibit 4.1., which is based on the

default truck fleet age distribution taken from EPA's MOBILE5a model[5]. For this reason, Exhibits 4.2 and 4.3 are provided which offer emissions rates for truck fleets which are, respectively, Newer and Older than the nominal fleet in Exhibit 4.1. Use these emissions rates to either correct for a current disparity, or as part of a strategy that may wish to assume a more rapid rate of replacement in the existing fleet.

Speed Correction Factors: Emissions rates vary with vehicle speed, and vary differently for each type of pollutant. The emissions factors shown in Exhibit 4.1. reflect Congested Urban operating conditions, with mean speeds of 20 mph. Obviously, travel occurring under less congested or uncongested conditions would produce different emissions characteristics. Exhibit 4.4.A presents speed correction factors that allow the emissions factors in Exhibits 4.1., 4.2. or 4.3. to be adjusted to reflect the different conditions of non-congested Urban travel (assumes mean speed of 35 mph) or Rural travel (60 mph). Adjustment factors are shown only for VOC (HC), CO and NOx, as SO_2 and PM-10 do not vary predictably with speed. Note in the table that both CO and VOC emissions decline with higher speeds, while NOx drops slightly as speed rises from 20 to 35 mph, but then rises sharply as speed increases to 60 mph.

The adjustment factors in Exhibit 4.4.A are rough approximations for the range of speed conditions that might occur in practice. A more continuous level of control on the link between speed and emissions rates may be found in Exhibit 4.4.B, which provides VOC, CO and NOx emissions rate adjustment factors for heavy duty diesel vehicles for speeds ranging from 5 mph to 65 mph, in 5 mph intervals. Users needing to match speed levels not shown in table should interpolate between the shown speed values.

The analyst should apply the speed correction factors -- either the generic Urban/Rural or the speed-specific -- to adjust emission rates in light of known speed or locational conditions, both in the baseline and as an outcome to strategies which are tested. Simply adjust the starting rate chosen in Exhibits 4.1., 4.2., or 4.3. with the factor selected from Exhibit 4.4. A or B.

Vehicle Load: While intuitively fuel consumption and emissions would be expected to increase with load, the relationship between load and emissions is not well defined. Hence, this methodology treats only VMT as the determinant of emissions[6]

Grade: The steepness of grade is an important factor in fuel consumption and in emissions, particularly in regard to NOx. Exhibit 4.5 provides adjustment factors for NOx emissions rates based on changes in percent grade for trucks at different weight levels. To use these factors it would be necessary to enter truck VMT by highway segment where grade is an issue, adjusting the NOx factor accordingly for that segment.

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[5] See Tables 8 through 11 and accompanying discussion in Appendix A-4 to examine the assumptions made in relation to the vehicle distribution in Exhibits 4.1, 4.2 and 4.3.

[6] See discussion in Appendix A-4 in relation to Table 19

Fuel Type: Use of Natural Gas as a replacement fuel for diesel causes a change in the emissions rate for those vehicles. Emissions rates are shown for Natural Gas fueled vehicles in Exhibit 4.6 for both Line-Haul and Drayage vehicles. To use these factors, it is necessary to estimate the percent of vehicles which have been or may be converted, and weight the emissions factor for that class by the average of the Diesel/Natural Gas VMT balance.

VOC, NOx, CO, SO_2 and PM-10 Emissions: Multiply the respective VMT by the [adjusted] emissions rates for each facility segment entry in the table of Figure 4.14.B to get total emissions. Sum to the bottom line for total emissions by pollutant. Note that at the bottom of the table there is provision for an accumulation of emissions due to Idling. Transfer the minutes of idling determined in Part A (Fig. 4.14.B) to the provided space at the bottom of 4.14.B. Idling emissions estimates, in grams per hour, for VOCs, NOx and CO are provided in Exhibit 4.7. for vehicles at different idling rpm rates and whether or not fitted with air conditioning.

Exhibit 4.1. Line Haul and Drayage Emission Rates Based on Default Age Distribution* Valid for Speeds Corresponding to Congested Urban Conditions✕										
Calendar Year	Line Haul Fleet					Drayage Fleet				
	VOC (g/mi)	CO (g/mi)	NOx (g/mi)	SO_2 (g/mi)	PM_{10} (g/mi)	VOC (g/mi)	CO (g/mi)	NOx (g/mi)	SO_2 (g/mi)	PM_{10} (g/mi)
1995	3.52	16.97	19.89	0.527	1.302	3.44	16.58	19.52	0.518	1.278
1996	3.46	16.94	19.02	0.522	1.199	3.39	16.55	18.67	0.513	1.178
1997	3.41	16.91	18.15	0.517	1.096	3.33	16.51	17.82	0.508	1.077
1998	3.35	16.88	17.28	0.512	0.993	3.28	16.48	16.97	0.503	0.977
1999	3.30	16.84	16.41	0.506	0.890	3.22	16.44	16.11	0.498	0.877
2000	3.24	16.81	15.55	0.501	0.787	3.17	16.41	15.26	0.492	0.777
2001	3.20	16.81	14.75	0.496	0.726	3.12	16.40	14.48	0.488	0.716
2002	3.15	16.80	13.96	0.491	0.664	3.07	16.40	13.70	0.483	0.655
2003	3.10	16.79	13.16	0.486	0.603	3.02	16.39	12.91	0.478	0.594
2004	3.05	16.79	12.37	0.481	0.541	2.98	16.38	12.13	0.473	0.533
2005	3.00	16.78	11.57	0.476	0.480	2.93	16.38	11.35	0.469	0.472
2006	2.86	16.78	10.97	0.473	0.454	2.79	16.38	10.76	0.465	0.446
2007	2.72	16.78	10.37	0.469	0.429	2.66	16.37	10.17	0.461	0.421
2008	2.58	16.77	9.77	0.465	0.404	2.52	16.37	9.58	0.458	0.396
2009	2.43	16.77	9.16	0.461	0.379	2.38	16.36	8.99	0.454	0.370
2010	2.29	16.77	8.56	0.457	0.354	2.24	16.36	8.40	0.450	0.345
2011	2.21	16.77	8.28	0.455	0.346	2.17	16.36	8.11	0.448	0.337
2012	2.13	16.77	7.99	0.453	0.338	2.09	16.36	7.83	0.446	0.329
2013	2.06	16.77	7.70	0.451	0.330	2.01	16.36	7.55	0.444	0.321
2014	1.98	16.76	7.42	0.449	0.322	1.94	16.36	7.26	0.442	0.313
2015	1.90	16.76	7.13	0.447	0.314	1.86	16.36	6.98	0.440	0.304
2016	1.85	16.76	7.00	0.446	0.313	1.81	16.36	6.85	0.439	0.303
2017	1.80	16.76	6.87	0.445	0.312	1.76	16.36	6.72	0.438	0.302
2018	1.75	16.76	6.74	0.444	0.311	1.72	16.36	6.59	0.437	0.301
2019	1.71	16.76	6.61	0.443	0.310	1.67	16.36	6.46	0.436	0.300
2020	1.66	16.76	6.48	0.442	0.309	1.62	16.36	6.33	0.435	0.299

* The default age distribution is the one used in MOBILE5a. The "newer" and "older" distributions are constructed as follows. The newer distribution consists of trucks that are five years old or less; the older distribution consists of trucks that are six years old or more. More details about these distributions are given below.

✕ Congested urban conditions correspond to a mean speed of 20 miles per hour. Other conditions are defined in Exhibit 4.2.

Exhibit 4.2. Line Haul and Drayage Emission Rates Based on Newer Age Distribution Valid for Speeds Corresponding to Congested Urban Conditions										
Calendar Year	Line Haul Fleet					Drayage Fleet				
	VOC (g/mi)	CO (g/mi)	NOx (g/mi)	SO_2 (g/mi)	PM_{10} (g/mi)	VOC (g/mi)	CO (g/mi)	NOx (g/mi)	SO_2 (g/mi)	PM_{10} (g/mi)
1995	3.16	15.59	12.90	0.514	0.748	3.08	15.19	12.57	0.505	0.729
1996	3.16	15.58	12.59	0.507	0.661	3.08	15.18	12.27	0.498	0.643
1997	3.16	15.57	12.28	0.499	0.573	3.08	15.17	11.97	0.490	0.557
1998	3.16	15.56	11.97	0.492	0.485	3.08	15.16	11.67	0.483	0.471
1999	3.16	15.55	11.66	0.484	0.397	3.08	15.15	11.37	0.476	0.385
2000	3.16	15.54	11.35	0.477	0.309	3.08	15.14	11.07	0.469	0.299
2001	3.09	15.54	10.91	0.472	0.309	3.01	15.14	10.63	0.464	0.299
2002	3.02	15.53	10.46	0.467	0.309	2.94	15.14	10.19	0.460	0.299
2003	2.95	15.53	10.01	0.463	0.309	2.87	15.13	9.76	0.455	0.299
2004	2.88	15.53	9.56	0.458	0.309	2.81	15.13	9.32	0.450	0.299
2005	2.81	15.53	9.11	0.453	0.309	2.74	15.13	8.88	0.446	0.299
2006	2.56	15.53	8.54	0.451	0.309	2.49	15.13	8.32	0.444	0.299
2007	2.31	15.53	7.96	0.449	0.309	2.25	15.13	7.76	0.442	0.299
2008	2.06	15.53	7.38	0.447	0.309	2.01	15.13	7.19	0.440	0.299
2009	1.81	15.53	6.81	0.445	0.309	1.76	15.13	6.63	0.438	0.299
2010	1.56	15.53	6.23	0.443	0.309	1.52	15.13	6.07	0.436	0.299
2011	1.56	15.53	6.23	0.443	0.309	1.52	15.13	6.07	0.436	0.299
2012	1.56	15.53	6.23	0.442	0.309	1.52	15.13	6.07	0.435	0.299
2013	1.56	15.53	6.23	0.442	0.309	1.52	15.13	6.07	0.435	0.299
2014	1.56	15.53	6.23	0.441	0.309	1.52	15.13	6.07	0.434	0.299
2015	1.56	15.53	6.23	0.440	0.309	1.52	15.13	6.07	0.434	0.299
2016	1.56	15.53	6.23	0.440	0.309	1.52	15.13	6.07	0.433	0.299
2017	1.56	15.53	6.23	0.440	0.309	1.52	15.13	6.07	0.433	0.299
2018	1.56	15.53	6.23	0.440	0.309	1.52	15.13	6.07	0.433	0.299
2019	1.56	15.53	6.23	0.440	0.309	1.52	15.13	6.07	0.433	0.299
2020	1.56	15.53	6.23	0.440	0.309	1.52	15.13	6.07	0.433	0.299

Exhibit 4.3. Line Haul and Drayage Emission Rates Based on Older Age Distribution Valid for Speeds Corresponding to Congested Urban Conditions										
Calendar Year	Line Haul Fleet					Drayage Fleet				
	VOC (g/mi)	CO (g/mi)	NOx (g/mi)	SO_2 (g/mi)	PM_{10} (g/mi)	VOC (g/mi)	CO (g/mi)	NOx (g/mi)	SO_2 (g/mi)	PM_{10} (g/mi)
1995	3.83	18.21	26.12	0.539	1.795	3.76	17.78	25.54	0.529	1.753
1996	3.73	18.15	24.75	0.536	1.679	3.65	17.72	24.21	0.526	1.640
1997	3.63	18.10	23.39	0.532	1.563	3.55	17.67	22.87	0.523	1.527
1998	3.53	18.05	22.02	0.529	1.447	3.45	17.61	21.54	0.519	1.415
1999	3.42	18.00	20.65	0.526	1.330	3.35	17.56	20.21	0.516	1.302
2000	3.32	17.95	19.28	0.523	1.214	3.24	17.51	18.88	0.513	1.189
2001	3.29	17.94	18.18	0.518	1.098	3.21	17.50	17.80	0.508	1.075
2002	3.26	17.93	17.08	0.512	0.981	3.19	17.49	16.72	0.503	0.962
2003	3.24	17.92	15.97	0.507	0.865	3.16	17.48	15.64	0.498	0.848
2004	3.21	17.91	14.87	0.502	0.748	3.13	17.47	14.56	0.493	0.734
2005	3.18	17.90	13.77	0.497	0.632	3.10	17.46	13.48	0.489	0.620
2006	3.13	17.90	13.14	0.492	0.584	3.05	17.45	12.86	0.483	0.573
2007	3.09	17.89	12.52	0.486	0.536	3.01	17.45	12.25	0.478	0.526
2008	3.04	17.89	11.89	0.481	0.489	2.96	17.44	11.64	0.473	0.479
2009	2.99	17.88	11.27	0.475	0.441	2.92	17.43	11.02	0.468	0.432
2010	2.94	17.88	10.64	0.470	0.393	2.87	17.43	10.41	0.462	0.384
2011	2.80	17.87	10.10	0.466	0.379	2.73	17.43	9.88	0.459	0.369
2012	2.65	17.87	9.56	0.463	0.364	2.59	17.42	9.35	0.455	0.354
2013	2.50	17.87	9.02	0.459	0.349	2.44	17.42	8.82	0.452	0.339
2014	2.35	17.87	8.48	0.455	0.334	2.30	17.42	8.29	0.448	0.324
2015	2.21	17.87	7.94	0.452	0.319	2.16	17.42	7.77	0.445	0.309
2016	2.11	17.87	7.69	0.450	0.317	2.07	17.42	7.52	0.443	0.307
2017	2.02	17.87	7.45	0.449	0.315	1.98	17.42	7.28	0.442	0.305
2018	1.93	17.87	7.20	0.447	0.313	1.89	17.42	7.04	0.440	0.303
2019	1.84	17.87	6.96	0.445	0.311	1.80	17.42	6.79	0.438	0.301
2020	1.75	17.87	6.71	0.444	0.309	1.71	17.42	6.55	0.437	0.299

Exhibit 4.4.A. Speed Correction Factors for Congested Urban Travel, Urban Travel, and Rural Travel			
Congestion Level	HC	CO	NOx
Congested Urban	1.00	1.00	1.00
Urban	0.630	0.566	0.874
Rural	0.453	0.544	1.422
Note: The travel conditions described here refer to the following mean speeds: Congested Urban, 20 mph; Urban, 35 mph; Rural, 60 mph.			

Exhibit 4.4.B. Speed Correction Factors for Heavy-Duty Diesel Vehicles			
Speed (mph)	Speed Correction Factor for		
	HC	CO	NOx
5	1.935	2.661	1.574
10	1.519	1.835	1.306
15	1.219	1.324	1.123
20	1.000	1.000	1.000
25	0.839	0.790	0.923
30	0.719	0.654	0.882
35	0.630	0.566	0.874
40	0.564	0.513	0.898
45	0.517	0.486	0.955
50	0.484	0.482	1.052
55	0.463	0.501	1.202
60	0.453	0.544	1.422
65	0.453	0.619	1.743

Exhibit 4.5. Grade NOx Factor						
Grade	Factor for Truck Weights (in Pounds) Shown Below					
	30,000	40,000	50,000	60,000	70,000	80,000
2%					0.16	0.25
3%			0.15	0.28	0.41	0.54
4%		0.17	0.32	0.49	0.67	0.86
5%	0.11	0.30	0.51	0.73	0.96	1.20
6%	0.21	0.44	0.70	0.97	1.25	1.54
7%	0.31	0.60	0.91	1.23	1.55	1.89
8%	0.42	0.76	1.11	1.48	1.86	2.24
9%	0.53	0.92	1.33	1.74	2.16	2.59
10%	0.65	1.09	1.54	2.00	2.47	2.94
11%	0.77	1.26	1.76	2.27	2.78	3.29
12%	0.89	1.43	1.97	2.53	3.09	3.65
13%	1.02	1.60	2.19	2.79	3.40	4.00
14%	1.14	1.77	2.41	3.06	3.71	4.35
15%	1.27	1.95	2.63	3.32	4.02	4.71

Exhibit 4.6. Emission Factors for Natural Gas Heavy-Duty Vehicles (g/mi)					
Fleet	VOC	CO	NOx	SO_2	PM_{10}
Line Haul	1.55	9.36	5.28	0.0071	0.0627
Drayage	1.51	9.11	5.14	0.0070	0.0611

Exhibit 4.7. Idling Emissions For Heavy Truck Diesel[8] (g/hr)				
Idle Conditions	NOx	HC	CO	Fuel Consumption (1/hr)
700 rpm No accessories	165	28	23	3.6
700 rpm with Air Cond.	223	28	22	4.2
625 rpm with Air Cond.	198	25	19	3.7

[8] EPA Technical Memo" Heavy Duty Diesel Emissions at Idle", C.E. Lindhjam, September, 1994. Test Parameters: Engine: Cummuns N14-350; 350Bhp Age: Mfg 6/94, mileage 468 Certification: 5g NOx/Bhp-hr; 0.1g PM/Bhp-hr.

Rail Transportation Inputs:

Figures 4.15.A and 4.15.B are the equivalent spreadsheets for the estimation of Rail-based emissions. The data items and guidelines for their completion are detailed below. Note that the descriptive information at the top of the form is essentially identical with that asked for in the Truck spreadsheet. If line-haul rail operations can be separated from those of yard and switching activity (where there is significant idling), do so with separate spreadsheets, and indicated the difference in the space Rail Mode.

Note that the calculation of rail emissions is most frequently done directly from fuel consumption. This consumption may be derived either from measured fuel use, or through the application of some allocation formula to proportion out a given line or area's usage from a larger consumption base. The spreadsheet below provides for the possibility or likelihood that the estimation of rail emissions -- and fuel consumption -- could be derived from an ***activity*** estimate, namely ton-miles of traffic. If the analysis is to proceed directly from a fuel consumption starting point, then the use of the spreadsheet should begin in the Fuel Consumption column.

Tons Shipped: Enter in this column the number of tons of a particular commodity which are shipped by rail on a daily or annual basis, depending on the needs of the analysis. A separate entry should be made for each direction that the freight is being shipped [and where an analysis will be targeted]. It is suggested that the movements be recorded by the type of rail transport, namely container, double-stack, piggyback, bulk, or box car, since fuel consumption rates tend to vary with these methods of shipment.

Mileage by Type of Shipment: Record the segment length for the given movement. For intercity line haul movements, it may be prudent to break down the mileages by segments which are inside or outside the analysis area, or which reflect fundamentally different track or traffic characteristics.

Ton Miles: Multiply the first column by the second to get annual or daily (depending on time frame selected) ton miles which are moved. It may be appropriate to account for empty backhauls if that is occurring, in order to maintain comparability with the assumptions and procedures for truck.

Average Speed: While it is known that speed is related to fuel consumption, as is acceleration/deceleration, grade, curvature, track conditions, etc., reliable factors are not currently available to relate the effect of variations in these inputs to fuel consumption. Thus, at present, this column may be left empty unless the user has information to make such an adjustment.

Line-Haul Fuel Consumption: Exhibit 4.8 provides estimates of fuel consumption rates for rail freight for different horizon years. Use these to convert the ton-mileage to gallons of fuel consumed. Alternatively, the procedures from EPA's AP-42 manual may be used to develop fuel consumption estimates.

Figure 4.15.A. Analysis Spreadsheet
Rail Transportation Inputs

Problem Setting Description: ______________________________

Condition: ☐ **Existing** ☐ **Improved (Describe)** ______________________________

Rail Mode: ____________________ **Environment:** ____________________ **Sheet:** ___ **of** ___

Tons Shipped	Mileage by Type of Shipment By (speed) Segment	Ton Miles	Average Speed	Line Haul Fuel Consumption	Hours of Idling	Idling Fuel Consumption	Total Fuel Consumption
	Container:						
	Container:						
	Container:						
	Doub. Stack:						
	Doub. Stack:						
	Doub. Stack:						
	Piggyback:						
	Piggyback:						
	Piggyback:						
	Bulk:						
	Bulk:						
	Bulk:						
	Box Car:						
	Box Car:						
	Box Car:						

Figure 4.15.B. Analysis Spreedsheet
Rail Emissions Estimation

Problem Setting Description: ____________________

Condition: ☐ Existing ☐ Improved (Describe) ____________________

Rail Mode: ____________ **Environment:** ____________ **Sheet:** ___ **of** ___

Fuel Consumption by Type of Shipment By (speed) Segment	VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Container:										
Container:										
Container:										
Doub. Stack:										
Doub. Stack:										
Doub. Stack:										
Piggyback:										
Piggyback:										
Piggyback:										
Bulk:										
Bulk:										
Bulk:										
Box Car:										
Box Car:										
Box Car:										
Total										

Idling and Idling Fuel Consumption: Primarily for Yard and Switching Locomotive operations, idling may be a significant element in emissions. The current methodology from EPA's AP-42 provides for Yard Locomotive emissions to be calculated directly from the number of locomotives in service. If the hours of idling and/or service are available, and they can be used in the analysis as a way to increase insight and sensitivity, then those data would be entered here.

Total Fuel Consumption: Total up fuel consumption from all sources in this column.

Rail Emissions Spreadsheet:

Figure 4.15.B provides for the calculation and inventory of emissions stemming from the inputs compiled in 4.15.A. The following are the features of this spreadsheet:

VOC, NOx, CO, SO_2 and PM_{10} Emissions Rates: Weighted emissions factors for each of these pollutants may be found in Exhibit 4.9 for the composite rail fleet, with difference by horizon year for years between 1995 to 2020. If separate emissions are to be estimated for line haul and yard operations, Exhibit 4.10 presents separate emissions rates for these two types of operations.

VOC, NOx, CO, SO_2 and PM_{10} Emissions: Multiply the fuel consumption estimates by the respective emissions factors to get total emissions for each segment and train type, and sum to the bottom line for each pollutant.

To test strategies and scenarios with the spreadsheet-based methodology, follow the same general principles and procedures as were outlined above to construct the baseline. The important thing to note is that the number of spreadsheets which will be necessary to perform an analysis is based on the detail and complexity of the problem application or the strategy. In general, every time that a change is anticipated/desired, a comparable "line" will be necessary in the spreadsheet, or in many cases, the use of several spreadsheets to portray the given problem or solution in all of its required detail

For example, a separate line entry or comparable spreadsheet would be necessary each time one of the following things changed:

- The facility on which the travel occurred, and the portion of that facility which lies within or outside the given metropolitan area.
- The condition of that facility (at a segment level), in terms of its capacity, grade, congestion level (V/C) ratio, and the relation of these to speed.
- Travel or conditions change by time of day.

The technique is quite versatile in pursuing a variety of options, requiring only of the user a commitment to the detailing which is necessary to engage all of the important variables in the analysis. Clearly, there becomes a scale where the practical capability of this technique in manual form becomes limited. Conversion of these techniques to a computerized spreadsheet format is a logical way to extend the technique's and the analyst's capability. A preliminary version of such a spreadsheet was developed by this project, and may be transformed into a software package in a subsequent phase. For those complex problems with effects that are systrmwide, application and involvement of elements of the regional planning models, especially the trip table, assignment, and level

Exhibit 4.8. Railroad Freight Fuel Economy (ton miles per gallon) Projections to 2020													
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Fuel	366	371	376	381	386	390	395	399	403	407	411	414	418
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fuel	421	425	428	431	434	437	440	443	446	449	451	454	456

Exhibit 4.9.
Rail Emission Factors
Weighted Composite Factors for Entire Rail Fleet

Calendar Year	Emission Factors in pounds per gallon of fuel				
	HC	CO	NOx	SO_2	PM_{10}
1995	0.0233	0.0646	0.4940	0.0360	0.0118
1996	0.0233	0.0646	0.4940	0.0360	0.0118
1997	0.0233	0.0646	0.4940	0.0360	0.0118
1998	0.0234	0.0646	0.4940	0.0360	0.0118
1999	0.0234	0.0647	0.4940	0.0360	0.0118
2000	0.0234	0.0647	0.4940	0.0360	0.0118
2001	0.0234	0.0647	0.4788	0.0360	0.0118
2002	0.0234	0.0647	0.4482	0.0360	0.0118
2003	0.0234	0.0647	0.4174	0.0360	0.0118
2004	0.0234	0.0647	0.3863	0.0360	0.0118
2005	0.0234	0.0647	0.3517	0.0360	0.0117
2006	0.0234	0.0647	0.3307	0.0360	0.0115
2007	0.0234	0.0647	0.3236	0.0360	0.0114
2008	0.0235	0.0647	0.3188	0.0360	0.0112
2009	0.0235	0.0648	0.3139	0.0360	0.0111
2010	0.0235	0.0648	0.3089	0.0360	0.0109
2011	0.0235	0.0648	0.3039	0.0360	0.0107
2012	0.0235	0.0648	0.2989	0.0360	0.0106
2013	0.0235	0.0648	0.2940	0.0360	0.0104
2014	0.0235	0.0648	0.2894	0.0360	0.0102
2015	0.0235	0.0648	0.2847	0.0360	0.0101
2016	0.0235	0.0648	0.2800	0.0360	0.0099
2017	0.0236	0.0648	0.2753	0.0360	0.0097
2018	0.0236	0.0648	0.2705	0.0360	0.0095
2019	0.0236	0.0649	0.2656	0.0360	0.0094
2020	0.0236	0.0649	0.2607	0.0360	0.0092

Exhibit 4.10 Rail Emission Factors (pounds per gallon) Projected to 2020										
Calendar Year	Yard Emission Factors					Line-Haul Emission Factors				
	HC	CO	NOx	SO2	PM_{10}	HC	CO	NOx	SO2	PM_{10}
1995	0.0506	0.0894	0.5044	0.0360	0.0138	0.0211	0.0626	0.4931	0.0360	0.0116
1996	0.0506	0.0894	0.5044	0.0360	0.0138	0.0211	0.0626	0.4931	0.0360	0.0116
1997	0.0506	0.0894	0.5044	0.0360	0.0138	0.0211	0.0626	0.4931	0.0360	0.0116
1998	0.0506	0.0894	0.5044	0.0360	0.0138	0.0211	0.0626	0.4931	0.0360	0.0116
1999	0.0506	0.0894	0.5044	0.0360	0.0138	0.0211	0.0626	0.4931	0.0360	0.0116
2000	0.0506	0.0894	0.5044	0.0360	0.0138	0.0211	0.0626	0.4931	0.0360	0.0116
2001	0.0506	0.0894	0.5012	0.0360	0.0138	0.0211	0.0626	0.4769	0.0360	0.0116
2002	0.0506	0.0894	0.4949	0.0360	0.0138	0.0211	0.0626	0.4443	0.0360	0.0116
2003	0.0506	0.0894	0.4886	0.0360	0.0138	0.0211	0.0626	0.4114	0.0360	0.0116
2004	0.0506	0.0894	0.4823	0.0360	0.0138	0.0211	0.0626	0.3781	0.0360	0.0116
2005	0.0506	0.0894	0.4760	0.0360	0.0138	0.0211	0.0626	0.3411	0.0360	0.0115
2006	0.0506	0.0894	0.4697	0.0360	0.0138	0.0211	0.0626	0.3187	0.0360	0.0113
2007	0.0506	0.0894	0.4634	0.0360	0.0138	0.0211	0.0626	0.3115	0.0360	0.0112
2008	0.0506	0.0894	0.4571	0.0360	0.0138	0.0211	0.0626	0.3067	0.0360	0.0110
2009	0.0506	0.0894	0.4508	0.0360	0.0138	0.0211	0.0626	0.3019	0.0360	0.0108
2010	0.0506	0.0894	0.4445	0.0360	0.0138	0.0211	0.0626	0.2970	0.0360	0.0106
2011	0.0506	0.0894	0.4382	0.0360	0.0138	0.0211	0.0626	0.2921	0.0360	0.0105
2012	0.0506	0.0894	0.4319	0.0360	0.0138	0.0211	0.0626	0.2871	0.0360	0.0103
2013	0.0506	0.0894	0.4287	0.0360	0.0138	0.0211	0.0626	0.2820	0.0360	0.0101
2014	0.0506	0.0894	0.4287	0.0360	0.0138	0.0211	0.0626	0.2769	0.0360	0.0099
2015	0.0506	0.0894	0.4287	0.0360	0.0138	0.0211	0.0626	0.2718	0.0360	0.0097
2016	0.0506	0.0894	0.4287	0.0360	0.0138	0.0211	0.0626	0.2666	0.0360	0.0095
2017	0.0506	0.0894	0.4287	0.0360	0.0138	0.0211	0.0626	0.2613	0.0360	0.0093
2018	0.0506	0.0894	0.4287	0.0360	0.0138	0.0211	0.0626	0.2560	0.0360	0.0091
2019	0.0506	0.0894	0.4287	0.0360	0.0138	0.0211	0.0626	0.2506	0.0360	0.0089
2020	0.0506	0.0894	0.4287	0.0360	0.0138	0.0211	0.0626	0.2452	0.0360	0.0087

of service/speed calculations may be of considerable value. These approaches were described as Level C in the section on Analytic Methods (4).

Step 3: Summary and Review

Having performed the analysis of individual strategies or packages in the preceding step, it becomes important to systematically tabulate the findings of those assessments to begin the process of evaluation, discussion and selection. The primary elements that would enter into this determination are:

1. The change in emissions.
2. The cost to implement the strategy, and the bearer of those costs (public or private).
3. The likelihood that the strategy will be implemented.

Clearly, the selection of one or more strategies for implementation is a complex process, involving multiple factors and the weighing of tradeoffs and acceptance of compromises across a range of possible outcomes. This section presents some suggestions for accomplishing this review and evaluation, and provides additional forms and guidelines to structure this process.

(7) Impact Summary

The first step in the summary and review process is to compile and tabulate the results from the individual analyses in a central place. Figure 4.16. is provided for this purpose. Initiate this table by entering a description of the strategy or strategy package that was tested and the identifying "Trial" number it has been assigned in the left column.

Next, enter the change in "Activity" levels that have occurred as a result of the strategy. The table makes provision for relating changes in activity by mode, including Rail, Truck, and Other (non-intercity freight highway traffic). Because rail and highway modes are treated differently in emissions estimation, the table provides for recording the Rail activity in terms of Ton-Miles, and for Truck and Other Highway in VMT. The user may wish to place the freight modes on a more comparable basis, suggesting a conversion of truck activity to Ton-Miles. At the other extreme, it may be simpler to express rail activity in terms of Fuel Consumption. All this variable is trying to record is how much the freight activity has changed under the strategy.

Next record the calculated changes in emissions, by individual pollutant, in Kg/Day, Tons/Year, or other unit which is most useful to the local analysis. Record these emissions changes by individual mode (from Figures 4.15. and 4.16.), ensuring that the units are comparable.

Finally, Figure 4.16 asks for information on the costs associated with implementing the strategy. Specifically, it tabulates the Net Cost per Ton (or Kg) of emissions reduced, where Net Costs are total capital and operating cost to implement the strategy, less any revenues that may be obtained as a result (say, from implementation of a fee or toll). These costs are calculated in a separate procedure, discussed in the following section.

Figure 4.16. Impact Summary Table

Trial			▲ Activity		▲ Emissions					Net Cost Per Ton				
No.	Strategy	Mode	Ton-Miles	VMT	VOC	CO	NOx	PM	SO_2	VOC	CO	NOx	PM	SO_2
		Rail Truck Other TOT.												
		Rail Truck Other TOT.												
		Rail Truck Other TOT.												
		Rail Truck Other TOT.												
		Rail Truck Other TOT.												

(8) Calculation of Costs and Benefits

The calculation of costs and benefits associated with implementing a strategy can be as direct or comprehensive as the local agency requires to properly assess the strategy and gain support for its implementation. Determining the direct Costs should probably be the highest priority, and is generally the most tractable measure to quantify. Other types of benefits add secondary value to a selection appraisal, and generally are more difficult to quantify with any certainty.

Figure 4.17. provides a table structure for compiling the estimate of costs. First note the number of the Trial and the Description of the Strategy in the left column. Proceed then to estimate the Annualized Public Cost to implement the strategy. In effect, these are the cost outlays of government, i.e., the public sector, to furnish the improvement or service; they may also be considered as costs to the taxpayer. This consists of the Capital Cost, if any, to construct or install the improvement, and the Operating Cost to maintain the improvement or service over time. Estimate any Revenues that would result from tolls, fees, taxes or surcharges associated with the strategy. Finally, Net Costs are determined by summing Capital and Operating Costs and deducting Revenue. All costs should be placed on Annual terms for comparability.

The next group of columns provides for a similar estimation of Private Costs, namely the costs (or savings) experienced by the private sector. This group consists, primarily, of the freight industry, and the monetary impact the strategy would have on their service, plant or equipment. It may also include costs (or savings) experienced by shippers of goods. And, it may also include costs (or savings) to the general traveling public.

The final columns of the table anticipate a summation of public and private costs into a total "Societal" Cost. It would be expected that the analysis would generally want to work with this total Net Cost as the evaluation basis in the Impact Summary table of Figure 4.16.

The enumeration of other costs and benefits associated with the implementation of any of these strategies could be made into a very extensive and comprehensive exercise. For initial assessments of most strategies, it is recommended that the focus be placed on forming the best estimates of Net Cost. As implied in the discussion above, there is ample provision in the definition of "costs" to incorporate less direct types of costs, such as changes in operating conditions that affect overall efficiency and cost of operation, to the extent these can be monetized. At the same time, it may be possible to reflect "savings" that would occur as a result of improvements to operating conditions, and these should be used to decrease the estimated costs.

There are some benefits and costs, however, which despite their existence and role in the outcome, are difficult to accurately quantify. Examples include:

- Cost or savings impact of changes in travel time or travel-related delays
- Costs or savings associated with reduced flexibility to providers or shippers to ship goods at particular times.

- Costs or savings associated with reduced or improved reliability in time of arrival of shipments.
- Costs or savings to carriers associated with gain or loss of customers due to uncontrollable changes in service induced by a strategy.
- Changes in noise, accident or other incidental impacts associated with freight transportation.
- Changes in travel times, delay, scheduling flexibility, reliability, etc. for non-freight travel.
- Avoided costs associated with reduced pavement wear rates, or reduced demand for new capacity or capacity modifications.

The quantification of these types of ancillary benefits and costs is outside the purview of this methodology, and pursuing these concerns is left to the requirements of the individual user. There are a number of studies that offer additional help in this area that may be consulted.[9]

[9] *User's Manual for StratBENCOST*, and *User's Manual for RAILDEC*; Hickling Lewis Brod, Inc., 1995.

Figure 4.17. Cost Summary Table

Trial		Annualized Public Cost				Annualized Private Cost				Combined Societal Cost			
No.	Strategy	Capital	Operating	Revenue	Net Cost	Capital	Operating	Revenue	Net Cost	Capital	Operating	Revenue	Net Cost

(9) Implementation Selection Criteria:

Once the compilation of costs and benefits has been done in (8), and the Impact Summary tabulations completed in (7) [Figure 4.16], the review and selection process may proceed to the evaluation phase. Obviously, the information contained in the Impact Summary Table and the Cost Summary Table are essential elements in the task of comparing and ranking strategies. However, each user/review group will key on different aspects of these impacts in making the actual comparisons and decisionmaking.

Suggested below are a set of criteria which might be of value in comparing and ranking strategies, such as would be expected to be important in an actual evaluation review. These are meant as guidelines and as an aid to users in structuring their own process. It is assumed that each area will have their own criteria and priority system.

Suggested Selection Criteria:

1. The strategy or strategies ***make good economic sense.*** They improve, rather than worsen travel or cost conditions for industry (although there may be some time phasing before the benefits are fully realized).
2. The strategy represents an attractive ***Win-Win*** situation for industry and government, in terms of opportunity, cost sharing/leveraging, implementation authority, etc.
3. The strategy represents a ***good "buy"*** in terms of its cost-effectiveness in reducing emissions (i.e., net cost per ton).
4. The strategy is particularly effective in reducing a strategic or ***critical pollutant***, such as NOx, PM, or SO_2, that might be difficult to achieve otherwise.
5. The strategy enables or promotes ***other desirable outcomes or benefits***, such as reduced congestion, noise, accidents, traffic conflicts, etc., which are valued by the general public.
6. The legal, institutional, or political barriers are not prohibitive, or, there are special attributes of the given strategy that allow it to sidestep or overcome these barriers.

Figure 4.18 is provided as an aid in performing this evaluation through the application of the Selection Criteria. The table lists each of the criteria cited above, and also leaves space for additional/different criteria favored by the user. Provision is also made for assignment of an Importance Weight to each criteria, should it be determined that the various criteria will carry different priority in the final selection.

To keep the analysis simple, it is suggested that the importance Weights be simple integers with values from 1 to 5, in order of increasing importance. The same recommendation is made for the Criteria themselves: a 1 to 5 point system to reflect lowest to highest attainment of the criteria should be sufficient. A weighted final score can then be tallied and recorded in the final Total column. Selection may be aided by both the weighted score total, representing a "desirability index", or by reflection on the values attained by the strategies across the shown criteria.

Figure 4.18. Stategy Selection Criteria

		Criteria							
		Economic	Joint Benefit	Cost-Effective	Critical Pollutant	Secondar y Benefits	Barriers	Other	
Assigned Weight		wt = ____	wt = ____	wt = ____	wt = ____	wt = ____	wt = ____	wt = ____	
Trial									Weighted Score
No.	Strategy								

5.0 Case Study Application of Methodology

5.1 Purpose and Approach

The research plan for the study that produced this report recommended inclusion of a "case study" element as a mechanism in the development and testing of the proposed methodology. Because freight issues and relationships are not always well-understood by public-sector planners or decisionmakers, and because the modeling tools are relatively crude in incorporating freight, the use of case study experience was seen as an important way of injecting realism into the research tools and recommendations.

The development and use of these case studies involved the following steps:

1. Identifying a small number of representative sites with major freight elements in their transportation systems, and with outstanding air quality attainment problems.
2. Contact with the selected sites and compilation of an Initial Profile of transportation and air quality conditions and problems, and the role of freight in those situations.
3. Identifying the programs or measures being considered by the sites, appraising their analytic capability to evaluate these or other related strategies, and then using these findings in design of the methodology.
4. Selection of problem examples at the sites and application of the study methodology to identify relevant improvement strategies and to estimate the travel and emissions consequences of those strategies.

This chapter provides a summary of the case study element which emphasizes the *key findings* from the above steps:

Section 5.2 describes the selected sites through a Site Profile, which features (1) an estimate of freight emissions contributions, (2) a profile of freight system characteristics and components, and (3) a rundown of identified freight problems, system deficiencies, and plans or projects which are being considered for their rectification.

Section 5.3 then describes the example problems which were identified, and the application of the methodology in identifying strategies to address those problems, and in estimating the impacts of those strategies.

An important objective of this Chapter is to demonstrate the application of the Methodology which was presented in Chapter 4. The same steps are followed as are laid out in the Methodology, and the relevant forms, worksheets, tables and look-up guides are used to demonstrate their properties and use.

■ 5.2 Profile of Case Study Sites

5.2.1 Overview

After some careful review and discussion, Los Angeles, Chicago and Philadelphia were chosen as the case study sites. This was based on each being a severe-or-worse air quality nonattainment area for ozone, having a major freight component to the transportation system, and having MPOs and states which were proactively considering freight issues and strategies. Each site was contacted and investigated according to the following questions:

1. The area's current and projected air quality status.
2. Composition of emissions by source, mode and type of pollutant.
3. Proportion of emissions due to *intercity* freight, and level of attention given to freight in relation to air quality planning.
4. Means available or efforts made to identify intercity freight activity, and contribution to emissions.
5. Nature of region's intercity freight activity, in terms of infrastructure features, types of modes/operations, commodity movements, markets served, link with regional economy.
6. Conditions regarded as existing or pending problems related to freight movements, that have implications for emissions, including infrastructure problems, disparities between freight facilities, shippers/markets, and infrastructure, through traffic, operating practices, technology, congestion and interaction between freight and other traffic.
7. Strategies considered/recommended to address freight needs or problems.
8. Analytic capabilities, including models, data, studies, personnel/experience and identifiable needs.

Detailed case study profiles have been developed for each of the three sites. These individual profiles are provided in Appendix B. In the sections below, the major findings have been distilled out of the unabridged profiles, and presented simultaneously for the three sites.

5.2.2. Summary of the Air Quality Problems and Attainment Status

Each of the three sites was selected because of serious air quality problems. The three are included among 10 U.S. metropolitan areas with the poorest air quality with regard to ozone. Philadelphia and Chicago are classified by EPA as "Severe" Nonattainment areas, while Los Angeles is the country's only "Extreme" ozone Nonattainment area, and must meet its ozone standards by 2010. The Philadelphia region is rated as Severe - 05, meaning that it must attain the NAAQS standards by 2005. The Chicago region's problems are somewhat worse; its status is Severe - 07, meaning that it must reach attainment by 2007.

While ozone is a pollutant which is determined by combinations of three precursor pollutants -- VOC (volatile organic compounds/reactive gasses) and NOx (oxides of Nitrogen), and CO (Carbon Monoxide) -- each of which must be considered in ozone abatement plans, CO is a pollutant that also carries its own EPA standards. Los Angeles and Philadelphia are both Moderate CO nonattainment areas, and must meet the CO standards by December 1995. A separate test and standard also exists for Particulate Matter, specifically PM-10. Philadelphia is facing no problem with PM-10, but certain portions of the Chicago region are in Moderate Nonattainment status. Los Angeles/South Coast region is a Serious Nonattainment area, with a compliance date of December 2001.

In most areas which have been addressing ozone problems, including these, short term meeting of the NAAQS guidelines has been achieved largely through VOC reductions, and these reductions may be almost exclusively credited to technology, fuels, and inspection/maintenance improvements. VOC improvements are expected to continue with technology, and each of the areas believes that it will achieve the long-term standards. However, NOx continues to be a difficult pollutant to control. While technology and fuels offer some hope, NOx is a pollutant which is heavily linked to travel and traffic conditions; it is also a pollutant that is heavily linked to diesel power, which supports most freight activity. What makes NOx even more problematic is that (1) it is also a contributor to PM, and (2) its contribution to ozone puts it into a "critical" relationship with VOC, such that reductions in either that exceed a proper balance with the other may actually be counterproductive to the reduction of ozone in some areas. On the basis of claims that further reductions of NOx would be limiting, the Chicago region has applied to EPA for a waiver from its NOx requirements. PM is also a pollutant that relates heavily to diesel and freight. A growing concern is that the PM standard may be lowered from 10 microns (particle size) to 2.5 microns. Attainment of a PM-2.5 standard will bear much more heavily on freight than PM-10.

5.2.3. Primary Source of Pollutants

The first step in addressing the question of freight's role in regional air quality status or attainment plans is to break down the area's emissions by primary source: Area, Point, Mobile and Off-Road. Figure 5.1. shows the relative contributions of each of these sources to the three primary pollutants which are precursors to ozone: VOCs, NOx and CO in the three case studies (Comparable figures on PM were not available). These statistics were obtained from the 1990 emissions inventories contained in the respective State Implementation Plans, which were assembled by the state environmental agencies. It is important to note when reviewing these statistics that:

- The levels of pollutants and the proportions by source reflect 1990 relationships; these relationships will have changed over time, demonstrating relative improvements in transportation emissions sources.
- Mobile and Off-Road sources are the categories in which freight contributions are to be found. Truck freight is captured under Mobile Sources, for which the emissions estimates are made by the MPO. Rail, marine, air and other non-highway contributors are contained in the Off-Road category, and are estimated by the state environmental agency.
- NOx is the primary pollutant generated by freight, along with PM (not pictured).
- The relationships in the figures for Chicago and Los Angeles reflect regional conditions, while those for Philadelphia reflect the condition for the entire state, since regional breakdowns were not developed by the state. There is some question, therefore, as to how representative the state condition is of its largest urban area.

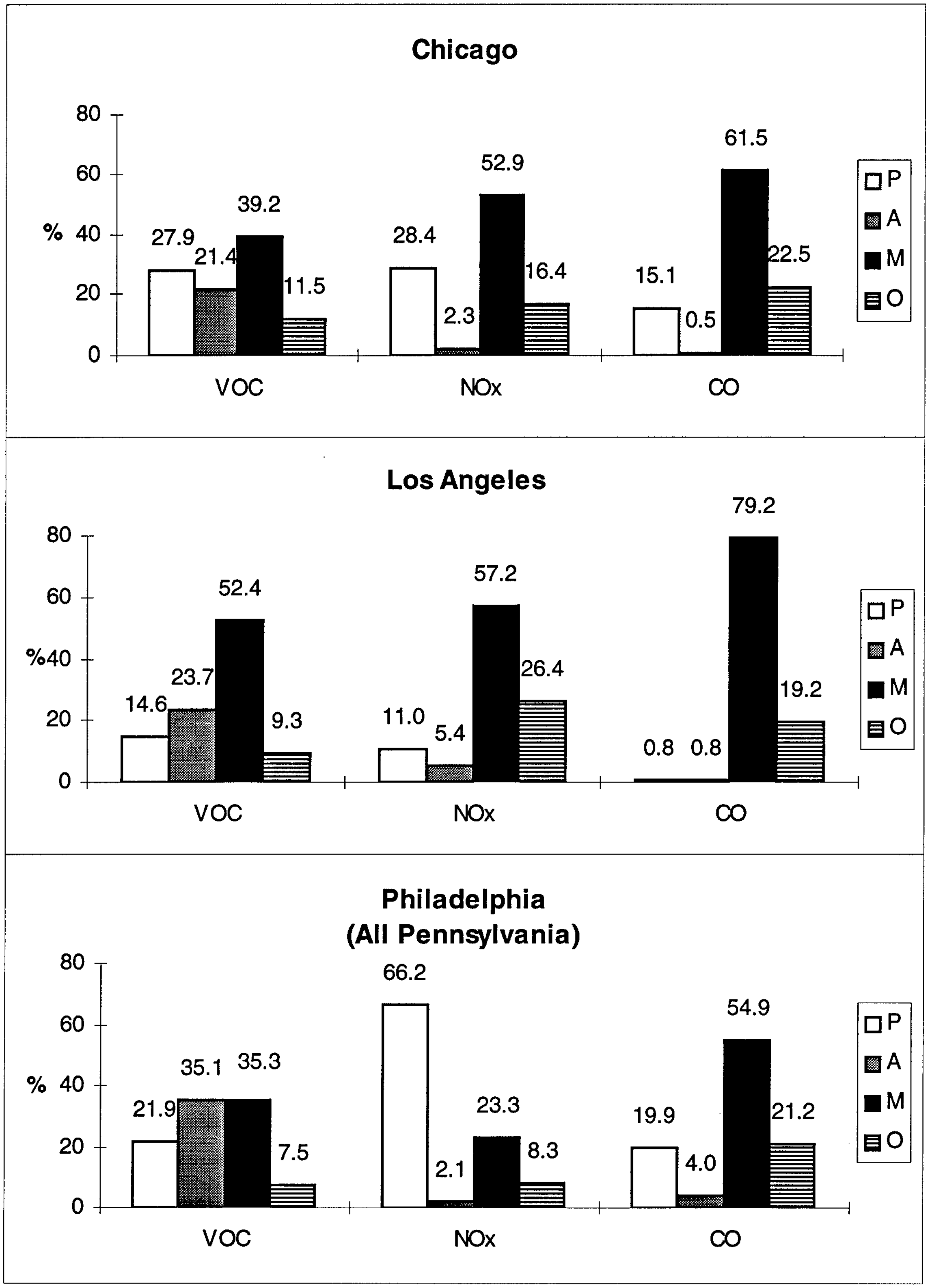
The relationships in the figure illustrate that:

- Mobile sources generally comprise the largest single contribution to VOCs: 52% in Los Angeles, 39% in Chicago, and 35% in Philadelphia. Off-Road sources are the smallest contributors to VOCs (8-11% range).
- Mobile sources are an even greater proportional contributor to NOx, at 53% in Chicago and 57% in Los Angeles; the 23% contribution in Philadelphia is viewed with suspicion given that the data is statewide, not regional. Off-Road sources also contribute at a higher rate to NOx than VOCs, at 16% in Chicago and 26% in Los Angeles (only 8% in Philadelphia).
- Mobile sources have their greatest proportional impact on CO emissions, where they comprise 62% in Chicago, 79% in Los Angeles, and 55% in Philadelphia. Off-Road sources are the second-heaviest contributor to CO, at the 19-23% level.

In summary, transportation-related sources comprised the majority of emissions in the regional inventories in each of these metropolitan regions (Philadelphia excepted because of its statewide profile), with the smallest relative contribution being in VOCs, and the largest being CO.

In general, for those sites where data is available to compare 1990 emissions relationships with those projected for 1996, the greatest reductions over this period are projected to occur in VOCs (because the Clean Air Act specifically required reduction in VOCs by 1990), and the greatest share of these reductions will be coming from Mobile, but not Off-Road, sources. The biggest NOx reductions will be gained from Point and Area sources, and only modestly from the transportation sources, which of course raises the issue of source targets for future NOx reductions.

Figure 5.1. 1990 Emissions of Ozone Precursors by Source



5.2.4. Emissions Contributions of Freight Modes

Specific estimates of emissions by freight modes were not found in the reviews of SIPs and planning studies for the three sites, and indeed this is standard practice. Break out of freight modes is not easily accommodated by the emissions models. Whereas the transportation models generally will allow evaluation of motor-freight movements, these distinctions are lost when the transportation inputs are taken into the Mobile (or other) emissions model. The emissions models do differentiate among nominal vehicle classes; however, these classes are only loosely connected with their possible functions, and there is a considerable amount of aggregation that is done in the application which greatly obscures these modes' operating and proportional contributions.

To formulate an estimate of freight emissions using the types of information which are commonly available to MPO or state agencies, it is necessary to apply various assumptions and factoring methods to the vehicle class information from Mobile. In particular, Mobile generally contains the following 8 vehicle classes:

LDGV: Light Duty Gas Vehicle (primarily passenger cars)

LDDV: Light Duty Diesel Vehicles (under 6,000 lbs, GVW)

LDGT1: Light Duty Gas Trucks (under 6,000 lbs, GVW)

LDGT2: Medium Duty Gas Trucks (6,000 to 8,500 lbs. GVW)

LDDT: Light Duty Diesel Trucks (6,000 to 8,500 lbs. GVW)

HDGV: Heavy Duty Gas Vehicles (over 8,500 lbs., GVW)

HDDV: Heavy Duty Diesel Vehicles (over 8,500 lbs., GVW)

MC: Motorcycles

There is some arbitrariness in how these classes are defined, and other class definitions are used by some agencies. For example, some areas define the first three classes as Passenger Cars, Light Duty Trucks (Gas and Diesel), and Medium Duty Trucks. Some do not distinguish between Light and Medium truck. Some include urban buses in HDDV, while others have a separate category.

In general, freight modes are captured within the definitions of the HDGV and HDDV classes. These are vehicles weighing over 8,500 GVW. However, whereas most light trucks and vans are captured in the LDGT and LDDV classes, certain pickup and van-type vehicles may have rated capacities of over 8,500 lbs GVW, and therefore may fall into the heavy duty classes. And within the Heavy Duty classes, really only combination trucks with related capacities over 33,000 lbs GVW are likely to be used in intercity service. So, from these rather imprecise class definitions, the assessment of how much emission contribution accrues to freight must be made.

An approximation of the emissions attributable to Intercity Truck has been made by assuming that the predominant vehicle for intercity freight is a combination truck with 3-or-more axles. The great majority of these trucks are diesel powered, which means they would be contained within the HDDV class's emissions total. To break out the combination truck share, data from HPMS and TIUS were used to generate an estimate of the percentage of HDDV in a given nonattainment region were comprised of combination trucks. These fractions, taken from Table 4.3, are 80.8% for Chicago, 60.2% for Los Angeles, and 69.5% for Philadelphia. Using this relationship figures 5.3.A., 5.3.B., and 5.3.C. show the estimated contribution of intercity truck to regional emissions by type of pollutant, illustrating VOCs, NOx and CO emissions, respectively. The left side of the figure shows the share of regional VMT which is accounted for by the particular type of motor vehicle, while the right side indicates the share of emissions which are contributed by the same modes. The number in parentheses in the pie graph indicates the mode's share of total regional emissions for that pollutant, while the number above without parentheses is the mode's share of mobile source emissions only.

- In Chicago, Intercity Truck accounts for about 7.2% of all regional VMT, while it contributes 3.8% of all Mobile Source VOCs, **39.1% of all Mobile Source NOx**, and 2.3% of all Mobile Source CO. From the standpoint of total emissions across all sources, Intercity Truck accounts for 1.5% of regional VOCs, **20.7% of regional NOx**, and 1.5% of regional CO.
- In Los Angeles, Intercity Truck accounts for only 2.6% of all regional VMT, while it contributes 3.0% of all Mobile Source VOCs, **19.7% of all Mobile Source NOx**, and 1.5% of all Mobile Source CO. From the standpoint of total emissions across all sources, Intercity Truck accounts for 1.3% of regional VOCs, **10.8% of regional NOx**, and 1.3% of regional CO.
- In Philadelphia, Intercity Truck accounts for only 3.5% of all regional VMT, while it contributes 2.2% of all Mobile Source VOCs, **24.1% of all Mobile Source NOx**, and 1.7% of all Mobile Source CO. From the standpoint of total emissions across all sources, Intercity Truck accounts for 0.8% of regional VOCs, **5.6% of regional NOx**, and 0.9% of regional CO.

The conclusions from this analysis is that Intercity Truck is a primary contributor to Mobile Source NOx emissions, particularly in relation to the VMT it generates, but is a relatively modest contributor to VOCs and CO , about proportionate to its VMT share. Even in relation to total emissions from all sources, NOx contributions are a fairly impressive share, at 20.7% in Chicago and 10.8% in Los Angeles. Only Philadelphia shows a small share of NOx from Intercity Truck at 5.6%, but this would appear to be explained by the small percentage of the State's NOx emissions which come from Mobile as opposed to Point sources; It is expected that if a regional source distribution were available for Philadelphia only, the NOx contribution would be higher.

Figure 5.2.A. 1990 Mobile Source Contributions by Type of Motor Vehicle: VOC

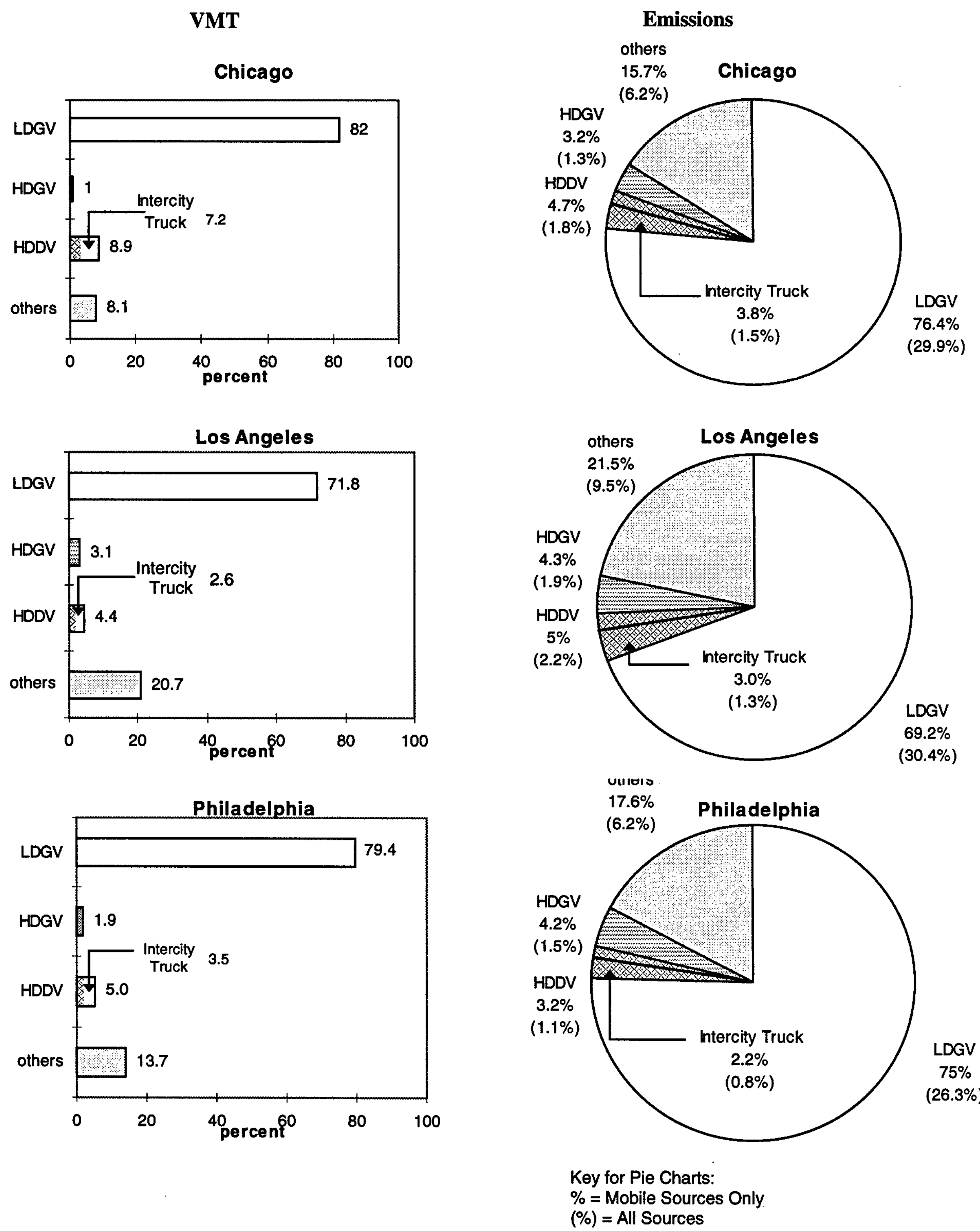
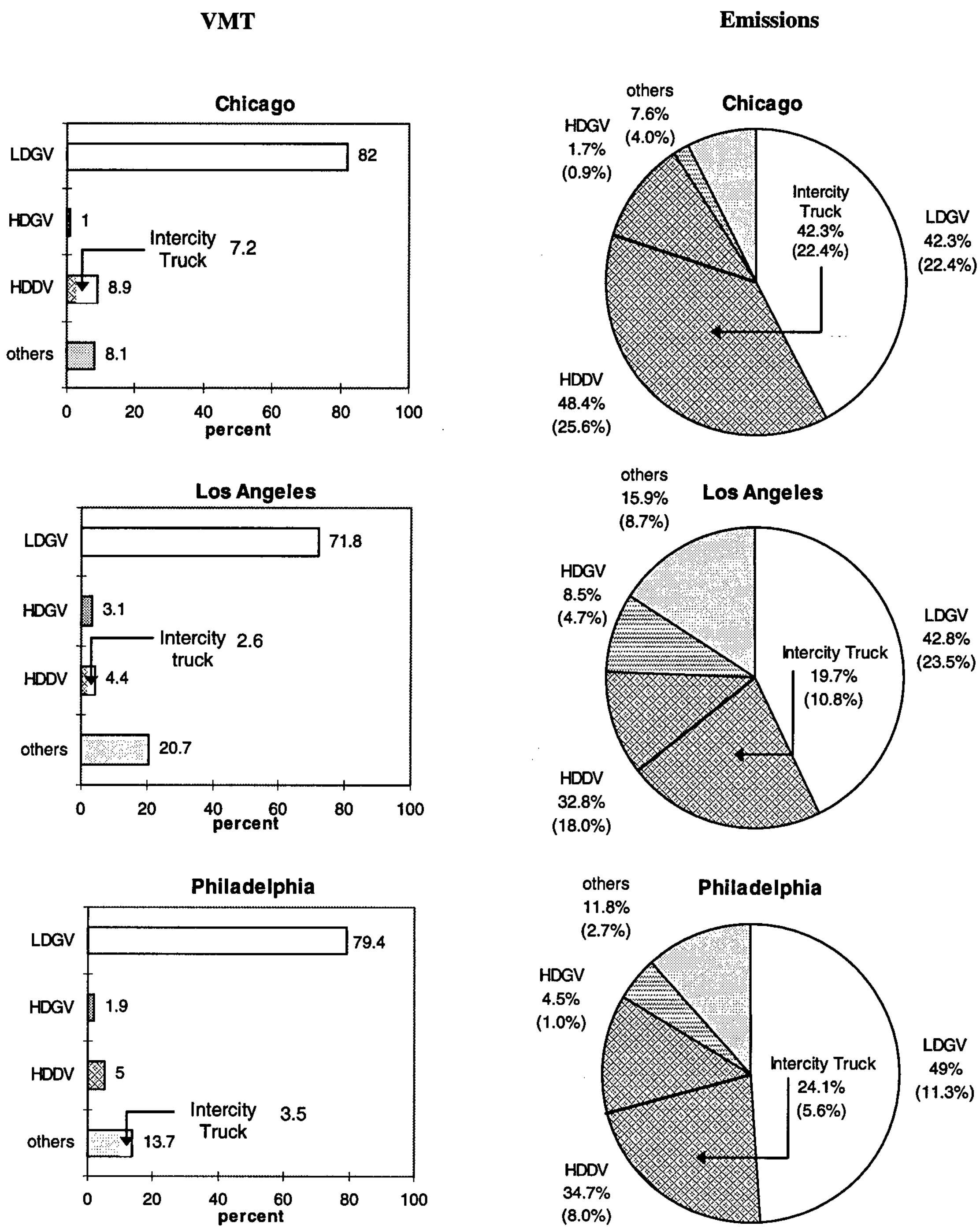
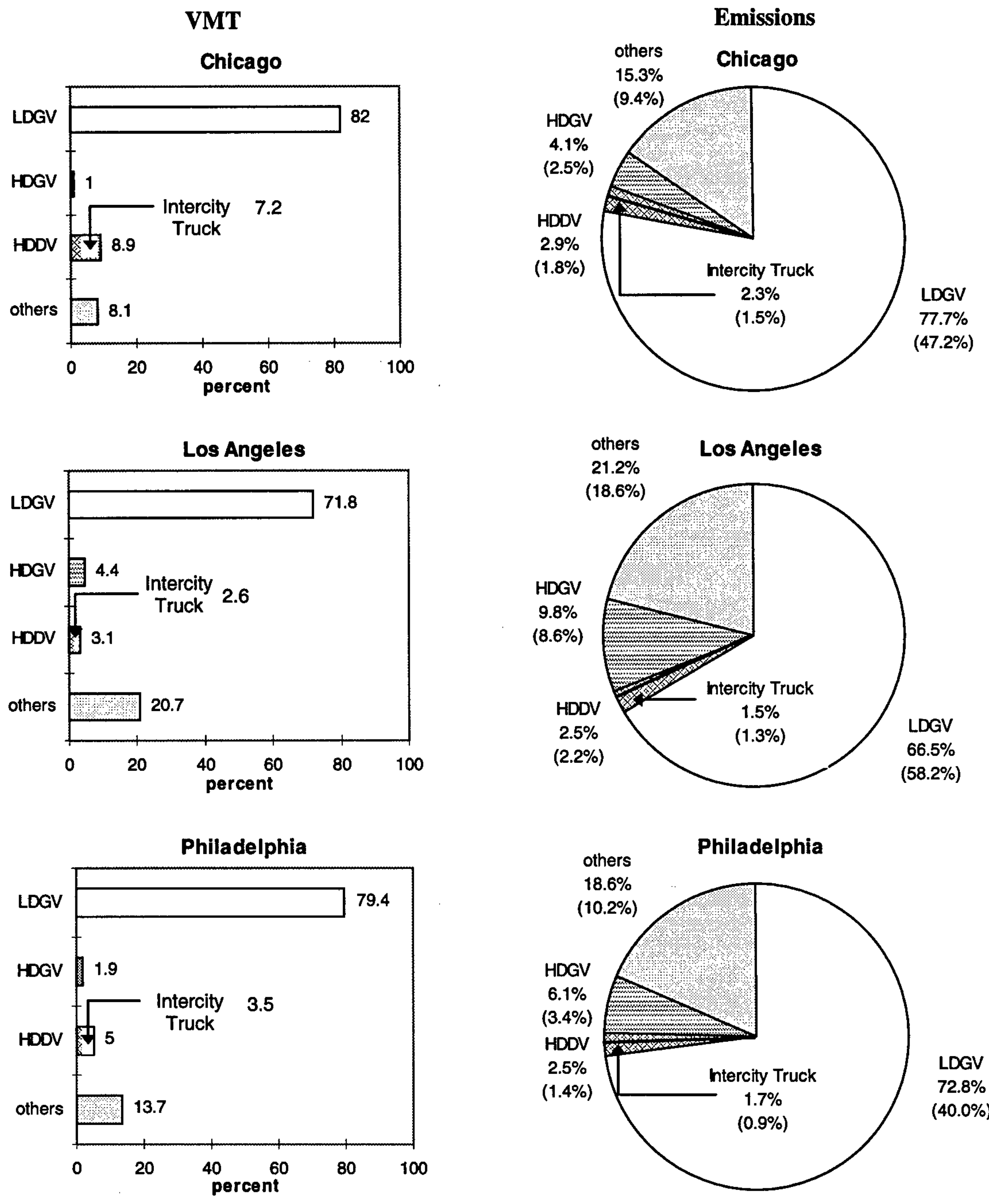


Figure 5.2.B. 1990 Mobile Source Contributions by Type of Motor Vehicle: NOx



Key for Pie Charts:
% = Mobile Sources Only
(%) = All Sources

Figure 5.2.C. 1990 Mobile Source Contributions by Type of Motor Vehicle: CO



Key for Pie Charts:
% = Mobile Sources Only
(%) = All Sources

Locomotive emissions are estimated in an entirely different way than truck. They are included in the Off-Road source portion of the inventory, and according to guidance provided by EPA's AP-42 procedures manual, locomotive emissions are calculated through multiplication of a grams/ton-mile emissions factor times locomotive diesel fuel consumed in the region. These emissions are also not always broken down by individual source within the emissions inventory. An estimate of locomotive emissions was identified for Chicago. As shown in Figure 5.3, locomotives account for 4% of the VOCs generated by Off-Road sources (0.5% of regional), 14% of Off-Road NOx (2.3% of regional), and only 0.8% of Off-Road CO (0.2% of regional). Again, NOx is the biggest area of contribution, although it is small by relative standards even given the character of Chicago as the nation's rail hub. The major sources of Off-Road emissions are lawn and garden equipment, heavy (mainly construction) equipment, and pleasure craft/recreational vehicles.

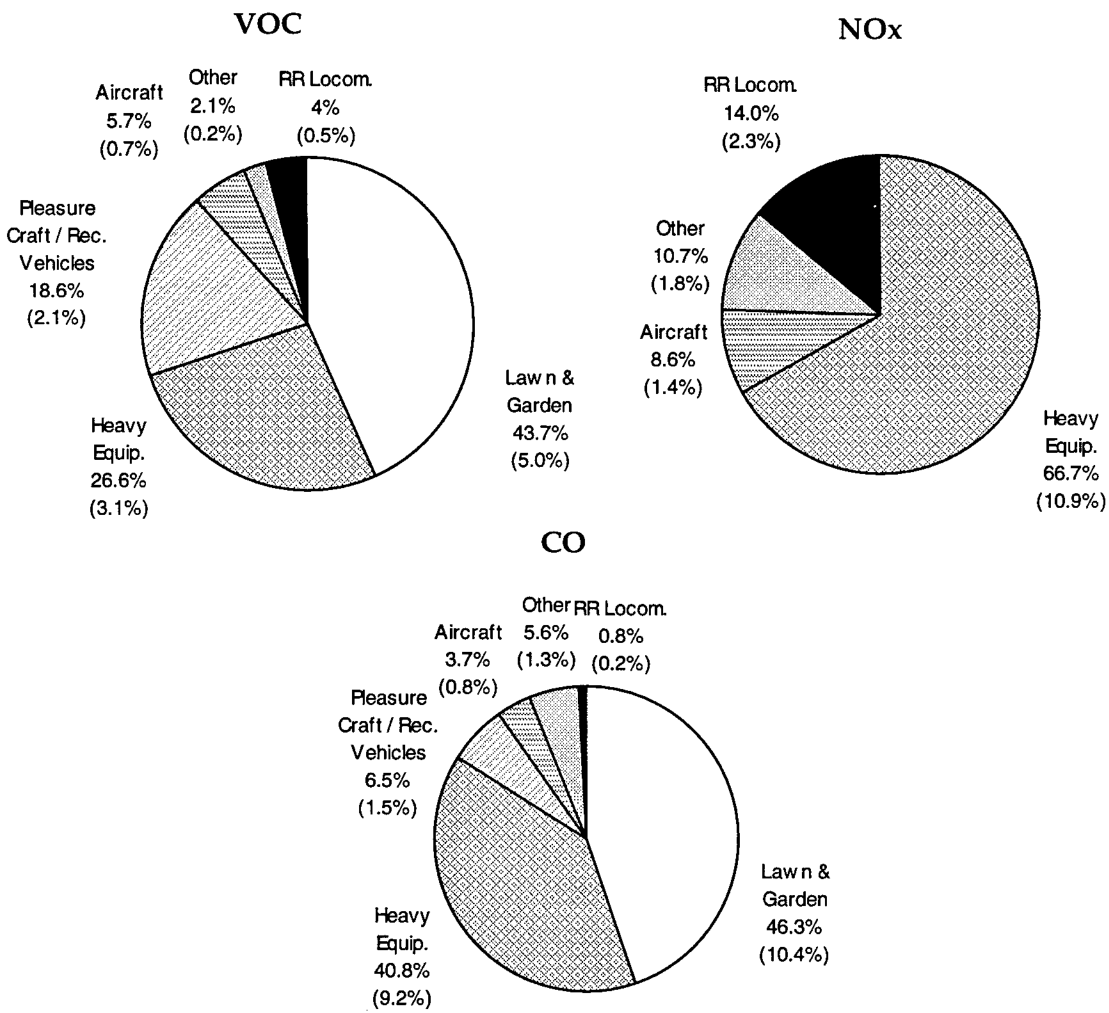
5.2.5. Regional Freight Characteristics and Problems

The three study areas are quite unique in some of their freight characteristics, but there is also similarity in the types of issues and problems that arise. Los Angeles is distinct in being a major national port. Chicago, while on Lake Michigan, has relatively little port/marine activity, but is a major land hub for freight, both rail and truck. And Philadelphia has a different character still: as a freshwater port, it generally serves regional rather than national markets, although for certain (typically South American) commodities such as Chilean fruit or cocoa beans, Philadelphia is a national distributor. Each site has a substantial local/regional market that ships or receives intercity goods, serves as a site for trans-shipment of goods to other locations and serves as a corridor or bridge for through travel. Each of these functions has a different character, carries a different level of importance, and presents different problems, needs and remedies.

There are certain types of infrastructure, industry or market patterns that tend to recur in similar form at each site:

- Intermodal freight movements are a major area of activity at each site. There are various obstacles or inefficiencies that impede additional growth and/or contribute to emissions: limited capacity at yards; poor connections between port, terminal and intermodal yards, requiring over-the-road drayage traffic; poor access to terminals or from terminals to the transportation system; and limited hours of operation.
- Drayage operations themselves contribute to local congestion, and can be inefficient in terms of empty backhauls, involving excessive idling while in waiting mode, and a concentration of shipments during the peak hours of the day There are numerous dray operators, which means that there is little or no coordination of dray operations.
- Freight facilities, such as rail yards and truck terminals, tend to be located near the center of the urban area, where congestion levels are highest, and flow and access problems are most exaggerated, not near shippers or receivers.

Figure 5.3. 1990 Off-Road Emissions by Source: Chicago



Key:
% Off-Road Source Only
(% Total Regional)

Furthermore, they are mot located near shippers or receivers.

- Transportation networks within and through a metropolitan area are not efficient for truck movements: typically, there are problems with bridge clearances, geometric restrictions and area/facility restrictions.
- indirect access, and poor information all contribute to circuitous routing and additional VMT and emissions.
- Shippers demand goods during peak travel periods.

5.2.6. Identification of Freight Strategies

The types of strategies which have been or are being considered to affect freight operations and emissions -- directly or indirectly -- are summarized below.

A general observation is that most of the strategies that are mentioned are not specifically directed at addressing an "intercity freight" problem or need; that term is something of a foreign concept among MPOs. Also, the only emissions strategies directed at freight have really been emissions standards, and not operational measures designed to change travel or operating patterns. A notable exception to this is in Los Angeles where the economic competitiveness of the region has been a major factor in their investments and planning.

Each area has one or more major projects under review that deal with intercity freight operations:

- **Philadelphia** is very focused on its port. The state, in a partnership with the railroads, is about to complete a project which has made the principal rail lines into Philadelphia "double-stack compatible", which demonstrates a major interest in intermodal activity, and should make the Philadelphia port much more attractive as a national and international connector. Also, a private concern is pushing ahead with plans to put in place a "fast ships" service between Philadelphia and Belgium that would give Philadelphia a link to the European market and stands to quadruple the level of container traffic through the port.
- **Chicago** is first and foremost a rail center (8 of the country's 9 Class I railroads serves Chicago), although most every major trucking company also has a terminal in the region. Chicago is therefore a center not just for shipping and receiving goods, but for transferring from mode to mode or carrier to carrier; this means that intermodal transfers are a vital part of the Chicago system. There is a large number of intermodal terminals in the region, (mostly near the core) some between rail terminals. Strategies are underway to affect this terminal infrastructure, including: increasing the capacity of existing terminals; re-opening or modernizing old or abandoned terminals; looking at options for improved terminal interconnections (rail-to-rail connections, rubber tire beltway, etc.). The region is also looking for ways to facilitate overall rail operations, including advanced information/scheduling systems to minimize predictable delays in the

yards, and investigation of an ITS early deployment corridor running between Milwaukee, WI and Gary, IN.

- Los Angeles is a major international port, and that activity is supported by an extensive rail and highway system. The major strategy under consideration to affect freight operations and emissions is the $1.8 billion Alameda Corridor. This project would consolidate rail routes into the ports of Los Angeles and Long Beach, eliminate grade crossings, and serve the anticipated growth of traffic. This project is targeted for completion in 2001. Another project under study is the concept of an inland port, where containers would be quickly moved to an inland location, outside the basin, where they would be sorted and dispatched, relieving emission-generating activity in the vicinity of the ports. Rail electrification and time-of-day controls on trucks are strategies that have also been considered, but are not considered practicable for implementation.

Another important step at each of the sites is the opening of formal dialogue with the private sector. While some areas had informal linkages with the freight industry or shippers, through planning or advisory committees, this process has taken on added substance under ISTEA, and each site has a major standing committee that deals with goods movement issues. These groups help to identify problems and solutions, and frequently involve partnerships that aid in funding, implementation, or ensuring the effective design and use of the improvement.

Other, more general, types of strategies which are being considered include:

- Standards for cleaner vehicles (mainly California).
- Economic incentives to hasten introduction of new technology or encourage use of alternative fuels.
- Alleviation of flow impediments, such as restrictive bridge clearances, geometric restrictions, etc., and traffic engineering modifications (including signalization) to improve flow.
- Incident management systems to mitigate major breakdowns and delays.
- Highway access improvements to intermodal terminals, particularly access to National Highway System links.
- Consideration of shipper incentives for shifting eligible movements to off-peak periods.

5.2.7. Freight Contributions to Secondary Congestion

The role of freight in emissions has a dual nature: the first is the emissions product of freight operations themselves, including emissions that are a result of freight vehicles moving in congested flow conditions; the second is a more pervasive impact, namely the effect on general traffic flow and emissions as a by-product of the activities of freight. In general, each of the sites was aware of the mixing and by-product effect, but had not taken any formal steps to analyze its impact or evaluate any control strategies.

Most major metropolitan areas maintain a four-step transportation planning process which develops trip tables for each mode -- including truck -- and major purpose. These trip tables are assigned to a computerized transportation network. These results are typically validated against actual count data which register truck volumes and shares of traffic by time of day. Technically, the capability more or less exists to examine truck mixing with regular traffic across the transportation network, and identify situations where congestion problems are also accompanied by high truck volumes. More difficult is identifying where trucks impact speed/delay patterns on signalized arterials, through intersections, or are involved in non-recurrent delay on freeways. The emissions arising from these types of stop/go situations are a problem in any transportation-based emissions analysis (for which an appropriate tool for analysis in microscoping traffic simulation), and it is complicated by the fact that truck vehicles consume more capacity and move at different speed than passenger vehicles. Some sites, like Chicago, have introduced a "vehicle-equivalence" procedure which applies VEQ factors to truck trips to take better account of their effect.

A separate problem regarding freight impact on secondary congestion is <u>time of day</u>: The superimposing of truck movements on congested peak period commuter networks naturally draws attention as to the added effect on congestion and emissions. However, data collected in Chicago, which is supported by observations from other sources, indicate that truck proportions of highway traffic are generally less during congested peak periods than at other times of the day, for the simple reason that the freight industry sees congestion as a cost also, and attempts to avoid it to the extent possible. Those trips which do occur are generally either logistically unavoidable, or are the results of shippers demanding priority delivery of goods at the beginning and end of the day. Rather than attempt to artificially force freight shipments to occur at other times of the day, industry experts have argued for more of a market based solution which offers incentives to shippers to ship off-peak whenever possible. Another area which has been investigated is constraints imposed by the operating hours of ports and terminals (due to work rules), which forces drayage and other transport patterns into the busiest hours of the day.

5.2.8. Analytic Tools, Capabilities and Needs

MPO representatives at each of the three case study sites indicated that their ability to investigate freight strategies, either for their transportation or emissions effect, was severely limited. Each of the subject MPOs performs its transportation analysis through a four-step transportation model, which is typical for urban transportation planning practice. The transportation model outputs are then entered into either EPA's Mobile 5A model, or in California, the ARB's EMFAC equivalent, to estimate emissions.

The ability of these existing tools to investigate strategies that are of the type that would address freight emissions is questionable. The types of concerns or strategies that MPO representatives would like to address include:

- Traffic engineering and flow improvements to alleviate congestion in situations where trucks are involved.
- Intermodal strategies, ranging from terminal access to improved terminal-terminal or port-terminal connections, and dealing with both the mode shifts and the operational changes.
- System changes that affect drayage operations.
- Effects of various market-based measures that affect technology, fuel use, operating patterns, or mode choice.
- The role of interstate trucking.
- The effects of standards or gradual market shifts in technology regarding emissions rates.

The regions are currently restrained in various ways when trying to address freight problems or identify and evaluate strategies:

- The planning methods are not well developed to treat freight; the detail and ability to perform policy analysis is much less than with passenger modes.
- Many freight strategies involve modifications to current operations in ways that are at a much more operational scale than is accommodated by network transportation planning models.
- The data on freight movements is scarce: the national databases are limited in detail and applicability for a given area's needs, and local data either doesn't exist or is derived from surveys which are either outdated or of inadequate scope to the issues being studied.
- Many freight issues are either avoided or treated in partial ways because of the presumed division between industry and government/planning agencies. If a pattern is linked to industry operating practices, the public agency generally does not presume to understand or question it, nor to get involved (this is changing somewhat under the public/private coordination impetus of ISTEA).
- Emissions estimation poses a separate set of problems: first, the MPO has responsibility for estimating on-road source contributions, which includes truck, while the contributions of rail, marine and air are performed through a completely different process by the state environmental agency. This raises questions about the comparability of the estimates, and also how the effects of shifts between modes would be handled. On top of all this are questions about the reliability and accuracy of the emissions procedures themselves.

The limitations in analytic capabilities for freight have generally meant that freight has not been given proper attention, and that projects or improvements that affect freight are generally the result of the political process rather than one based on benefits and costs. Clearly, practical planning tools are in great demand for those involved in freight transportation or air quality issues.

5.3 Methodology Application

5.3.1. Overview

Having developed a profile that illustrates freight characteristics and freight emissions contributions in what may be regarded as typical metropolitan regions via the three case study sites, this section now takes the step of applying the new Methodology to explore potential action strategies. The goal in this application test is twofold:

1. To illustrate how the Methodology from Chapter 4 would be applied in a real-world context.
2. To provide some initial insight into the process of mating appropriate strategies with freight problems, and a sense of the absolute and relative effectiveness of those strategies in affecting freight activity and emissions.

Upon review of the freight issues at the three sites, and the types of actions being considered by the sites in affecting those issues, a classification hierarchy became evident for grouping the application examples, selecting strategies, and applying the test procedures. Three different levels were suggested:

- **Site Level:** Operations at or access to a given freight facility, such as a port or an intermodal terminal, can give rise to a range of issues related to efficiency and traffic conflicts that have emissions implications. These types of micro-scale traffic and operations problems are typically addressed through traffic engineering or operational improvement strategies.
- **Corridor Level:** Operations at the next higher level of geographic resolution, represented by the connections between two or more terminals, and where the freight volumes may have regional corridor level impacts. While strategies at this level may still involve traffic engineering and operational improvements, the scale of the problem also gives way to infrastructure investment options, or policy actions that would affect choice of mode (particularly the submode), time of day, or choice of route.
- **Regional Level:** Operational issues or conditions that are of a scale that impact the region as a whole in terms of the overall level of freight activity (volume), the type of commodity, the orientation (origin-destination) of the freight flows, or the choice of mode. These issues would arise in the event of a major change in economic conditions (national or regional), new sources of shipper demand or new freight terminal facilities, major changes in infrastructure capacity or investment in particular modes and service. The entire range of actions and strategies would be candidate for addressing freight problems at this level.

Table 5.1 provides a simplistic but useful overview of the types of concerns that are associated with each of the three levels, and the types of strategies that would likely be considered, reflecting the range of potential impacts and dimensions that increase as the level of focus goes from a Site to a Corridor or Regional level.

For this exposition of applying the Methodology to some typical freight problems, the attention has been directed at Philadelphia. Problem examples which are illustrative of each of these three levels of scale have been identified, and representative strategies identified and evaluated for their impact on travel activity and emissions. For the present, the analysis has been restricted to the Philadelphia case study. While interesting problems in each of the three scale categories were identified also for Los Angeles and Chicago, the scale of those areas and plans which have been formed for obtaining suitable data will require more development time, and may be handled as an addendum through a future work activity. For purposes of illustrating the methodology and exploring the problems through three levels of geographic scale, the Philadelphia case study is fairly comprehensive, and as will be seen by the reader, fairly intensive in applications detail, such that the reader will gain a substantial exposure to the method and its findings through the Philadelphia example.

The problem examples selected within the Philadelphia case study that represent the three levels of analysis are summarized below. A more complete description of the setting, the problem and the nature of the analysis for each example is presented in the respective individual sections that follow.

1. Site Level

The **Tioga Freight Terminal** was selected as the site for this analysis of micro-level freight transportation problems and emissions. The Tioga Terminal is a port facility that receives both containerized cargo and seasonal shipments of refrigerated fruits. Significant daily truck movements take these shipments to or from the docks either to final users or to another modal terminal for the next leg of shipment. Emissions concerns relate to scheduling delay at the gate of the terminal, inducing substantial queuing and idling of diesel-powered drayage trucks, as well as inefficiencies in accessing the terminal from the Interstate via local streets, ramps and intersections.

2. Corridor Level

A substantial number of containers entering or leaving Tioga Terminal are transferred to or from regional rail intermodal terminals by **over-the-road drayage truck**. These movements range in distance from 3 to 23 miles from Tioga, and cause the superimposition of truck flows on high-traffic regional highways, generally during the peak daytime travel periods. Whereas rail facilities for a potential direct rail-to-rail link with these intermodal terminals exist at Tioga they are seldom if ever used. Questions to be addressed related to how much emissions are caused from present truck intermodal transfer, both primary and secondary, as against how much of this freight could be moved by rail directly and the emissions savings that would result.

3. *Regional Level*

A major change in overall freight activity for the Philadelphia region is expected to result from introduction of the **Fast Ships** service in 1998. A shift in technology will allow Philadelphia to pilot a new, high-speed trans-Atlantic shipping service that will cut ocean transit time from Europe (Belgium) by half, making Philadelphia more competitive than it has been in competing for European traffic, and opening up a market for a new class of higher-value commodity/client base that would benefit from the faster service. Emissions-related questions relate to the increase in volume that the new service will introduce, its modal shipping requirements to or from the Fast Ships port, and the juxtaposition of this traffic on existing truck and rail activity and service levels.

In the sections that follow, each of the individual problem examples is presented as a mini case study. The discussion describes the problem setting and major issues or concerns, and then describes the process of identifying candidate strategies. The Chapter 4 Methodology is then applied to assess the impacts of the alternative strategies, with the reader walked through the application of the various forms and tables. Guidelines for assessment and implementation are discussed at the conclusion of the case.

Table 5.1. Freight Concerns and Mitigation Strategies by Problem Scale

Geographic Scale	Concerns	Type of Strategy
Site Level	• Local traffic conflicts • Access Impediments • Excessive Queuing & Idling	• Transportation System Management • Low-capital infrastructure • Operational changes • Technology & Fuel emission rates
Corridor Level	• Corridor Level traffic volumes speeds • Truck vs. Rail interterminal transfer • Time of Day	• Facility management • Operational changes • Incentives • Congestion pricing • Technology & Fuels
Regional Level	• Change in freight volume • Change in orientation • Change in primary mode	• Transportation infrastructure • Terminal location & capacity • Access between shippers & terminals • Incentives • Technology & Fuels

5.3.2. Site-Level Example: Tioga Terminal

The Tioga terminal complex is one of eleven major Delaware River port terminals in the Philadelphia - Camden NJ region that handle general cargo. It is located in Northeast Philadelphia, about 100 miles upstream of the mouth of the river at Lewes, Delaware. It is the northernmost of a series of ports strung out along the river, and is just south of the Betsy Ross Bridge, which crosses the river between Philadelphia and New Jersey. The Tioga complex actually consists of two separate terminals, one for containerized cargo, and the other for break-bulk reefer (refrigerated) cargo, roll-on roll-off cargo, cocoa products and fruit. In 1990, the Tioga terminal ranked second among the ports of the Delaware River in total units processed, with 40,000, or 18.3%, of the total. Counts of truck traffic at the terminals indicate considerable seasonal variation in activity. The fruit terminal reaches peak levels of activity in March, while October is the container terminal's busiest month, as shown in the table below. As will be discussed further in subsequent sections, the facility is highly accessible to both the regional highway system and the rail system. The Tioga terminal is owned and managed by the Delaware River Valley Port Authority (DVRPA).

Truck Traffic at Tioga Fruit and Container Terminals 1995

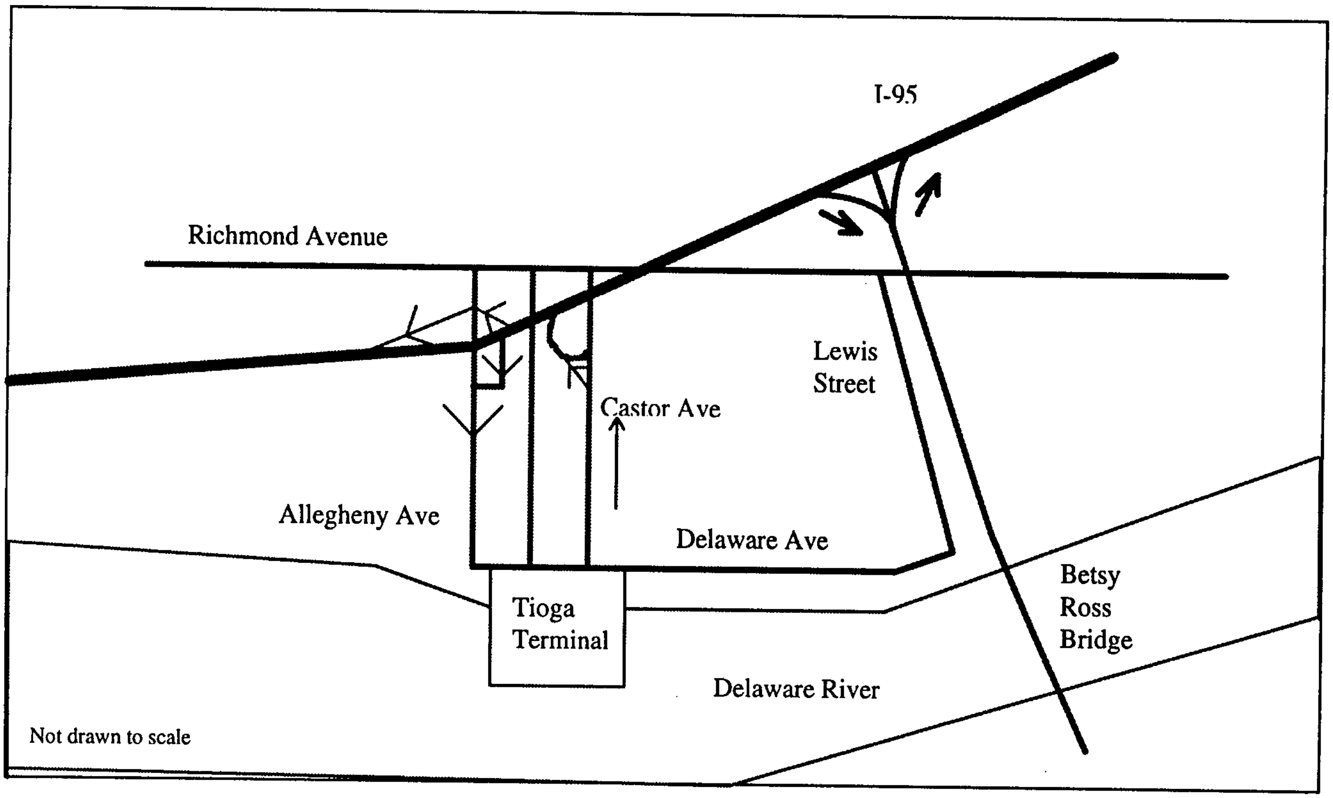
Month	Container Terminal	Fruit Terminal	Total
January	4,215	4,528	8,743
February	3,861	4,740	8,601
March	3,516	5,439	8,955
April	3,204	3,029	6,233
May	3,378	3,981	7,359
June	3,947	2,453	6,400
July	3,492	1,907	5,399
August	5,206	1,333	6,539
September	5,340	1,868	7,208
October	5,828	1,441	7,269
November	4,763	1,176	5,939
December	4,836	3,013	7,849
Totals	**51,586**	**34,908**	**86,484**

Source: Philadelphia Regional Port Authority
* each truck is counted upon entering and leaving the terminal.

5.3.2.1 Site Access

Like many of the other ports located along the Philadelphia side of the Delaware River, the Tioga terminal is well connected to the local and regional highway system as shown in Figure 5.4. Interstate I-95, the major transportation corridor along the east coast, provides north-south access to the region less than a one-half mile from the site. I-95 also provides access to the major east-west connections through the area via I-76 and I-676, some three miles to the south of the site. Two major river crossings relatively close to the

Figure 5.4. Access Pattern for Tioga Terminal



terminal, the Betsy Ross Bridge to the north, and the Benjamin Franklin Bridge to the south, provide access to New Jersey and to the east.

The local street system adjacent to the terminal serves a fairly busy industrial area extending along the riverfront. A grid street pattern distributes traffic from the interstate highway system and areas further to the west and north to Delaware Avenue, where the Tioga terminal is located. Delaware Avenue, the main north-south street serving the terminal, is a wide 4 lane road which has ample room for parking on both sides of the street. Several closely-spaced two and four-lane east-west roads, providing access to the residential and commercial areas to the west, terminate at Delaware Street. Traffic counts and visual observations indicate very little congestion on the streets in the immediate vicinity of the terminal during peak and offpeak hours of travel. There is, however, intermittent congestion at the terminal and other sites in the area caused by trucks turning into and out of the various industrial sites. The percentage of total traffic composed of heavy-duty truck traffic during peak hours is as high as 25% percent on some streets. Roughly speaking, about half of the truck traffic on Delaware Avenue is related to activity at the Tioga terminal; the rest is generated from other sources such as the municipal recycling facility just to the north.

Freeway access to the terminal is provided by a series of ramps located about one-half mile apart. South of Tioga terminal, northbound I-95 traffic exits at a ramp leading to a small two-lane street, which forms a T-intersection with Allegheny Avenue. Southbound I-95 access and egress is provided by a diamond interchange at Allegheny Avenue. North of these ramps and west of the site, access to I-95 northbound is provided on Castor Avenue, where a T-intersection leading to the northbound ramp is located. The separation of northbound I-95 traffic from other freeway traffic is necessitated by the very limited rights-of-way in the area.

Once at the gate, the truck drivers follow established protocol for the pickup or drop-off of cargo. Papers indicating the contents, ownership and destination of the container or trailer must be presented at the gate and verified by the appropriate personnel. If the trailer or container belongs to the terminal operator, it must be inspected for any damage. Once inside the gate, the truck is directed to the proper location and the cargo is loaded on or unloaded from the truck.

5.3.2.2. Problems and Candidate Strategies

Some of the problems associated with operational features of Tioga and with access to the site area discussed below, along with suggestions for possible improvements. These problem assessments are the result of DVRPC staff studies, and observations made by CSI staff during visits to the site. Table 4.4, *Freight Strategy Options to Address Particular Concerns,* was consulted for possible strategies for the problems identified:

I-95 northbound exit ramp

Problem: Queues form on the I-95 northbound exit ramp near Allegheny Avenue. These queues sometimes extend back to the mainline lanes. Traffic turning right at the one-lane exit ramp is prevented from bypassing left-turning vehicles by the narrow parameter width and by extensive curbing.

Possible Strategies: Increase the capacity of the ramp approach. Eliminate the curbed section in the ramp area and extend the paved shoulder to the intersection. This will allow trucks headed for the Tioga Terminal and turning right at the intersection to bypass left-turning traffic.

I-95 southbound exit ramp

Problem: Truck traffic exiting at I-95 southbound at Allegheny Avenue has limited space for trucks making right turns. Trucks often cross the median stripe and encroach upon lanes used by oncoming traffic to effect their turns.

Possible Strategies: Increase the turning radius for right turns from I-95 SB off-ramp to westbound Allegheny Avenue. Erect signs along the Port area clearly indicating the location of the Tioga terminal to reduce the likelihood of wrong turns and delayed arrivals.

I-95 northbound entrance ramp

Problem: The turning radius for the ramp at the I-95 Northbound ramp at Castor Avenue is not adequate for truck approaching from either direction. Adding to the problem is the on-street parking which limits the maneuvering ability of the turning trucks.

Possible Strategies: Increase the turning radius for left turning traffic from westbound Castor Avenue to the northbound ramp. Eliminate or move on-street parking.

Delaware Avenue at Terminal

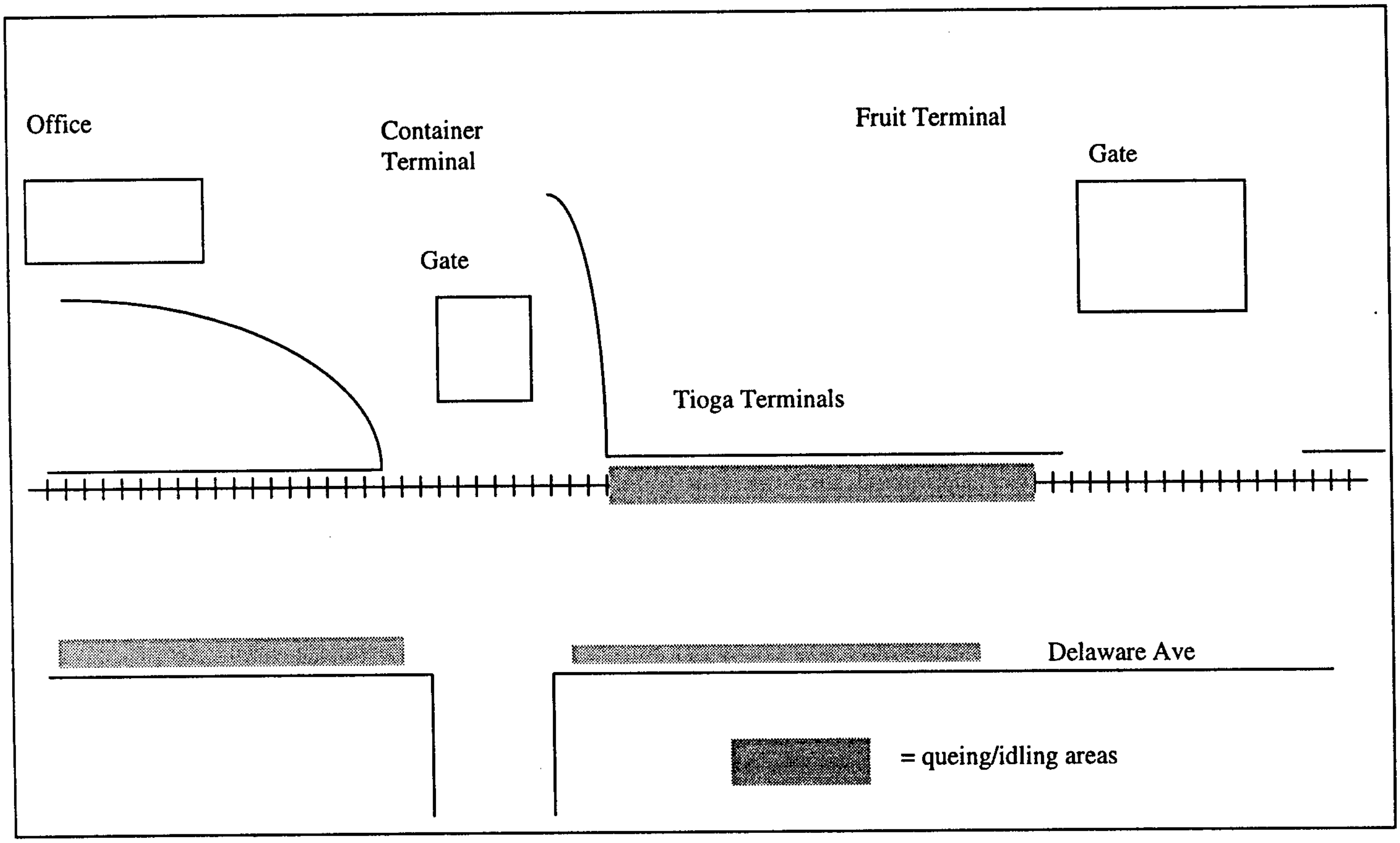
Problem: Delaware Avenue is wide enough to accommodate parked trucks on both sides of the street and is generally traveled at a high rate of speed. As illustrated in Figure 5.5. double-parked trucks and cars near the entrances to the terminal decrease sight distance and increase difficulty of turns into and out of the terminal. The absence of any lane markings contributes to a general lack of order in traffic flow.

Possible Strategies: Clearly stripe the travel lanes. Prohibit parking within the vicinity of the gate entrances. Provide off-street parking and holding area for trucks waiting to be processed.

Entrance and Exit from I-95

Problem: Trucks leaving or entering I-95 en route to the Tioga Terminal may pose conflicts to other travel on I-95, and may generate additional emissions associated with traffic merging patterns. Trucks departing from I-95 must vie for position with other traffic in getting to the exit ramp; backups on this ramp occasionally extend onto the mainline highway. Truck entering onto I-95 must accelerate abruptly to merge with traffic which is already at speed, with the rate of acceleration and the degree of mainline impact based on the length of the ramp, load of the truck, and prevailing traffic levels and speed.

Figure 5.5. Immediate Site Access Conditions at Tioga



Possible Strategies: Could include extensions of ramps or metering systems. If backups occur at exit ramps, modification of signalization or intersection management could be introduced.

Processing Time at Tioga Terminal

Problem: The transfer of cargo from or to the terminal via truck involves significant processing time beyond the actual transfer of the container or trailer. Carriers surveyed in 1990 reported *minimum* delays of two hours to load and unload cargo, with a maximum processing time of *three to four hours* depending on the time of day and the terminal. The long turnaround times were cited as the most important factor in the relatively high cost of dray operations at ports along the Delaware River.[1] Trucks with diesel engines generally remain at idle while waiting to be processed.

Possible Strategies: Installing electronic data retrieval and storage capabilities, using scanners and computer databases, can vastly improve processing times.

5.3.2.3 *Preliminary Assessment of Candidate Strategies.*

The table below lists the strategies that were suggested by the initial review of the operational and access problems at Tioga that had potential emissions implications.

Table 5.2. Preliminary Screening of Candidate Strategies

Location	Strategy	Comments
I-95 NB off-ramp near Allegheny	Remove curb, provide right turn lane.	Will benefit all traffic using ramp, with possible safety benefits. Unknown number of trucks using ramp for Tioga.
I-95 NB on-ramp at Castor	Improve turning radius for left-turning vehicles. Eliminate on-street parking.	Will benefit all traffic using ramp. Unknown number of trucks using ramp from Tioga.
I-95 SB exit ramp at Allegheny	Improve turning radius for trucks headed west. Increase signage.	Will improve safety, but be of marginal benefits for trucks using Tioga terminal. Impact of signage difficult to gauge, since number of wrong-turning trucks unknown.
I-95 entry/exit	Improve efficiency of on/off movements	No current data on extent of problem.
Delaware Ave.	Mark lanes, eliminate on-street parking.	Will benefit all traffic, increasing safety primarily. Impact on Tioga emissions probably minor.
Tioga terminal	Efficiency/scheduling improvements. Electronic processing to speed transfer time.	Will benefit emissions of all traffic into and out of terminal, by reducing idling times and emissions.

1 "Drayage Costs in the Ports of the Delaware River", Prepared for the Delaware Port Authority, Delaware Valley Regional Planning Commission, March, 1991

Each of the various problems and the initial strategies were subjected to a reasonability assessment before proceeding to a formal analysis of their emissions impacts. This step must be done carefully, such that resources are not wasted investigating strategies which offer limited payback, but that strategies which may be unconventional are not dismissed out of hand. In light of the conditions observed at the Tioga site, therefore, and the probable impact of those conditions on emissions, the following conclusions were drawn:

- The layover and accompanying idling of diesel trucks for extended periods at the Terminal draws the greatest attention as an emissions generating imperfection of the existing system operation.
- The traffic engineering and flow improvements to the local street access network would not appear to deliver any significant emissions savings, either for Tioga-bound trucks or other area traffic. In general, traffic flow through the local subarea appears to be fairly efficient: Speeds are not impeded by congestion, nor are there obvious major delays at ramps or intersections. Also, the flow paths from the Interstate to the terminal and back are fairly direct, with no obvious constraints or elongated trips due to geometric constraints or overhead clearances. ***This is a fairly important conclusion, since many transportation planning efforts might well focus on such local-area improvements (e.g., NHS connector programs) though their payoff in emissions terms may be negligible. However, while this is the case in relation to Tioga, efficiency in access to terminals may be an important issue with air quality implications in some places.***
- The entry/exit issues on the I-95 mainline may be important as regards emissions, but the data on the extent and severity of those conditions is not currently available. And since an analysis of improvements would likely require a fairly sophisticated microsimulation flow analysis, and pursuit of this strategy with limited data does not appear realistic at this time.

Based on these observations, the strategy of reducing idling times by increasing scheduling and processing efficiency was chosen as the strategy most likely to produce an impact on emissions caused by trucks using the Tioga facilities.

5.3.2.4. Analysis

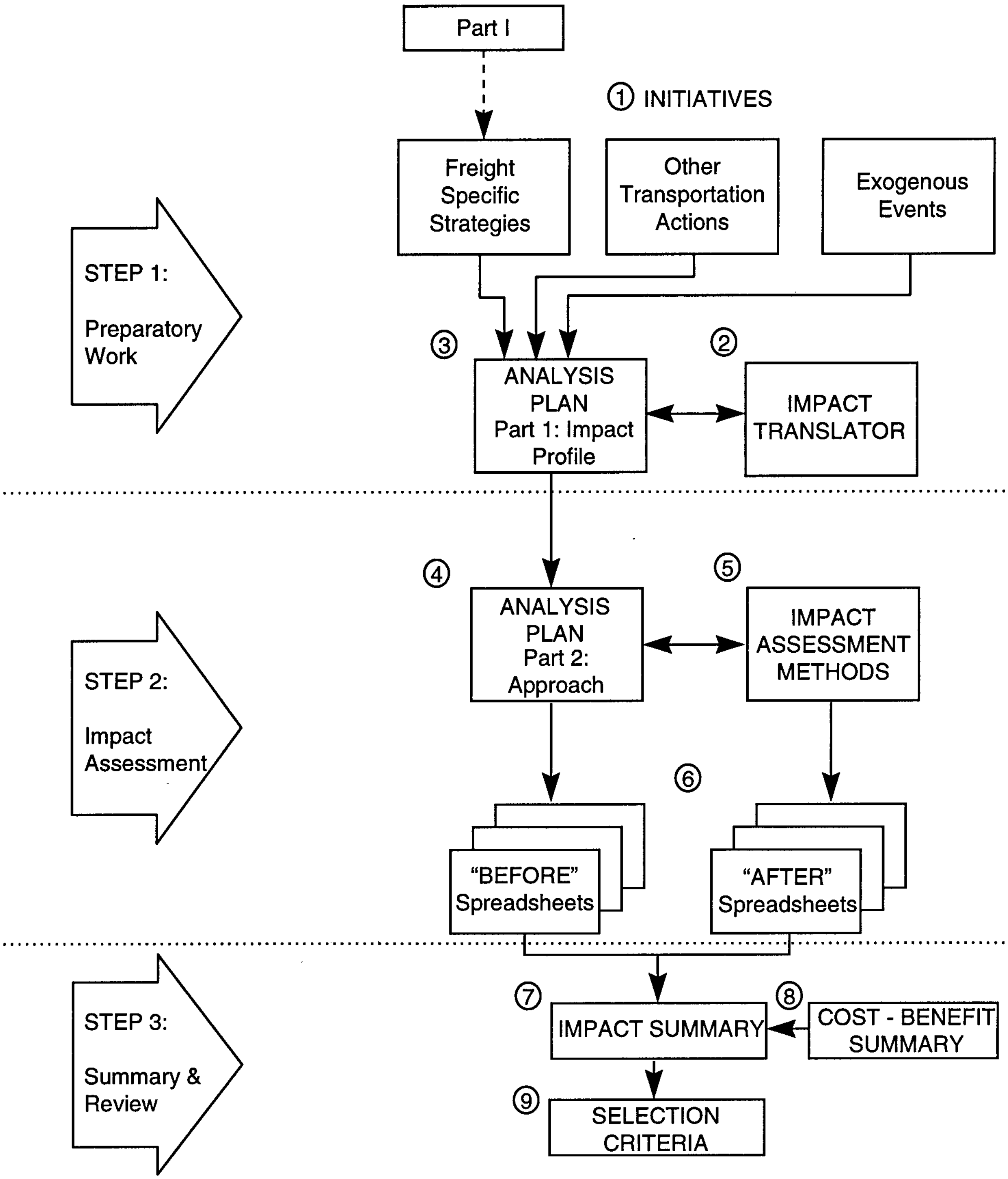
Proceeding into the analysis phase, following the methodology steps as laid out in Figure 4.12. (Exhibit 5.1.), the following are the next steps to be performed:

- Consulting the **Impact Translator** to determine where to focus the analysis.
- Preparing the **Analysis Plan**, which details the proposed approach.
- Completing the emissions estimating **Before** and **After** spreadsheets.

Each step is described in turn below:

Impact Translator Guide As described in Table 4.6, *Delineation of Impact Analyses for Freight Emissions Strategies*, the primary impact of this improvement will be to reduce idling time and emissions. One should also be aware of the secondary impacts listed in he table as well. By increasing efficiency in the processing of cargo to and from trucks, the terminal may become more attractive, or its processing capacity may increase. This

Exhibit 5.1.
Part II Emissions Impact Assessment Procedure
(Figure 4.12.)



being the case, demand for the terminal may increase, which would increase intermodal traffic and terminal volumes. Shippers may be more able to provide their services at times of the day more favorable to them, and thus there may be time of day impacts as well.

Analysis Plan:

The methodology calls for completion of an Analysis Plan, in two parts: an Impact Profile (Part 1) and a proposed Analysis Approach (Part 2). As completed for the idling strategy, (Figure 4.13 from Chapter 4) is shown as Exhibit 5.2. The left half of Exhibit 5.2, which contains the Anticipated Impact, notes those steps in the freight activity hierarchy where this strategy would be expected to have an impact, the level of that impact (P, S, or U) as taken from the Impact Translator, and a description of the nature of that impact which would be expected.

In order to then complete the second half of the Analysis Plan, the proposed Analysis Approach, the **Impact Assessment Guide** (Table 4.13A-E) would be consulted to help select the most effective analysis approach. In this instance, in light of the data and tools available, the decision is made to opt for a Sketch Planning analysis, which is described as Level B in Table 4.13. Selection of this method of analysis requires quantifying the parameters of the strategy or change to various local experts (yard operator, dray operators) and asking them to help indicate what level of change might occur in:

- Minutes of idling.
- Volume of service to/use of Tioga.
- Orientation of trips within region.
- Distribution of trips by time of day/day of week.
- Any other changes in operational procedures that would be felt in volumes or other emissions precursors.

It should be noted that the effects related to idling itself are the only **Primary** impacts anticipated and for which most attention is devoted in the analysis. All the other mentioned impacts would be expected to be secondary. If they prove <u>not</u> to be secondary, based on appraisal of the magnitude of the changes to industry experts, then a more intensified and formal analysis would be warranted.

"Before" Spreadsheets

The first part of the analysis in examining the impact of reduced idling times on emissions entails preparation of a "Before" spreadsheet. Shown as Exhibits 5.3.A and 5.3.B, these spreadsheets furnish the estimates of the truck activity inputs and the emissions impacts, respectively.

In order to carry out the calculations, certain data must be obtained. Where data are lacking, reasonable assumptions must be made. The data and assumptions used to carry out the "Before" analysis is summarized below:

Exhibit 5.2 Analysis Plan (Figure 4.13)

Problem/Setting:	
Test Strategy, Action or Event:	
Summary of Overall Expected Impact:	

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Overall Volume	Regional Origin or Destination			
	Through Trips			
	Intermodal Trips			
Modal Activity Levels	Line-Haul Truck			
	Drayage Truck			
	Line-Haul Rail			
	Rail Yard/ Switching			

Exhibit 5.2 Analysis Plan (Continued)

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Rail Emissions Precursors	Ton-Miles			
	Energy Consumption			
	Emissions Rate			
Truck Emissions Precursors	Time of Day			
	Route/ VMT			
	Speed/Accl & Idling			
	Emissions Rate			
Secondary Emissions				

- **Number of trucks processed at the facility per day:**

The latest count of trucks processed at the Tioga terminals indicates that 86,494 trucks passed through the container and fruit terminal's gates in 1995. The number of trucks to consider is thus:

86,494/250 (working days per year) = 346 truck trips

Since each truck is registered upon entering and leaving the gate:

346/2=173 trucks per day

- **Average idling time per truck:**

An average current idling time assumed is 90 minutes, per full truck cycle through the Terminal, i.e. covering both entry *and* exit delay with processing at the gate[2].

- **Other parameters:**

  - Year of analysis: 1995
  - Type of vehicle: drayage truck
  - Type of fleet distribution: normal/average age and condition

Exhibits 5.3.A and 5.3.B illustrate the procedure for estimating emissions from idling in the base case ("before"). Exhibit 5.3.A estimates that 173 trucks would use the Tioga Terminal on an average day, and experience an average of a 90 minute processing time, during which time they would be idling. This calculates to 15,570 minutes of idling a day, or almost 260 hours. Exhibit 5.3.B estimates the emissions product of this idling, using emissions factors for idling taken from Exhibit 4.7 which reflects heavy-duty diesel engines idling at 700 rpms, and with an allowance made for air conditioning being engaged for one-third of the year. The emissions resulting from this pattern of idling amount to **7.3 kg/day of VOC, 46.6 Kg/day of NOx, and 6.0 Kg/day of CO.**

"After" Spreadsheets:

A set of "After" spreadsheets were completed in a similar manner to estimate the change in emissions that would result from changes in the amount of delay and idling at the Tioga site. Because the exact amount of idling reduction will be a function of the particular type of system or operational change that may be devised, we have chosen to test different levels of change in idling time to cover our uncertainty and demonstrate the range of possible outcomes. Total idling times of 60, 45 and 30 minutes per truck cycle at the Terminal were tested in contrast to the assumed base condition of 90 minutes.

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[2] While this estimate is considerably less than that reported in the DVRPC 1990 drayage study, it is a more conservative number based on observations on site in May 1996. Since loads and delay fluctuate widely by season and time of day, this represents our best estimate of a "typical" idling delay.

Exhibit 5.3.A

Figure 4.14.A. Analysis Spreadsheet
Truck Transportation Inputs

Problem Setting Description: Idling Emissions Base Case Tioga Terminal

Condition [X] **Existing** [ ] **Improved (Describe)** ____

Truck Mode: Drayage **Environment:** 90 min Idle **Sheet:** ___ **of** ___

Number Truck Trips	Mileage by Functional Class & Segment	Empty Backhaul Ratio	Effective Daily VMT	Roadway Volume	Heavy Truck Percent.	Roadway Capacity	Average Speed	Accel/Decel Adjustment Factor
	Freeway 1:							
	Freeway 2:							
	Freeway 3:							
	Maj. Art. 1:							
	Maj. Art 2:							
	Maj. Art. 3:							
	Min. Art 1:							
	Min. Art 2:							
	Min. Art 3							
	Collector 1:							
	Collector 2:							
	Collector 3:							
	Local Road 1:							
	Local Road 2:							
	Local Road 3:							

	Number Trucks Affected	Total Minues of Idling
Terminal Idling	173	*90 = 15,570

Exhibit 5.3.B

Figure 4.14.B. Analysis Spreadsheet
Truck Emissions Estimation

Problem Setting Description: Idling Emissions Tioga Terminal

Condition: [X] **Existing** [ ] **Improved (Describe)** ______

Truck Mode: Drayage **Environment:** 90 min Idle **Sheet:** ___ **of** ___

Daily Mileage by Functional Class & Segment		VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Running Emissions											
Freeway 1:											
Freeway 2:											
Freeway 3:											
Maj. Art. 1:											
Maj. Art 2:											
Maj. Art. 3:											
Min. Art 1:											
Min. Art 2:											
Min. Art 3											
Collector 1:											
Collector 2:											
Collector 3:											
Local Road 1:											
Local Road 2:											
Local Road 3:											
Idling Emissions											
Idling Hours	259.5										
Idling Emissions		28	7.27	179.5	46.58	23	5.97				
Total Emissions			7.27		46.58		5.97				

It is not necessary to show the completed spreadsheets for the these new calculations, since all that is really changing is the total number of hours of idling used as the "multiplier". The emissions "rates" themselves do not change, since the underlying operating conditions are not changing. The table below summarizes the results of these changes in idling:

Scenario	Idling Hours/Day	VOC Kg/day	NOx Kg/day	CO Kg/day
Base: 90 mins	259.5	7.27	46.6	5.97
Strategy: 60 mins.	173.0	4.80	31.10	3.98
Strategy: 45 mins	129.75	3.63	23.30	2.98
Strategy: 30 mins.	86.50	2.42	15.50	1.99
1990 Regional Intercity Truck		4,000	37,700	19,700

As can be seen in the table, the reductions in emissions in each of the pollutant categories measure in Kg/day; as a matter of absolute impact, reducing idling at Tioga from an average of 90 minutes per truck cycle to 30 minutes per truck cycle would save about 5 kg/day of VOCs, 30 Kg/day of NOx and 4 Kg/day of CO. These seem like important absolute savings, but in relative terms, this particular strategy represents only about 0.125% of VOCs due to Intercity Truck, 0.08 % of NOx, and 0.02 % of CO from Intercity Truck.

5.3.3 Corridor Level Example: Terminal to Terminal Intermodal Transfer

Where the first example focused on freight activity and emissions impacts at a site, or micro-system, level, this example focuses on the next level of activity scale and impact: the corridor. Shipment of goods by rail commonly involves an intermediate transfer, either from port to rail terminal, or even from rail terminal to rail terminal. And frequently, this transfer is performed by truck over-the-road. While these exchanges are vital to the function of the different modal systems, the transfer of containerized cargo or trailers between terminals by dray truck can have important impacts on local traffic conditions and emissions. Thus, the focus in this case example is to look at these transfer movements and assess their emissions implications while determining whether there are any strategies which would serve as alternatives.

5.3.3.1 Overview of Intermodal Facilities

The Tioga Terminal is a classic case in point. Container traffic through Tioga moves by truck. Some of this traffic is headed directly to the final user, which may be inside or outside the region. However, a substantial amount also goes to its final destination via one of the three major Railroads which service the area: CSX, Conrail, or Canadian

Pacific. While trackage reaches Tioga, all or virtually all container movements to the respective rail terminals occur via dray truck.

Figure 5.6 offers a profile of the Philadelphia port area, showing the location of the principal port and rail terminals and the location of the regional highway and rail facilities which serve them. There are three primary rail terminals in this corridor which receive cargo from Tioga.:

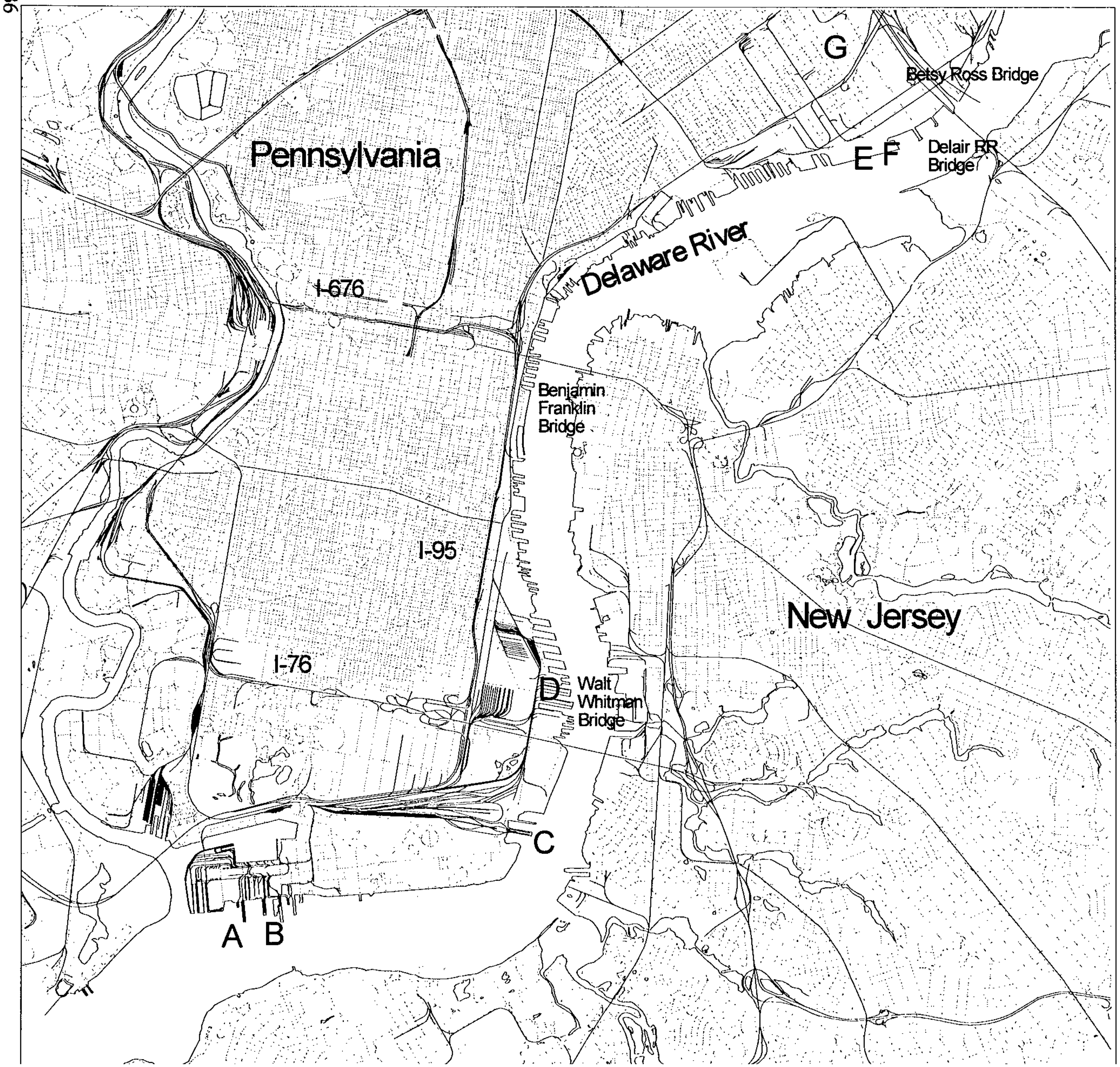
- The **CSX Marine Terminal**, which is owned and operated by CSX Corporation, and is located to the south of the Tioga terminal. This terminal serves the midwestern and southern portions of the United States. Containers that are shipped to nearby marine terminals and are usually drayed by truck from the ports to this facility.
- The **Ameriport Terminal**, which is a publicly-owned facility that was opened in 1992. It is located about 3 miles south of the Tioga Terminal. Ameriport was explicitly designed to expedite the transfer of cargo between rail and port and increase the overall handling capacity of the port area. Ports in the Northeast with which the Philadelphia region competes for business have built similar facilities as well. Centrally located and with the capability to handle cargo relatively swiftly, Ameriport serves CSX, and also CP Rail through shared trackage rights.
- Conrail maintains an intermodal facility in **Morrisville**, approximately 30 miles north of the port area, in Bucks County Morrisville is a junction of several of Conrail's main lines.

5.3.3.2 *Problems and Potential Strategies*

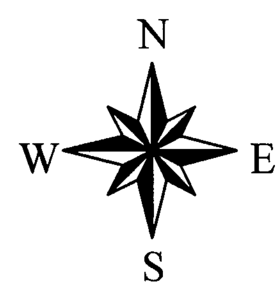
As Figure 5.6 shows, the Tioga Terminal is served by rail lines. From the map, it would appear that virtually all of the port and rail terminals are interconnected by rail, and are capable therefore of exchanging freight by rail. However, there are a number of physical, institutional and economic impediments to this option. First, Conrail has the track rights to the yard at Tioga. This means that any equipment using the yard would have to belong to Conrail, which is an impediment to CSX and CP. Physically, the trackage south from Tioga to Ameriport and CSX Marine is not double-stack capable, and hence is not attractive for container transfer. Practically, Ameriport was created largely for the purpose of making an efficient intermodal transfer to CSX and CP services to south and west, where the facilities were explicitly designed to make up containerized trains efficiently, and where it was assumed that truck drayage would be the major link.

Conrail, meanwhile, has direct rail connections between Tioga and its Morrisville yard. It has two surface tracks which reach the apron of the terminal, and one surface track which reaches the storage sheds. In 1990, Conrail shipped 1,570 containers directly between Tioga and Morrisville via this rail link. In recent years, however, this number has declined considerably, due to factors related to the share of international vs. domestic traffic now handled by Conrail and the role now played by Ameriport in servicing movements to the midwest and Canada.

Figure 5.6 Selected Port Facilities and Terminals in the Philadelphia Region



A	CSX Relocated
B	Fast Ships
C	Ameriport
D	CSX Current
E	Tioga Fruit Terminal
F	Tioga Container Terminal
G	Morrisville (Conrail) (actual location north of position indicated)



The types of problems induced by these system conditions and operating practices are as follows:

- Emissions generated by over-the-road dray truck trips.
- Juxtaposition of truck VMT on the most heavily congested portions of regional highway networks, resulting in poor operating conditions and higher emissions for both freight and non-freight traffic.
- Peak hour concentrations of dray traffic on highways competing for capacity with other uses.

Using the guidance provided by Table 4.4 in the Methodology section, a number of strategies could be considered in the interest of maximizing the efficiency of inter-terminal transfers and reducing related emissions. Those options include:

- Improved or restored direct rail-to-rail ("steel wheel") connections between terminals, and/or improved capacity for handling and building of trains at port sites.
- Improved intermodal connectors from the main highway system to terminals.
- Improvements in highway capacity for the trunk portions of the drayage route between terminals for truck transfer (either capital expansions or improved management).
- Special truck routes to separate dray truck traffic from other traffic.
- Use of road or congestion pricing to both provide improved service to that traffic that wishes to use the highway system in the peak periods, or economic incentive to traffic that is less time sensitive to shift to less congested times of day.
- Improved dray scheduling or planning to reduce number of trips and VMT, perhaps through improved load factors.

5.3.3.3 *Preliminary Strategy Assessment*

The table on the following page lists various problem situations described above, along with strategies which might be directed at them.

In a preliminary appraisal of these problem settings, it was decided to concentrate the analysis of corridor intermodal strategies on the Conrail Tioga to Morrisville connection. There are currently both physical and institutional factors discouraging the shift of inter-terminal movements from truck to rail in the Ameriport and CSX situations. The C-M rail to rail transfer offers the opportunity to test a rail to rail transfer which is a key strategy for this example.

The strategies recommended for testing in this example, therefore, are:

- Shifting of some portion of current truck drayage to rail.
- Shifting trips out of the peak to off-peak periods of the day, resulting in higher service levels and less congestion.

- Impacts of better scheduling/logistics capabilities to reduce empty backhauls for truck.

Preliminary Screening of Candidate Strategies for Corridor Analysis

Location	Strategy(# concern from Table 4.4)	Comments
Ameriport/CSX Terminals	Steel Wheel Connections (5)	Rail connections exist; however track is in disrepair. At-grade crossings will cause conflicts with vehicular traffic. Feasibility of obtaining track rights from Conrail unknown.
Ameriport/CSX Terminals	Truck Re-routing (3)	Connection between Tioga and Ameriport and CSX terminals is fairly direct and efficient.
Morrisville Connection (CSX)	Steel Wheel Connection (5)	Infrastructure in place to divert some dray operations from truck to rail. Economic feasibility unknown. Length of trip may increase feasibility.
Tioga Terminal	Reduction of backhauls	Increased scheduling/dispatching efficiency would reduce truck VMT and emissions. Should be cost-effective.
Morrisville Connection	Shifting of trips out of the peak hour (6).	Will benefit emissions of all traffic into and out of terminal, by reducing idling times and emissions.

5.3.3.4. Analysis

Anticipated Impact:

The first step in analyzing the proposed strategies is to develop an Analysis Plan for each. Exhibits 5.4., 5.5. and 5.6. illustrate the development of an Analysis Plan for each strategy. Using the information found in Tables 4.5.-4.12 *Delineation of Impact Analyses for Freight Emissions Strategies*, a profile of the anticipated impacts for each strategy is developed. First, the magnitude of the expected impact is noted, using the primary, secondary or uncertain/minor (P,S,U) codes offered in the Tables. This is then enhanced by a brief description of the nature of the impact in the space provided in Figure 4.13.

Analysis Approach:

For each strategy, a proposed Analysis Approach is delineated for each level of the hierarchy, tailored to the magnitude of the impact expected in that level. This feature is also illustrated in Exhibits 5.4., 5.5., and 5.6. The selection of analysis method is aided by the guidance given in the Impact Assessment Guide, corresponding to Tables 4.13.A-E.

Before and After Spreadsheets:

The corridor level analysis focuses on improving connections between the Tioga terminal and the Conrail Intermodal facility in Morrisville. In order to carry out the analysis outlined in the Analysis Plan for the three strategies under consideration, Before and After spreadsheets are compiled to reflect the change in activity level and emissions. To complete these spreadsheets, certain basic assumptions must be made and parameters established that affect all strategies.

- **Truck trips between Tioga terminal and Morrisville:**

As mentioned above, current data were not available on truck trips between the two facilities at the time the analysis was carried out. This estimate may be revised should better data become available.

Exhibit 5.4 Analysis Plan (Figure 4.13)

Problem/Setting:	Corridor Level: Congestion/Emissions
Test Strategy, Action or Event:	Shift Truck Drayage to Rail from Tioga Terminal
Summary of Overall Expected Impact:	Shift should produce net reduction in emissions and reduce congestion slightly

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Overall Volume	Regional Origin or Destination	U	No direct impact expected	
	Through Trips	U	No direct impact expected	
	Intermodal Trips	S	May effect cost/time components and change attractiveness of terminal	Level A: ask experts or pick ranges
Modal Activity Levels	Line-Haul Truck	S/U	Small impact on attractiveness of line-haul shipping vs. drayage by rail	Compare service levels & cost; consult experts
	Drayage Truck	P	Reduction in truck volumes	Estimate change in service conditions; ask experts or make judgments about degree of change
	Line-Haul Rail	S	Will increase rail volumes, line haul volumes	Compare service levels & cost; consult experts/make judgment
	Rail Yard/Switching	P	Will increase rail volumes	Compare service levels & cost; consult experts/make judgment

Exhibit 5.4 Analysis Plan (Continued)

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Rail Emissions Precursors	Ton-Miles	P	Increase in ton-miles	Level B: Specify impact on rail/truck service for market; consult experts to estimate changes
	Energy Consumption	P	Energy consumption will increase as containers moved by rail increases	Consult data on changes in energy use based on changes in fuel price, availability or competition
	Emissions Rate	U	No change anticipated	
Truck Emissions Precursors	Time of Day	U	No change anticipated	
	Route/VMT	S	Truck VMT will be reduced	Sketch current typical trips, estimate change in route & VMT based on conditions
	Speed/Accl & Idling	S	Speeds will increase slightly	Use change in V/C ratio to estimate change in speed
	Emissions Rate	U	Rates will change slightly as speed changes	
Secondary Emissions		S	Impact depends on truck volume here, expected to be low	If truck volume significant compute change to background vehicles speed based on change in truck volumes

Exhibit 5.5 Analysis Plan (Figure 4.13)

Problem/Setting:	Corridor Level: Congestion/Emissions
Test Strategy, Action or Event:	Incentives to Move Trucks Out of Peak Period of Travel from Tioga Terminal
Summary of Overall Expected Impact:	Net reduction of emissions, depending on level of congestion

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Overall Volume	Regional Origin or Destination	S	Increased speeds reduce some emissions	Level B: Define strategy effects ask experts to estimate change
	Through Trips			
	Intermodal Trips	S	As above	Level B: Project based on trends that are shifted intermodal
Modal Activity Levels	Line-Haul Truck			
	Drayage Truck			
	Line-Haul Rail			
	Rail Yard/ Switching			

Exhibit 5.5 Analysis Plan (Continued)

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Rail Emissions Precursors	Ton-Miles			
	Energy Consumption			
	Emissions Rate			
Truck Emissions Precursors	Time of Day	P	By definition, trips out of peak	Level B: Estimate time shift due to policy or system change
	Route/VMT	S	Some more direct routes possible in off-peak	Level B: Sketch current typical trips, estimate change in route and VMT based on conditions/response of freight haulers
	Speed/Accl & Idling	S	Increased speeds decrease some emissions	From analysis above, estimate V/C and change in speed for affected facilities Level B
	Emissions Rate	S	Rates change as speed changes	Level B: Relate speed change to change in emissions rate
Secondary Emissions		S	Small impact to many vehicles	If volumes are significant, estimate emissions of other vehicles before and after change Level B

Exhibit 5.6 Analysis Plan (Figure 4.13)

Problem/Setting:	Corridor Level: Congestion/Emissions
Test Strategy, Action or Event:	Better Scheduling/Logistics from/to Tioga Terminal
Summary of Overall Expected Impact:	Proportional reduction in VMT & emissions from reduced backhauls

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Overall Volume	Regional Origin or Destination	S	Level B: Define strategy, service level & cost, ask experts to estimate change, or pick range	Reduction in truck backhauls due to better scheduling
	Through Trips	U		
	Intermodal Trips	S	Project based on trends	Reduced volume as above
Modal Activity Levels	Line-Haul Truck	S	Level A: Ask experts/pick ranges	Small increase in LH truck possible
	Drayage Truck	S	As above	Small increase in truck drayage possible
	Line-Haul Rail	S	As above	Small decrease in LH rail possible
	Rail Yard/ Switching	S	As above	Small decrease in volumes possible

Exhibit 5.6 Analysis Plan (Continued)

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Rail Emissions Precursors	Ton-Miles			
	Energy Consumption			
	Emissions Rate			
Truck Emissions Precursors	Time of Day	P	Will change pickup/drop-off times	Estimate time shift due to policy (ask haulers for opinions) Level B
	Route/VMT	P	Reduction in bachuals will reduce volumes	Sketch current typical trips estimate change in VMT based on conditions Level B
	Speed/Accl & Idling	S	Small increase in speed possible	Use V/C ratio to calculate change in speed
	Emissions Rate	S	Rates change as peed increases	Use change in speed to calculate change in emissions rate
Secondary Emissions		S	Depending on volumes, small change in secondary impacts	If volumes are significant use speeds with and without truck volumes to calculate secondary emissions

Estimate of Daily Truck Trips to Morrisville

Annual Trips (from counts)	% Drayage trips (from 1990 survey)	% of Drayage trips to/from Morrisville (assumed)	Daily Trips from/to Morrisville (w/ 15% backhauls, 250 workdays/year)
86,494	13%	50%	32

- **Highway Attributes:**

For those strategies that shift or alter truck traffic such that improved speeds result in lower emissions, speed estimates for affected links are necessary. Speed estimates require information on roadway capacity, background highway volumes and freeflow speed. Additionally, an estimate of signals per mile is required for calculation of arterial speeds. The parameters used in the analysis are shown in the table below:

Principal Assumptions/Data used in Corridor-Level Analysis

Item	Data	Source
Trip length	24 miles on I-95 6 Miles on arterials	Map
Freeflow Speed/Capacity	Freeway: 55/1850 per lane Arterials: 30 mph/950 per lane	Observation/Assumption Observation/Assumptions
Backhaul ratio	0.15	Assumption
Daily Trips	28	As described above

The spreadsheet analysis utilizes hourly volumes and capacities for "typical" roadway segments to capture speed effects along the entire route. In this analysis one segment is used to represent highway travel and one to represent travel along signalized arterials. The basic analysis assumes that all truck trips occur during the peak period. Traffic counts for the hours during the peak periods have been averaged to simulate peak period conditions. Typical volumes were selected from hourly traffic counts and maps. These assumptions are also contained in the table.

- **Trip Attributes:**

Information on trip lengths is required for the VMT calculations. The distance to Conrail facility is roughly thirty miles. The trip distance has been apportioned to both freeway and arterial segments, as shown in the table, with the assumption that 24 miles occur on Freeway and 6 miles on Arterial.

- **Secondary Impacts:**

For all of the analyses, it is assumed that the secondary impacts of the freight shifts on other traffic and emissions can be ignored.

- **Other General Parameters:**

  Year: 1995

  Type of Fleet: Drayage

  Fleet Age Composition: Default

Strategy Impacts: Diversion of Truck Drayage to Rail

Exhibits 5.7. and 5.8. illustrate development of the spreadsheets necessary to calculate the emissions impacts for the direct rail "steel wheel" connector strategy. Exhibit 5.8. shows the sheets for existing conditions, and Exhibit 5.9. contains three sets of sheets for the various levels of the strategy which have beef tested.

In essence, the analysis shifts a certain percentage of the 30-mile dray trips from truck to rail, requiring one set of spreadsheets for the ***reduction*** in truck activity and another to track the ***increase*** in rail activity. The base case assumes that currently ***all*** cargo from/to Morrisville is by truck. Scenarios are then tested that propose a 25%, 50%, and 75% diversion to rail.

Some key assumptions were needed to perform this analysis:

- The average container weight is 22 tons. This figure is based on judgment and the opinion of experts familiar with freight operations in the area.
- The strategy is feasible and would be implemented with the proper incentives. As mentioned above, actual rail drayage shipments have apparently been on the decline in recent years. It is unclear whether any institutional impediments have contributed to this decline, or whether the decline is purely due to economic reasons. A third possibility is that the rail connection is in disrepair, and would be expensive to rehabilitate. Further research will be necessary to determine the feasibility of the steel wheel connection.
- The ***level*** of incentive is not associated with the traffic shift and the emissions impact. Clearly, this is an unrealistic assumption, but it is made because information is lacking at this time to ascertain the magnitude of incentives necessary to induce changes in mode from truck to rail. One way this could be estimated is through inquiries to industry representatives.
- The increased amount of diesel locomotive engine idling incurred with a shift from truck to rail drayage is negligible and can be ignored. This will overstate the benefits of a mode shift in drayage operations. However, rail drayage in theory, does not encounter the processing delays for individual containers as occurs with truck drayage, since the containers would be received and processed as a single unit, with corresponding gains in efficiency.

Given the assumptions and data described above and procedures outlined in the Proposed Analysis Plan, emissions rates for rail and trucks are determined and multiplied by the level of activity for each mode. For highway emissions which vary with speed (VOC, CO and NOx), the proper speed adjustment factor must be determined, using the equations provided in Chapter 4. The highway volumes used for the calculation are the

Exhibit 5.7.

Figure 4.14.A. Analysis Spreadsheet
Truck Transportation Inputs

Problem Setting Description: Tioga to Conrail Intermodal Terminal

Condition: [X] **Existing** [ ] **Improved (Describe)** ______

Truck Mode: Drayage **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Number Truck Trips	Mileage by Functional Class & Segment	Empty Backhaul Ratio	Effective Daily VMT	Roadway Volume	Heavy Truck Percent.	Roadway Capacity	Average Speed	Accel/Decel Adjustment Factor
32	Freeway 1: 24	.15	768	3,594		5,700	47.02	
	Freeway 2:							
	Freeway 3:							
32	Maj. Art. 1: 6	.15	192	1,636		1,900	13.85	
	Maj. Art 2:							
	Maj. Art. 3:							
	Min. Art 1:							
	Min. Art 2:							
	Min. Art 3							
	Collector 1:							
	Collector 2:							
	Collector 3:							
	Local Road 1:							
	Local Road 2:							
	Local Road 3:							

	Number Trucks Affected	Total Minues of Idling
Terminal Idling	32	32*90 = 2,880

Exhibit 5.7. (continued)

Figure 4.14.B. Analysis Spreadsheet
Truck Emissions Estimation

Problem Setting Description: Tioga to Conrail Intermodal Terminal

Condition: [X] Existing [ ] Improved (Describe) ______

Truck Mode: Drayage   Environment: Regional Corridor   **Sheet:** ___ **of** ___

Daily Mileage by Functional Class & Segment		VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Running Emissions											
Freeway 1:		1.60	1.22	23.37	17.9	8.30	6.37	0.52	0.40	1.28	0.98
Freeway 2:											
Freeway 3:											
Maj. Art. 1:		3.09	0.59	18.56	3.6	14.36	2.76	0.52	0.10	1.28	0.25
Maj. Art 2:											
Maj. Art. 3:											
Min. Art 1:											
Min. Art 2:											
Min. Art 3											
Collector 1:											
Collector 2:											
Collector 3:											
Local Road 1:											
Local Road 2:											
Local Road 3:											
Idling Emissions											
Idling Hours	48										
Idling Emissions		28	1.344	179.5	8.62	23	1.10				
Total Emissions			3.154		30.13		10.234		0.50		1.23

Exhibit 5.8.

Figure 4.14.A. Analysis Spreadsheet
Truck Transportation Inputs

Problem Setting Description: Tioga to Conrail Intermodal Facility (1995)

Condition: ☐ **Existing** ☒ **Improved (Describe)** 25% Diversion to Rail

Truck Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Number Truck Trips	Mileage by Functional Class & Segment	Empty Backhaul Ratio	Effective Daily VMT	Roadway Volume	Heavy Truck Percent.	Roadway Capacity	Average Speed	Accel/Decel Adjustment Factor
25	Freeway 1: 24	.15	600	3,644		5,700	47.13	
	Freeway 2:							
	Freeway 3:							
25	Maj. Art. 1: 6	.15	150	1,686		1,900	13.90	
	Maj. Art 2:							
	Maj. Art. 3:							
	Min. Art 1:							
	Min. Art 2:							
	Min. Art 3							
	Collector 1:							
	Collector 2:							
	Collector 3:							
	Local Road 1:							
	Local Road 2:							
	Local Road 3:							

	Number Trucks Affected	Total Minues of Idling
Terminal Idling	25	25*90 = 2,250

Exhibit 5.8. (continued)

Figure 4.14.B. Analysis Spreadsheet
Truck Emissions Estimation

Problem Setting Description: Tioga to Conrail Intermodal Facility (1995)

Condition: ☐ Existing ☒ Improved (Describe) 25% Diversion to Rail

Truck Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Daily Mileage by Functional Class & Segment		VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Running Emissions											
Freeway 1:		1.60	0.96	23.37	14.02	8.30	4.98	0.52	0.31	1.28	0.77
Freeway 2:											
Freeway 3:											
Maj. Art. 1:		3.09	0.46	18.56	2.78	14.35	2.15	0.52	0.08	1.28	0.19
Maj. Art 2:											
Maj. Art. 3:											
Min. Art 1:											
Min. Art 2:											
Min. Art 3											
Collector 1:											
Collector 2:											
Collector 3:											
Local Road 1:											
Local Road 2:											
Local Road 3:											
Idling Emissions											
Idling Hours	42.5										
Idling Emissions		28	1.19	179.5	7.63	23	0.98				
Total Emissions			2.61		24.43		8.11		0.39		0.96

Exhibit 5.8 (continued)

Figure 4.15.A. Analysis Spreadsheet
Rail Transportation Inputs

Problem Setting Description: Tioga to Conrail Intermodal Facility (1995)

Condition: ☐ Existing ☒ Improved (Describe) 25% Rail Diversion

Rail Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Tons Shipped	Mileage by Type of Shipment By (speed) Segment	Ton Miles	Average Speed	Line Haul Fuel Consumption	Hours of Idling	Idling Fuel Consumption	Total Fuel Consumption
22*7=154	Container: 30	4,620	-	366			12.62
	Container:						
	Container:						
	Doub. Stack:						
	Doub. Stack:						
	Doub. Stack:						
	Piggyback:						
	Piggyback:						
	Piggyback:						
	Bulk:						
	Bulk:						
	Bulk:						
	Box Car:						
	Box Car:						
	Box Car:						

Exhibit 5.8 (continued)

Figure 4.15.B. Analysis Spreedsheet
Rail Emissions Estimation

Problem Setting Description: Tioga to Conrail Intermodal Facility (1995)

Condition: ☐ Existing ☒ Improved (Describe) 25% Rail Diversion

Rail Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Fuel Consumption by Type of Shipment By (speed) Segment	VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Container:	0.023	0.1334	0.49	2.828	0.065	0.370	0.04	0.206	0.01	0.0676
Container:										
Container:										
Doub. Stack:										
Doub. Stack:										
Doub. Stack:										
Piggyback:										
Piggyback:										
Piggyback:										
Bulk:										
Bulk:										
Bulk:										
Box Car:										
Box Car:										
Box Car:										
Total		0.1334		2.828		0.370		0.206		0.0676

Exhibit 5.8. (continued)

Figure 4.14.A. Analysis Spreadsheet
Truck Transportation Inputs

Problem Setting Description: Tioga to Conrail Intermodal Facility (1995)

Condition: ☐ **Existing** ☒ **Improved (Describe)** 50% Diversion to Rail

Truck Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Number Truck Trips	Mileage by Functional Class & Segment	Empty Backhaul Ratio	Effective Daily VMT	Roadway Volume	Heavy Truck Percent.	Roadway Capacity	Average Speed	Accel/Decel Adjustment Factor
18	Freeway 1: 26	.15	432	3,630		5,700	47.23	
	Freeway 2:							
	Freeway 3:							
18	Maj. Art. 1: 6	.15	108	1,672		1,900	13.96	
	Maj. Art 2:							
	Maj. Art. 3:							
	Min. Art 1:							
	Min. Art 2:							
	Min. Art 3							
	Collector 1:							
	Collector 2:							
	Collector 3:							
	Local Road 1:							
	Local Road 2:							
	Local Road 3:							

	Number Trucks Affected	Total Minues of Idling
Terminal Idling	18	18*90 = 1,620

Exhibit 5.8. (continued)

Figure 4.14.B. Analysis Spreadsheet
Truck Emissions Estimation

Problem Setting Description: Tioga Terminal to Conrail Intermodal Facility (1995)

Condition: ☐ Existing ☒ **Improved (Describe)** 50% Diversion to Rail

Truck Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ of ___

Daily Mileage by Functional Class & Segment		VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Running Emissions											
Freeway 1:		1.59	0.69	23.37	10.10	8.30	3.58	0.52	0.22	1.28	0.55
Freeway 2:											
Freeway 3:											
Maj. Art. 1:		3.08	0.33	18.56	2.0	14.34	1.55	0.52	0.06	1.28	0.14
Maj. Art 2:											
Maj. Art. 3:											
Min. Art 1:											
Min. Art 2:											
Min. Art 3											
Collector 1:											
Collector 2:											
Collector 3:											
Local Road 1:											
Local Road 2:											
Local Road 3:											
Idling Emissions											
Idling Hours	27										
Idling Emissions		28	0.756	179.5	4.85	23	0.62				
Total Emissions			1.776		16.95		5.75		0.28		0.69

Exhibit 5.8 (continued)

Figure 4.15.A. Analysis Spreadsheet
Rail Transportation Inputs

Problem Setting Description: Tioga to Conrail Intermodal Facility (1995)

Condition: ☐ Existing ☒ Improved (Describe) 50% Rail Diversion

Rail Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Tons Shipped	Mileage by Type of Shipment By (speed) Segment	Ton Miles	Average Speed	Line Haul Fuel Consumption	Hours of Idling	Idling Fuel Consumption	Total Fuel Consumption
14*22=154	Container: 30	9,240	-	366 (tm/gal)	-	-	25.25
	Container:						
	Container:						
	Doub. Stack:						
	Doub. Stack:						
	Doub. Stack:						
	Piggyback:						
	Piggyback:						
	Piggyback:						
	Bulk:						
	Bulk:						
	Bulk:						
	Box Car:						
	Box Car:						
	Box Car:						

Exhibit 5.8 (continued)

Figure 4.15.B. Analysis Spreadsheet
Rail Emissions Estimation

Problem Setting Description: Tioga to Conrail Intermodal Facility

Condition: ☐ Existing ☒ Improved (Describe) 50% Rail Diversion

Rail Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Fuel Consumption by Type of Shipment By (speed) Segment	VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Container: 25.25 gal	0.0233	0.2668	0.49	5.656	0.065	0.740	0.04	0.412	0.01	0.1351
Container:										
Container:										
Doub. Stack:										
Doub. Stack:										
Doub. Stack:										
Piggyback:										
Piggyback:										
Piggyback:										
Bulk:										
Bulk:										
Bulk:										
Box Car:										
Box Car:										
Box Car:										
Total		0.2668		5.656		0.740		0.412		0.1351

Exhibit 5.8. (continued)

Figure 4.14.A. Analysis Spreadsheet
Truck Transportation Inputs

Problem Setting Description: Tioga to Conrail Intermodal Facility (1995)

Condition: ☐ Existing ☒ **Improved (Describe)** 75% Diversion to Rail

Truck Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Number Truck Trips	Mileage by Functional Class & Segment	Empty Backhaul Ratio	Effective Daily VMT	Roadway Volume	Heavy Truck Percent.	Roadway Capacity	Average Speed	Accel/Decel Adjustment Factor
11	Freeway 1: 26	.15	264	3,616		5,700	47.33	
	Freeway 2:							
	Freeway 3:							
11	Maj. Art. 1: 6	.15	66	1,658		1,900	14.01	
	Maj. Art 2:							
	Maj. Art. 3:							
	Min. Art 1:							
	Min. Art 2:							
	Min. Art 3							
	Collector 1:							
	Collector 2:							
	Collector 3:							
	Local Road 1:							
	Local Road 2:							
	Local Road 3:							

	Number Trucks Affected	Total Minues of Idling
Terminal Idling	11	11*90 = 990

Exhibit 5.8. (continued)

Figure 4.14.B. Analysis Spreadsheet Truck Emissions Estimation

Problem Setting Description: Tioga Terminal to Conrail Intermodal Facility (1995)

Condition: ☐ Existing ☒ **Improved (Describe)** 75% Diversion to Rail

Truck Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ **of** ___

Daily Mileage by Functional Class & Segment		VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Running Emissions											
Freeway 1:		1.59	0.42	23.37	6.17	8.30	2.19	0.52	0.14	1.28	0.34
Freeway 2:											
Freeway 3:											
Maj. Art. 1:		3.08	0.20	18.55	1.22	14.34	0.95	0.52	0.03	1.28	0.08
Maj. Art 2:											
Maj. Art. 3:											
Min. Art 1:											
Min. Art 2:											
Min. Art 3											
Collector 1:											
Collector 2:											
Collector 3:											
Local Road 1:											
Local Road 2:											
Local Road 3:											
Idling Emissions											
Idling Hours	16.5										
Idling Emissions		28	0.46	179.5	2.96	23	0.38				
Total Emissions			1.08		10.35		3.52		0.17		0.42

Exhibit 5.8. (continued)

Figure 4.15.A. Analysis Spreadsheet
Rail Transportation Inputs

Problem Setting Description: Tioga to Conrail Intermodal Facility (1995)

Condition: ☐ Existing ☒ Improved (Describe) 75% Rail Diversion

Rail Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ of ___

Tons Shipped	Mileage by Type of Shipment By (speed) Segment	Ton Miles	Average Speed	Line Haul Fuel Consumption	Hours of Idling	Idling Fuel Consumption	Total Fuel Consumption
21*22=462	Container: 30	13860	-	366	-	-	37.87
	Container:						
	Container:						
	Doub. Stack:						
	Doub. Stack:						
	Doub. Stack:						
	Piggyback:						
	Piggyback:						
	Piggyback:						
	Bulk:						
	Bulk:						
	Bulk:						
	Box Car:						
	Box Car:						
	Box Car:						

Exhibit 5.8. (continued)

Figure 4.15.B. Analysis Spreedsheet
Rail Emissions Estimation

Problem Setting Description: Tioga to Conrail Intermodal Facility

Condition: ☐ Existing ☒ Improved (Describe) 75% Rail Diversion

Rail Mode: Dray **Environment:** Regional Corridor **Sheet:** ___ of ___

Fuel Consumption by Type of Shipment By (speed) Segment	VOC Emis. Rate	VOC Emis-sions	NOx Emis. Rate	NOx Emis-sions	CO Emis. Rate	CO Emis-sions	SO_2 Emis. Rate	SO_2 Emis-sions	PM Emis. Rate	PM Emis-sions
Container:	0.0233	0.4002	0.49	8.48	0.065	1.109	0.04	0.618	0.01	0.2027
Container:										
Container:										
Doub. Stack:										
Doub. Stack:										
Doub. Stack:										
Piggyback:										
Piggyback:										
Piggyback:										
Bulk:										
Bulk:										
Bulk:										
Box Car:										
Box Car:										
Box Car:										
Total		0.4002		8.48		1.109		0.618		0.2027

background highway volumes plus the truck trips assumed in the example, expressed in passenger car equivalents (in this analysis, each truck counts as two cars for the purposes of determining speeds, hence PCE=2). Once the speed is estimated, the appropriate speed factor can be obtained by locating the factor most nearly matching the estimated speed, or adjusted, using interpolation. The emissions rate for type pollutant, year of analysis and type of vehicle, once adjusted by the speed adjustment factor, is multiplied by the VMT for the vehicles under study. The speed adjustment step is not carried out for PM10 or SO_2, since they are not particularly sensitive to speed differences.

For rail emissions, the calculation is only slightly different. Rates vary as a function of fuel consumption rate, and fuel consumption rate varies by the year of the analysis. In contrast to heavy truck emissions, whose rates are expressed in grams per mile, emissions rates for rail are calculated in pounds per gallon. To express rail emissions in units equivalent to those used for trucks, emissions in pounds must be converted to grams (kilograms). Otherwise, the analysis simply involves calculating the amount of fuel used, multiplying by the appropriate emissions rate, and converting the result to equivalent grams (kilograms) of emissions per day.

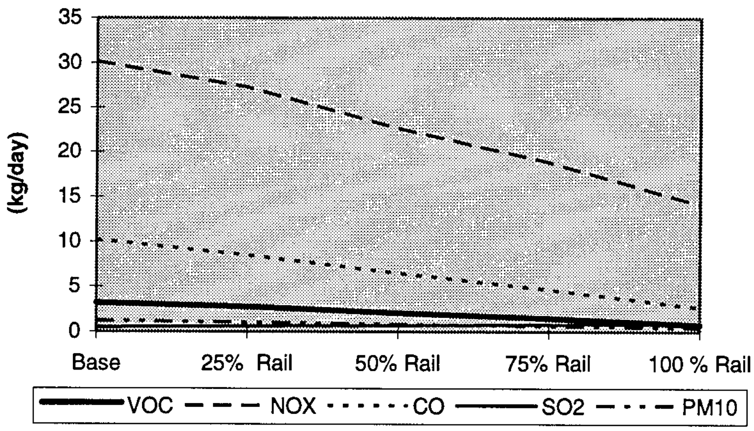
The analysis estimates the emissions effects of truck-to-rail diversions of 25%, 50%, and 75%. "After" spreadsheets have been completed for each of these levels. As suggested by the Impact Assessment guidance, a *range* of changes is an appropriate approach when the impact of the strategy cannot be estimated with confidence.

The net impact of this strategy on emissions is summarized in the table and companion graphic below. The emissions totals are the net result of a reduction in truck emissions countered by an increase in rail emissions. The calculations for each mode and each level of assumed diversion can be seen in the "After" spreadsheets, Exhibit 5.8.

Estimated Daily Emissions "Steel Wheel" Strategy

Scenario	VOC Kg/day	NOx Kg/day	CO Kg/day	SO_2 kg/day	PM10 kg/day
Base: 100% truck	3.15	30.13	10.23	0.50	1.23
Strategy: 25% rail	2.74	27.26	8.48	0.60	1.03
Strategy: 50% rail	2.04	22.61	6.49	0.692	0.83
Strategy: 75% rail.	1.480	18.83	4.629	0.78	0.62
1990 Regional Intercity Truck	4,000	37,700	19,700	NA	NA

Estimated Emissions Drayage at Tioga Terminal



Strategy Impacts: Reduced Empty Backhauls

Empty backhauls increase the number of truck trips and VMT associated with terminal transfer of cargo. Motor carriers must face the choice when dispatching trucks as to whether they should maximize service to shippers or minimize the amount of time spent traveling without cargo. Presumably, advanced scheduling and dispatching systems, perhaps with a capability to track the location of trucks in real time, could effectively reduce empty backhauls. Clearly, an incentive exists to reduce such backhauls in the form of reduced highway trip demand by trucks and resultant emissions..

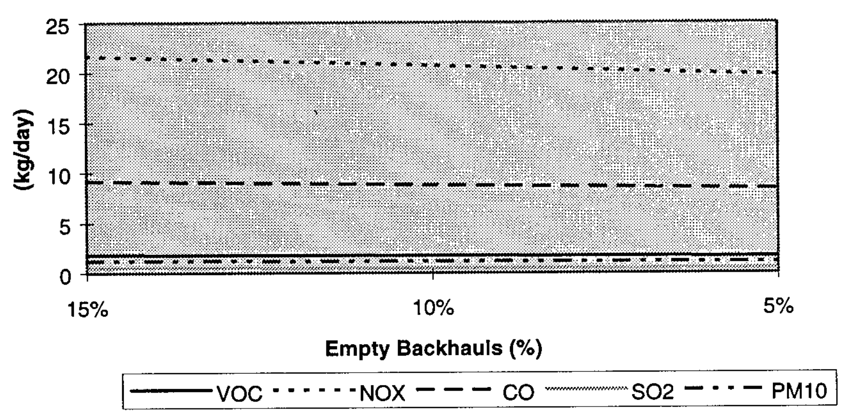
The emissions savings associated with different levels of empty backhaul ratio are summarized in the tables and charts below. A repetition of the methodology's worksheets has not been done, since the pattern of the application should now be evident. For the existing (before) case, an empty backhaul ratio of 15% is assumed. For the "After" case, it is assumed that backhaul ratios of 10% and 5% can be achieved.

As demonstrated by the results summarized in the charts below, the emissions impacts of decreasing empty backhaul ratios are proportional to the VMT reduced. The impacts, in relation to regional Intercity Truck emissions as shown in the table, are not significant. However, as is the case with all of the strategies illustrated in this example, more significant impacts would be realized if the strategy were implemented more comprehensively on a regional level.

Estimated Daily Emissions from Reductions in Empty Backhaul Ratios

Scenario: Empty Backhaul Ratio	VOC Kg/day	NOx Kg/day	CO Kg/day	SO_2 Kg/Day	PM10 Kg/Day
Base: 15%	1.82	21.51	9.13	0.50	1.23
Strategy: 10%	1.75	20.71	8.79	0.48	1.18
Strategy: 5%	1.67	19.77	8.39	0.46	1.13
1990 Regional Intercity Truck	4,000	37,700	19,700	N/A	N/A

Emissions due to Reduced Empty Backhaul Ratios



Strategy Impacts: Congested vs. Uncongested Travel

In most urban areas, travel during peak hours operates under congested conditions. Shippers may respond to delays precipitated by congestion by shifting certain operations out of the peak, especially if the commodity shipped is not highly time-sensitive. Higher speeds decrease travel time and increase efficiency for freight operators. Depending on the pollutant in question, it may be advantageous from an emissions standpoint to encourage use of excess capacity during off-peak hours. A package of incentives, such as congestion pricing or off-peak pricing incentives at the terminal and possible easing of certain restrictions placed on trucks, could be part of a policy designed to shift truck traffic out of the peak hours of the day.

This analysis examines the effect on emissions of shifting those drayage operations performed during the peak hours of travel, as has been assumed in the base case, to off-peak hours. Since the emissions impact will result from the change in speed, it is necessary to estimate peak and off-peak volumes speed relationships. Estimates of off-peak volumes are the additional piece of information needed to perform this analysis. The off-peak estimates were derived by first subtracting the peak volumes from the remainder of the 24-hour traffic counts. The results was divided by 18 (the number of off-peak hours) to arrive at an average hourly off-peak volume. Using the volume/capacity/speed relationships in Chapter 4, Figure 4.17, it is determined that the average peak-periods congested speed is 40.38 mph, while off peak speed would increase to 47.32 mph. In both cases, congested and uncongested, the arterial portion of the trip is the more congested of the two typical roadway segments analyzed. Due to the relatively short length of the arterial segment, its impact on the trip is overshadowed by that of the freeway segment. A more complete analysis would consider more segments to capture more variation in delays and speeds.

Results of this strategy are summarized in the table below:

Estimated Daily Emissions from Reductions in Peak Hour Intermodal Truck Travel

Scenario:	VOC Kg/day	NOx Kg/day	CO Kg/day	SO_2 Kg/day	PM10 Kg/day
Base: Peak Truck Travel (40.38 mph)	1.82	21.51	9.13	0.50	1.23
Strategy: Off-Peak Truck Travel (47.32 mph)	1.76	21.52	8.80	0.50	1.23
1990 Regional Intercity Truck	4,000	37,700	19,700	N/A	N/A

The table indicates that only VOC and CO emissions are sensitive to speed changes, while NOx, PM and SO_2 are unaffected. The reduction in emissions is about 3% both for VOCs and CO.

To further investigate the impact of speeds on freight emissions, a hypothetical case study was devised. Volume-to-capacity (V/C) ratios were set at levels of 0.25, 0.50, 0.75, 1.0 and 1.25. The analysis assumed a thirty mile trip for 100 trucks, 24 miles of which occurs over freeways, with the remainder on surface arterials. Current emissions factors for SO_2 and PM_{10} do not vary with speed. The results, shown in the table below, indicate a relatively minor change in emissions over the range of speeds tested. While reducing speeds can have a noticeable effect where regional travel is the focus of study, strategies that reduce heavy truck VMT, if feasible, are likely to be more effective in reducing emissions. Such strategies include those that reduce circuity, such as, re-routing or reduction of backhauls.

Sensitivity of Truck Emissions to Speed Levels

Freeway/ Arterial Speed	V/C	VOC	NOx	CO	SO_2	PM-10
54.8/22.4	0.25	5.527	66.980	27.628	1.554	3.834
51.8/19.8	0.5	5.541	66.914	27.679	1.554	3.834
41.2/17.8	0.75	5.554	66.846	27.730	1.554	3.834
25.7/15.5	1	5.568	66.783	27.791	1.554	3.834
15.9/7.7	1.25	5.585	66.729	27.871	1.554	3.834

5.3.4 Regional Example: FastShip/Atlantic

The example presented in this section demonstrates application of the methodology to freight issues with a regional scale of impact. Such an impact might occur in the wake of a major change in policy, a shift in economic trends, addition of a new industry, a major transportation investment, or the movement or introduction of a new terminal or service. A recent proposal for the Philadelphia area brings together several of these elements, and offers an excellent test of the study's methodology.

5.3.4.1. The FastShip/Atlantic Service Proposal

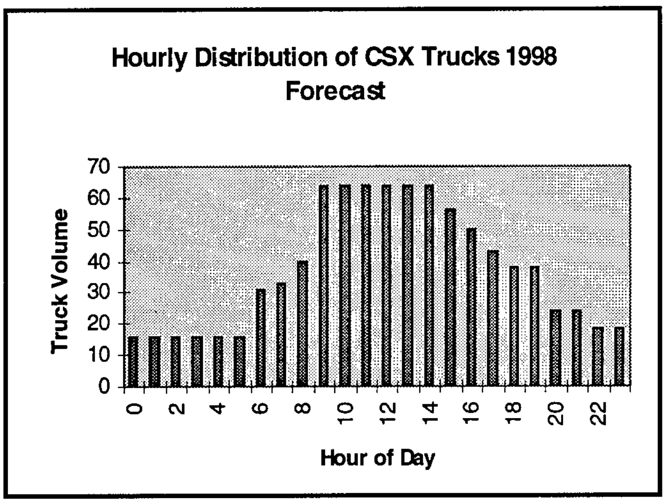
The Delaware River Port Authority has proposed to build a port and terminal to provide exclusive service for a carrier that has introduced a state-of-the-art containerized freight service known as FastShip. FastShip Atlantic's container vessel is designed to be the world's fastest cargo carrier. FastShip claims its vessel will reduce Trans-Atlantic crossing time from the current average of seven days to five days, and will operate at a speed of forty-five knots, twice the speed of other container ships. Service is expected to operate exclusively between Zeebrugge, Belgium and Philadelphia. Air-cushioned cargo carriers will transfer cargo directly from the ship's container bay to waiting trains and trucks, thus expediting intermodal transfers. As illustrated in Figure 5.6. the terminal will be located in southern Philadelphia at the site of a former Navy Yard, adjacent to both I-95 and I-76, offering highway access north-south and east-west respectively.

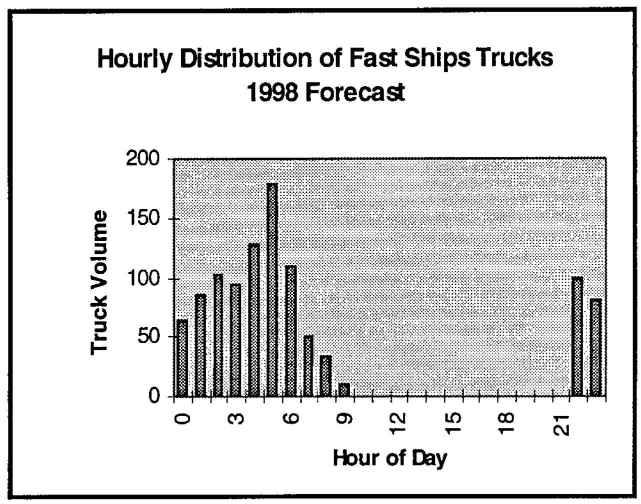
At the same time, the CSX Corporation has proposed a new intermodal facility to replace its smaller, existing one about two miles away. The proposed terminal would be situated directly south of the FastShip site, and would consist of six 4,300-foot loading tracks, truck roads and adjacent storage areas. If built, CSX would transfer its current operations from the older site and Ameriport to this new facility.

5.3.4.2. Operational Characteristics and Anticipated Problems

Although the FastShip and CSX proposals would increase the volume of rail intermodal traffic through Philadelphia, these new facilities can also be expected to generate significant truck traffic, particularly during the early stages of their operations, according to a recent DVRPC study of the two proposals[3]. The Fast Ships terminal is expected to generate 638 container movements three days a week by 1998, of which 75% is estimated to be carried by truck. The CSX terminal is expected to handle 590 container movements per day, five days per week, of which 50% are anticipated to be carried by truck. The two terminals would operate with not only different day-of-week patterns, but different time-of-day staging of truck movements. The remaining container movements would be directly from/to the terminals by rail.

The two charts below show the anticipated hourly distribution of truck trips over a 24-hour period. The CSX trucks reach their peak during the midday hours, although there are truck arrivals and departures anticipated for the peak hours of travel as well. The Fast Ships truck forecasts indicate that arrivals and departures will occur outside of the peak, in the early hours of the morning. Whether by design or not, truck impacts, according to these estimates, are mitigated by their distribution over the course of the day.





All truck trips are estimated to leave and enter the region via Interstate highway. On a daily basis, 64% of the trips would use I-95 for north/south movements, with the remainder traveling east or west via I-76. Although the terminals will be located quite near to the regional interstate system, some travel over local roads will be necessary. According to the mentioned DVRPC study, this local street system has ample capacity and should not be seriously affected by the anticipated truck traffic generated by the two terminals.

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[3] *Intermodal Facilities Land Side Access Study*; DVRPC, 1995.

5.3.4.3. Identification of Strategy Options

As done in the previous two example analyses, Table 4.4 was consulted to identify strategies with the potential to mitigate the impacts of the new FastShips/CSX operations. The initial strategies developed from this review are listed below. As can be seen, these strategies would focus on mitigating the emissions impact associated with the truck trips to and from the new terminals.

Problem: New truck trips from terminals imposed on local street access system to Interstates.

Strategy: Designation of optimal access routes and elimination of barriers in local access to the terminals.

Problem: Imposition of new truck trips onto Interstate highways through region, potentially affecting level of service during high demand periods for both trucks and other traffic.

Strategy: Consider incentives that would shift all or portion of peak period truck trips out of the peak to a time period with lower demand levels.

Problem: Net new trips by truck generated by terminal traffic, producing additional truck VMT and emissions.

Strategy 1: Incentives to maximize proportion of containers moved to or from terminals by rail.

Strategy 2: Minimize the *emissions rates* from the trucks themselves, through use of alternative fuels or actions/incentives to accelerate turnover of the fleet to a higher proportion of vehicles with lower emissions rates.

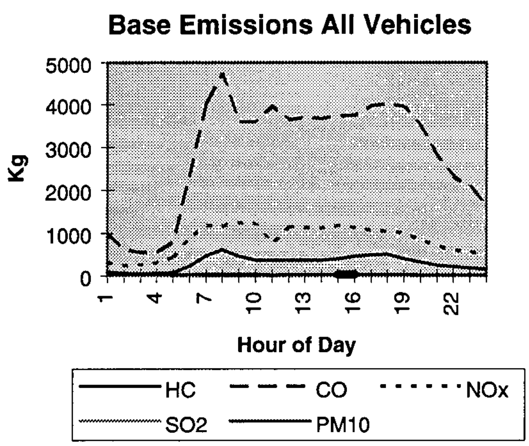
Upon preliminary review of the applicability and potential impact of these strategies suggested by the Table 4.4 guide, those strategies brought forward for analysis were the following:

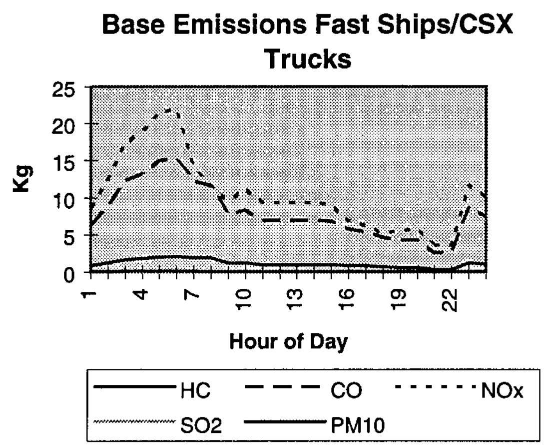
- Actions to increase the percentage of containers shipped out of or to the terminals by rail.
- Actions to improve the emissions rates of the trucks that provide service.

It did not appear that the impacts of the new truck traffic levels on the local street access network would be a major concern for emissions. The distance between the terminals and the Interstates is fairly short, and there is clearly ample reserve roadway capacity in this area due to its transitioning nature.

We also elected to not run a formal test of strategies which would shift those truck trips out of the peak period into the off peak. As depicted in the preceding figures which show planned movements by time of day, the great majority of the FastShips truck moves would occur during the "overnight" hours, and hence not raise an issue as to congestion impacts. A substantial percentage of the CSX truck moves <u>would</u> occur during prime travel hours (6 am to 6 pm). However, the total truck volumes that would be generated would only be about 60 vehicle trips per hour. Even converting these large, combination-truck trips to standard Vehicle Equivalents using a equivalency multiplier of 3, this would still be only about 120 vehicles per hour *split among 4 major directions/highways*, and both current and projected volumes for these facilities do not suggest congested operating conditions or constrained speeds. Therefore, the only likely advantage to shifting the new truck trips to the off-peak hours would be to shift the timing of the production of their emissions to a different time period than the peak. Since air quality models "roll up" emissions by hour and location, this might affect the estimated concentrations of different pollutants, but the direction of this change is not intuitive and would require further study.

The figures below illustrate the divergent patterns of emissions generated by the two different vehicle populations – regular traffic and new FastShips/CSX truck traffic - by time of day, based on some preliminary analysis.





5.3.4.4 *Analysis*

Analysis Plan

Following the procedure demonstrated in the site-level and corridor examples, an Analysis Plan was prepared to lay out the Anticipated Impact and Proposed Analysis Approach for each strategy. A completed Analysis Plan for the Technology/Emissions Rate strategies is shown as Exhibit 5.9. Since the previous corridor example looked at a truck-to-rail diversion scenario, a similar plan is not repeated here.

Exhibit 5.9Analysis Plan (Figure 4.13)

Problem/Setting:	Fast Ships/CSX
Test Strategy, Action or Event:	1) Natural Gas Fleet 2) New Fleet
Summary of Overall Expected Impact:	Reduced Emissions, Higher Efficiency

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Overall Volume	Regional Origin or Destination	S	If costs to shipper change overall demand may change	Level B: Ask experts to estimate change - Landside access study
	Through Trips	S	As above	Level B: Ask experts to estimate change - Landside access study
	Intermodal Trips	S	As above	Level B: Project based on trends - Landside access study
Modal Activity Levels	Line-Haul Truck	S	Change of modal activity depends on relative attractiveness of truck vs. rail	Level B: Make judgments about amount of diversion
	Drayage Truck	S	As above	Level B: Make judgments about degree of change
	Line-Haul Rail			
	Rail Yard/ Switching			

Exhibit 5.9 Analysis Plan (Continued)

Primary Level	Secondary Level	Impact Code	Anticipated Impact	Proposed Analysis
Rail Emissions Precursors	Ton-Miles			
	Energy Consumption			
	Emissions Rate			
Truck Emissions Precursors	Time of Day			
	Route/VMT	S	Level B: Estimate change based on changed V/C ratio	Technological improvements will change speed/accel characteristics
	Speed/Accl & Idling	P	Level B: Use new emissions rtes supplied for new technology	Will decrease
	Emissions Rate			
Secondary Emissions				

To summarize the principal features of the Analysis Plan for the Emissions Rate Strategies, the primary impact would clearly be in relation to the Emissions Rates themselves. Secondary impacts on freight activity levels might result if these strategies have cost or service implications to carriers or shippers. The proposed analysis focuses primarily on the linkage of new emissions rates to the same truck activity (VMT) levels.

Impact Analysis

The analysis of these candidate strategies benefits from a recently-conducted study focused on freight demand at the two sites[4]. This study provides estimates of overall volumes and levels of modal activity at the regional level, as specified in the Impact Analysis Plan. In this respect, the regional analysis starts from a more fundamentally sound basis than the site-level and corridor-level analyses.

The following information is required to carry out the impact analysis:

- Truck volumes.
- Directional distribution of truck traffic.
- Trip distance.

The background data used to produce the estimates are displayed in the table below, and have been provided by the study cited above. The analysis was refined from those presented in the site and corridor-level analyses, to reflect the variation in background traffic volumes across roadway segments and hours of the day. Sixteen separate highway segments were considered in the analysis and hourly traffic volume data was assembled by time of the day. The truck traffic volumes cited in the study were distributed to freeway and arterial roadway segments by direction, and added to background traffic obtained from hourly traffic counts.

Traffic/Service Characteristics of FastShips Atlantic Terminal
Background Data for Impact Estimates

	Fast Ships	CSX	Daily Combined
Anticipated start of service	1998	1998	
Containers per day	850 (3 days/week)	1180 (5 days/week)	
Weekly truck trips	638 (75% mode share)	590 (50% mode share)	
Weekly Rail Trips	212 (25%)	590 (50%)	
Truck Trip Distribution			
Trips to/from north	246	290	438
Trips to/from south	119	120	191
Trips to/from west	306	148	21
Trips to/from east	9	16	332
Trips in peak periods	-	-	21%[5]

[4] "Intermodal Facilities Landside Access", DVRPC, 1995.

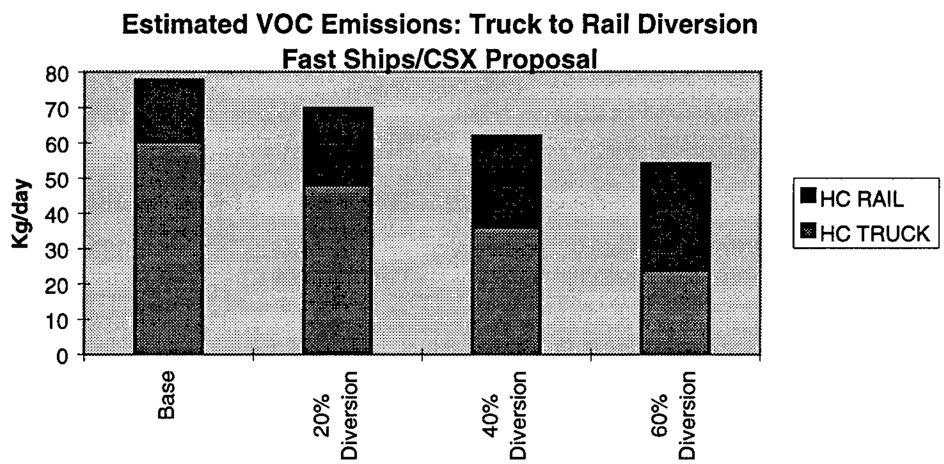
[5] Peak Period is defined as the hours between 6-9 am and 4-7 pm.

Strategy Effects: Diversion of Linehaul Trucks to Rail.

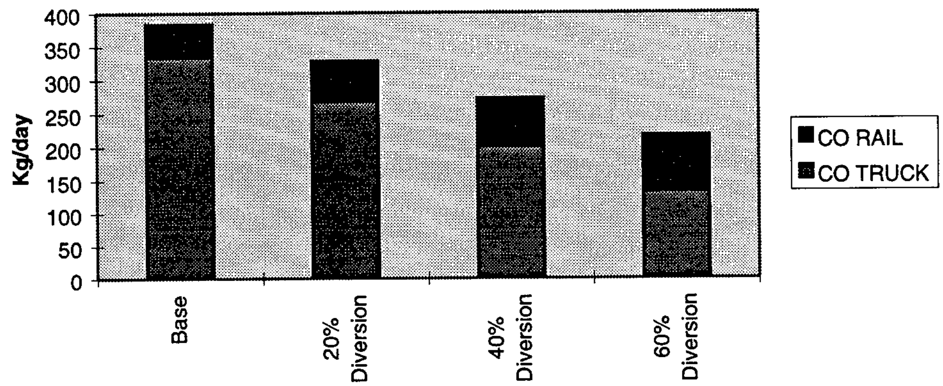
This analysis is similar to the one carried out for the corridor-level example. A set of Before and After spreadsheets was developed to estimate the emissions effects of diverting truck trips to rail at levels of 20, 40 and 60 percent. The assumptions underlying the analysis include:

- Each container is moved to/from a location *outside* the region.
- Average VMT per trip within the region is 20 miles.
- The age distribution of the truck fleet is average (default).
- The type of truck is *linehaul,* rather than dray.
- The average container weighs *44,000* pounds.

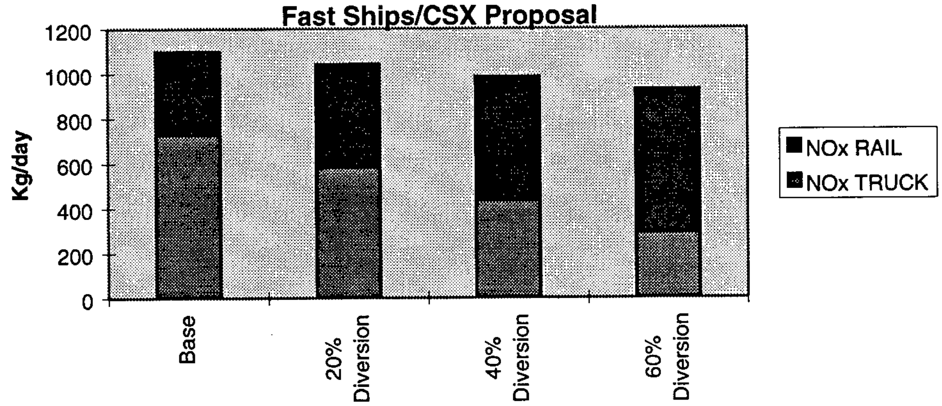
The charts below show the relative contributions of rail and truck emissions as the percentage of trucks carrying freight declines. As the proportion of shipments by rail increases, the contribution of rail emissions increases as well. With lower emissions rates per unit shipped by rail however, overall emissions are lower than the base case, with a net reduction in emissions as higher percentages are shifted from truck to rail.



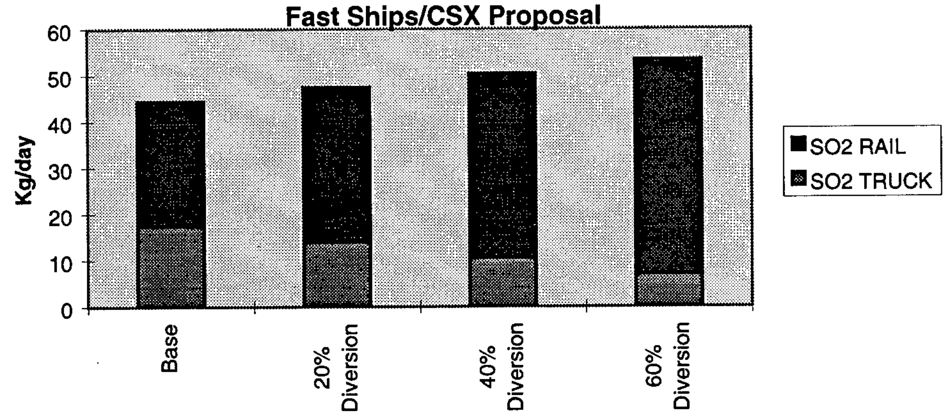
Esimtated CO Emissions: Truck to Rail Diversion
Fast Ships/CSX Proposal

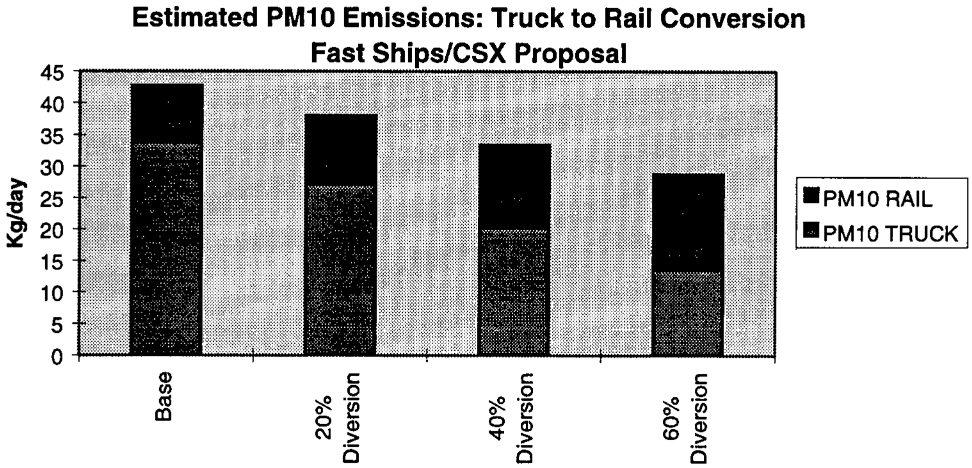


Estimated NOx Emissions Truck to Rail Conversion
Fast Ships/CSX Proposal



Estimated SO2 Emissions: Truck to Rail Conversion
Fast Ships/CSX Proposal





Summary of Emissions Analysis for Truck to Rail Strategy

Scenario	VOC Kg/day truck rail total	NOx Kg/day truck rail total	CO Kg/day truck rail total	SO_2 Kg/day truck rail total	PM10 Kg/day truck rail total
Base:	60 18 78	727 371 1098	335 48 383	17 27 44	34 9 43
Strategy: 20% truck to rail	48 22 70	582 459 1041	268 60 328	14 33 47	27 11 38
Strategy: 40% truck to rail	36 26 62	437 547 984	200 72 272	10 40 50	20 13 33
Strategy: 60% truck to rail.	24 30 54	291 636 927	134 83 217	7 46 53	14 15 29
1990 Regional Intercity Truck	4,000	37,700	19,700	NA	NA

Strategy Effects: Technological Improvements in Truck Emissions Rates

This strategy assumed that base rates of truck vs. rail carriage would not change (per the diversion scenario above), but that all technological efforts would be made to reduce the emissions production rates of the trucks themselves through a newer fleet of vehicles and through conversion to natural gas from diesel.

Newer trucks have improved emissions characteristics, and one policy option might be to use incentives to increase the rate of turnover in the fleet to one that is "newer" in its distribution than the current fleet. Exhibit 4.1 in Chapter 4 lists emissions rates (factors) for each pollutant for a truck fleet that is presumed to be "typical" in its age distribution by national standards for a given analysis (horizon) year. The emissions rates associated with this "default" age distribution is the one most commonly used in the analysis. Exhibits 4.2 and 4.3, on the other hand, portray different corporate average emissions rates which reflect a fleet composition that is, respectively, younger and older than the default "normal" fleet. Using these numbers for the FastShips/CSX situation results in the revised emissions shown in the table below. VOC emissions drop by 4 Kg/day, or 5.1%; CO emissions drop by 25 Kg/day, or 6.5%; **PM-10 emissions drop by 18 Kg/day, or 42%; and NOx emissions drop by 210 Kg/day, or 19.1%.** SO_2 emissions are not affected by this shift.

The second strategy in this group tests the effect of converting this group of trucks from diesel to natural gas. Clearly, a 100% shift to natural gas for line-haul trucks in particular is fairly unrealistic in this time period, so hypothetical rates of conversion of 25% and 50% were examined, simply to assess the sensitivity. Using emissions factors taken from Exhibit 4.6, the emissions numbers shown in the summary table below, suggest that conversion to natural gas would pay dividends across all pollutants at the same general rate of reduction as the shift to a newer fleet above, but with a major advantage in the reduction of SO_2, which is not affected by the new fleet scenario.

Summary of Emissions Analysis for Natural Gas and New Fleet Strategies

Scenario	VOC Kg/day	NOx Kg/day	CO Kg/day	SO_2 Kg/day	PM10 Kg/day
Base:	78	1098	383	44	43
Strategy: Newer Fleet	74	888	358	44	25
Strategy: Natural Gas Conversion					
25%	70	980	347	40	35
50%	61	861	311	35	27
1990 Regional Intercity Truck	4,000	37,700	19,700	NA	NA

5.3.5 Synthesis and Review of Findings

5.3.5.1. Overview

The previous three sections featured analysis of a range of strategies designed to reduce emissions resulting from freight operations. The goal was to demonstrate how the Methodology developed and presented in Chapter 4 could be used to address a range of typical problem concerns, and identify and estimate the effectiveness of potential strategies. Problem settings were purposely drawn up to address site-level, corridor-level and regional-level scales and impacts. To some extent, the types of strategies tested differ in relevance and applicability in relation to the scale of the problem. However, there is also a pattern of recurrence in the issues being addressed that makes many of the strategies applicable at each of the levels, if only in a somewhat different packaging. For example:

- Improvements in emissions rates of trucks or locomotives through fuels or technology measures, where feasible, would add emissions savings across any scenario.
- Efforts to shift from truck to rail the transfer of containerized cargo between terminals would probably induce transportation and emissions benefits in most environments.
- Redistribution of freight traffic by time of day from peak period congested conditions to off-peak would result in improved operating conditions and reduced emissions for both freight and regular traffic. This temporal management of facility capacity is applicable in all settings.
- Physical constraints or poor connectivity limit free movement of freight on highways or railroad, and contribute to emissions through elongated trip tours, delays, and sub-optimal operating conditions. These issues are relevant at any scale.

Because of these similarities in strategy objective, even though they have been applied in different problem settings in this set of case study examples, we conduct a review and assessment of the strategies in this section as a group, as though we were conducting an MPO analysis of alternative emission control strategies, and looking for the most effective and implementable. The strategies that were examined are as follows:

1. Reduction of truck idling delays due to scheduling and processing patterns at an intermodal yard. Scenarios tested: idling dwell times reduced to 60 minutes, 45 minutes and 30 minutes per truck visit to terminal, compared to a base dwell time of 90 minutes.
2. Diversion of inter-terminal container movements from truck to rail, for a trip movement of 30 miles (one-way). Scenarios tested: diversion rates of 25%, 50% and 75% against a background rate of 0 %.
3. Reduction in the rate of empty backhauls for truck for the 30-mile terminal transfer in (2). Scenarios tested: reduce empty backhaul ratio to 10% and 5% against base rate of 15%.
4. Shift of truck trips for trip in (2) out of the peak period to the off-peak, resulting in unconstrained travel speeds.
5. Diversion of containerized shipments through a new terminal from truck to rail. Scenarios tested: diversion from truck to rail at rates of 20%, 40% and 60% against a baseline where 50% of all trips from one terminal were shipped by truck, and 75% at the other terminal.
6. Incentives that reduce average age of truck fleet servicing facility setting in (5). Scenario tested: average "new" fleet tested against average "normal" fleet (age distribution).

7. Conversion of truck in setting (5) from diesel to natural gas. Scenarios tested: 25% and 50% conversion rates against a background rate of zero units operating on natural gas.

Following the methodology steps as shown in the procedure diagram in Exhibit 5.1, the steps in this part of the methodology are:

Step 7: List and summarize strategy impacts

Step 8: Calculate costs and benefits

Step 9: Establish implementation priority

Each of these steps is described below.

5.3.5.2 *Summarize Impacts*

The first step in assessing the relative effectiveness and desirability of the various strategies is to list them and their key impact effects in one place. Figure 4.16 in Chapter 4 is designed for this purpose. Exhibit 5.10 shows how this would be done for the strategies tested in this case study.

Shown in the Exhibit, the strategies are listed by number and description in the leftmost column. Note that a separate line entry is used for each strategy's variation in level of application, e.g., 20%, 40%, 60% diversion rate. The table then provides for separate accounting of activity changes and emissions changes for each mode affected by the strategy: rail, truck and "other" traffic. Whether these modal breakdowns are shown depends on the user and the needs of the analysis. The example table shows only the total change in emissions, not the modal differences. Provision exists to note the change in activity level, which for rail would be in ton-miles, while for truck and other highway, VMT is the primary measure. The central columns indicate the reduction in the respective pollutant. This is the reduction obtained when comparing the strategy results to the baseline case.

Finally, the last set of columns portrays the "cost effectiveness" of the strategy. The user will estimate the Net Cost associated with the given strategy, following the guidance and procedure in Step 8, and compare that cost with the reductions in emissions to obtain a measure of "cost per ton" or similar set of units that allow the strategies to be compared on comparable (i.e., unit) terms.

5.3.5.3. *Calculating Benefits and Costs*

The Net Cost information that goes into Figure 4.17, the Impact Summary, are determined in this step. This step amounts to quantifying the costs and benefits associated with the individual strategies, using the guidance provided at the end of Chapter 4, and through use of Figure 4.18, shown as Exhibit 5.11.

The Net Cost called for in Figure 4.17 is the difference between the calculated benefits less the costs for the strategy. In simplest terms, the Net Cost to implement the strategy would be the difference between the revenues, if any, which would be derived from

Exhibit 5.10.

Figure 4.16. Impact Summary Table

Trial		▲ Activity		▲ Emissions (kg/day)					Net Cost Per Ton				
No. Strategy	**Mode**	**Ton-Miles**	**VMT**	**VOC**	**CO**	**NOx**	**PM**	**SO_2**	**VOC**	**CO**	**NOx**	**PM**	**SO_2**
1) Site Level: Reduce idling emissions trough scheduling/computerized processing (60 min)	Rail ***Truck*** Other TOT.			2.47	1.99	15.5							
2) Reduced idling (45 min)	Rail ***Truck*** Other TOT.			3.64	2.99	23.3							
3) Reduced idling (30 min)	Rail ***Truck*** Other TOT.			4.85	3.98	31.1							
4) Corridor-level truck to rail steel wheels connection (25%)	***Rail*** ***Truck*** Other TOT.			0.41	1.75	2.87	0.2	(0.1)					
5) Corridor-level truck to rail steel wheel connection (50%)	***Rail*** ***Truck*** Other TOT.			1.11	3.74	7.52	0.4	(0.19)					

Exhibit 5.10. (continued)

Figure 4.16. Impact Summary Table

Trial		▲ Activity		▲ Emissions (kg/day)					Net Cost Per Ton				
No. Strategy	Mode	Ton-Miles	VMT	VOC	CO	NOx	PM	SO_2	VOC	CO	NOx	PM	SO_2
6) Corridor-level truck to rail steel wheel connection (75%)	***Rail*** ***Truck*** Other TOT.			1.68	5.6	11.3	0.61	(.28)					
7) Corridor level reduce empty (10%) backhauls w/ improved scheduling/ dispatching	Rail ***Truck*** Other TOT.			0.07	0.34	0.8	0.05						
8) Reduction to 5% empty backhauls	Rail ***Truck*** Other TOT.			0.15	0.74	1.74	0.1						
9) Corridor level move trips out of peak	Rail ***Truck*** Other TOT.			0.06	0.33	(0.01)							
10) Regional level truck to rail (20%)	***Rail*** ***Truck*** Other TOT.			8	55	57	5	(3)					

Exhibit 5.10. (continued)

Figure 4.16. Impact Summary Table

Trial No. Strategy	Mode	▲ Activity Ton-Miles	VMT	▲ Emissions (kg/day) VOC	CO	NOx	PM	SO_2	Net Cost Per Ton VOC	CO	NOx	PM	SO_2
11) Regional level truck to rail (40%)	***Rail*** ***Truck*** Other TOT.			16	111	114	10	(6)					
12) Regional level truck to rail (60%)	***Rail*** ***Truck*** Other TOT.			24	166	171	14	(9)					
13) Regional level conversion to natural gal	Rail ***Truck*** Other TOT.			33	143	474	32	14					
14) Regional level new truck fleet	Rail ***Truck*** Other TOT.			4	25	210	18						
	Rail Truck Other TOT.												

Exhibit 5.11.

Figure 4.17. Cost Summary Table

Trial		Annualized Public Cost				Annualized Private Cost				Combined Societal Cost			
No.	Strategy	Capital	Operating	Revenue	Net Cost	Capital	Operating	Revenue	Net Cost	Capital	Operating	Revenue	Net Cost

the strategy (such as a road pricing scheme), less the capital and operating costs to implement and maintain the strategy. These costs and revenues should be put on comparable terms, generally meaning that they would be ***annualized*** and put in terms of present value (with appropriate discounting applied).

In the case of freight emissions strategies, the determination of costs and benefits can be somewhat more complex and involved than this simple formula above. The following issues would need to be taken into consideration as well:

- Upon whom do the costs fall or do the benefits accrue? It is important to distinguish between public and private sector costs, at a minimum. In the case of freight, the costs to the industry may not be easy to elicit and will probably need the assistance of the freight industry representative.
- There is an important difference between "direct" and "indirect" benefits or costs. Direct benefits or costs are those that are clearly traceable, quantifiable and relatable to the strategy. Indirect benefits or costs are those that would be expected to occur *as a result of* the strategy, e.g., savings to society/government in road construction or maintenance expense or avoided costs to industry. These indirect costs or benefits are often the most difficult to objectively quantify, and the most likely to raise controversy and difference of opinion, particularly if assumptions critical to their valuation provide substantial weight in the implementation recommendations.
- There are also another class of secondary costs and benefits that are even tougher to work into the analysis, dealing more with the aspect of "opportunity cost". At issue is whether a strategy that appears to produce not only fewer emissions but also a higher level of efficiency in the use of the transportation system and productivity to freight carriers *is necessarily a benefit, that will contribute to its support.* It may be that what appears to be an improvement (or an impediment!) may actually have the opposite effect on the carrier or the shipper. Again, these types of considerations are very important in assessing the feasibility of implementing a strategy, but may be difficult or ambiguous to quantify.

For the reasons cited above, it is generally safest to perform the basic cost-effectiveness analysis using only those costs and benefits that are direct, which can be readily quantified, and which involve few if any controversial assumptions. Other costs and benefits are important, but it is recommended that they be kept out of the primary cost-effectiveness determination (unless unanimity can be reached in how they are calculated) in the Impact Summary, and included instead as criteria or supporting decision factors in the final assessment and prioritization in the next step.

5.3.5.4 Selection Criteria and Assessment

Ultimately, the development of a priority list for implementation of any of the strategies will be the result of a comparison of their respective strengths and weaknesses, in relation to each other, and perhaps in relation to some absolute standards. Such standards could include: no strategy that costs more than $X to implement, or no strategy that doesn't at least reduce Y Kg of NOx per day. As explained above, while the emissions reductions of the various strategies and their cost-effectiveness are obvious first-order selection criteria, the complex process that leads to the selection and endorsement of a strategy for implementation typically involves a number of criteria that address the key issues or tradeoffs.

The last step in the Chapter 4 methodology provided some ideas and recommendations toward such a multi-attribute criteria-based valuation system. That guidance suggested that criteria which would probably factor heavily into the selection process (based on information from the Advisory Panel and gleaned from the site discussions) include the following:

1. **Economic Viability:** The strategy would be positive in terms of the movement of goods as well as having emissions benefits.
2. **Joint Benefit**: The strategy provides a gain for both private and public sector parties.
3. **Cost-Effectiveness:** The strategy affords a good ratio of emission reduction in relation to its net cost.
4. **Critical Pollutant:** The strategy is particularly effective in reducing a particular pollutant, like NOx.
5. **Secondary Benefits:** The strategy supports other desired or desirable outcomes, such as traffic congestion relief, reduced accidents, reduced noise, visual improvements, etc.
6. **Barriers:** The legal, institutional, financial or political barriers associated with implementing the strategy are not prohibitive.

Figure 4.18 was provided in Chapter to provide for the accounting of each strategy's performance against such criteria as these (the user is encouraged to use other criteria that may better reflect priorities or concerns at that site). Exhibit 5.12. illustrates how this process would work for the strategies assessed in the case study analysis. The criteria are used as suggested in Chapter 4, and an "Importance Weight" has been assigned to each, with values extending from 5 to 1, with 5 being most important. In this case, the Economic Viability and Cost-Effectiveness criteria carry the highest priority, and have been assigned a weight of 4. The concerns that the strategy represent a good opportunity for Joint Benefit in public-private cooperation reflects the next level of priority, and is assigned a weight of 3, along with the consideration of Critical Pollutants that are being mitigated by the strategy. The importance of Implementation Barriers is accorded a weight of 2, while the provision of Secondary Benefits has been given a weight of only 1, indicating that it has the lowest priority in the selection.

The body of Exhibit 5.12. has then been completed to indicate the judged "attainment" level for each strategy, again on a scale of 1 to 5, where 5 is the highest level of attainment. The weights are then applied to these attainment level scores, and the total obtained across all criteria for each strategy. This weighted score is shown in the last column, and for this group ranges in value from a high of "52", achieved by strategies (7) and (2) which reduces the Empty Backhaul ratio for trucks in the Tioga-Morrisville corridor to 10%, to a low of "32" for strategy (14), which involves actions to lower the average age of the regional truck fleet. As may be seen in perusing the tables, each strategy scores somewhat differently against the chosen criteria, representing a range of tradeoffs to the reviewer when performing an evaluation. Upon review of these tradeoffs, the implementation group may choose to change the weights it had initially assigned, introduce new criteria,

Exhibit 5.12.

Figure 4.18. Strategy Selection Criteria

		Criteria							
		Economic	Joint Benefit	Cost-Effective	Critical Pollutant	Secondary Benefits	Barriers	Other	
Assigned Weight		wt = 4	wt = 3	wt = 4	wt = 3	wt = 1	wt = 2	wt = 0	
Trial									Weighted Score
No.	Strategy								
1	Idling reduction at site (60)	3	4	3	3	1	1		48
2	Idling reduction at site (45)	3	4	3	3	1	1		48
3	Idling reduction at site (30)	3	4	4	3	1	1		52
4	Corridor Level truck to rail (25%)	3	3	3	3	3	2		49
5	Corridor level truck to rail (50%)	3	3	2	3	3	1		43

Exhibit 5.12. (continued)

Figure 4.18. Strategy Selection Criteria

		Criteria							
		Economic	Joint Benefit	Cost-Effective	Critical Pollutant	Secondary Benefits	Barriers	Other	
Assigned Weight		wt = 4	wt = 3	wt = 4	wt = 3	wt = 1	wt = 2	wt = 0	
Trial									Weighted Score
No.	Strategy								
6	Corridor level truck to rail (75%)	3	3	2	3	3	1		43
7	Corridor level 10% empty backhauls	4	2	3	4	4	1		52
8	Corridor level 5% empty backhauls	4	2	2	4	4	2		50
9	Corridor level move trips out of peak periods	3	2	2	2	4	2		40
10	Regional level truck to rail (20%)	3	3	3	3	3	2		49

Exhibit 5.12. (continued)

Figure 4.18. Strategy Selection Criteria

		Criteria							
		Economic	Joint Benefit	Cost-Effective	Critical Pollutant	Secondar y Benefits	Barriers	Other	
Assigned Weight		wt = 4	wt = 3	wt = 4	wt = 3	wt = 1	wt = 2	wt = 0	
Trial									Weighted Score
No.	Strategy								
11	Regional level truck to rail (40%)	3	3	1	3	3	1		43
12	Regional level truck to rail (60%)	3	3	2	3	3	1		43
13	Regional level conversion to natural gas	2	2	2	5	2	1		40
14	Regional level new truck fleet	2	2	1	3	3	1		32

change the definition of a criteria or how it is scored, or shift the focus to one or two particular criteria, perhaps establishing standards for those criteria.

A process such as this would be anticipated for any implementation effort entailing such a diverse collection of options.

5.4 Conclusions

This study has focused on the emissions impacts of public or private sector actions that cause a measurable change in freight emissions. Through the case study and exposition of the methodology of Chapter 4, tools were provided to guide the analyst through a series of decisions and relatively straightforward calculations to arrive at impact estimates. The larger and important question of decision-making in the private and public sectors that lead to such impacts remains to be examined in greater detail. The questions to be asked include:

- Do current industry trends favor policies that will reduce regional freight emissions? For example, what is the potential for increases in containerized shipments to reduce emissions?
- Are there feasible initiatives at the level of federal government, such as tightened vehicle standards, that are likely to have a measurable impact on emissions?
- Under what conditions will the share of freight shipped by rail increase?

Such basic research is needed to enhance the analyst's ability to screen potential strategies for feasibility based on actual experience.

Improving the methodology

In order to carry out the case study applications many assumptions were made, because data were lacking or unavailable. Data that would have improved the reliability and accuracy of the applications include:

For rail emissions estimates:

- Idling emissions and typical idling times of rail locomotives;
- Emissions factors for rail drayage locomotives, and
- Accurate information on gross container weights.

For truck emissions estimates:

- Better information on the distribution of dray volumes from and to the terminals under study;

- Better information on the relationship between truck load and emissions (ton-mile conversion for VMT); (see discussion in the Appendix)
- Emissions factors and energy use relationships that permit estimations of emissions from acceleration and deceleration events, and
- Data on backhaul ratios.

For the overall analysis:

- More scenarios should be built upon actual plans and proposals. These scenarios would reflect either some level of public policy or private sector decision-making in which, at some level, feasibility as measured by profit or net social benefit has been determined. They are quite useful and should be examined further. The scenarios built upon hypothetical situations illustrate the methodology and the necessary calculations that must be performed. They are of limited usefulness beyond that purpose, however, because there is no attempt to determine their feasibility.

Applicability of the case study to other areas.

This case study has focused on one city with a particular economic, geographic and demographic composition, and as such, is unique. One can argue that a separate analysis is necessary for any particular area that is contemplating policies or capital investments that will change freight's contributions to regional emissions. At a minimum, grouping and analyzing metropolitan areas by market served, economic make-up and other traits would be a necessary prerequisite to producing more generalizable results.

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