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FORWARD-Freight Options for Road, Water, and Rail for the Dutch

Executive Summary

Richard J. Hillestad, Warren E. Walker, Manuel J. Carrillo, Joseph G. Bolten, Patricia G.J. Twaalfhoven, Odette A.W.T. van de Riet

European-American Center for Policy Analysis

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Supported by the Netherlands Ministry of Transport, Public Works and Water Management

European-American Center for Policy Analysis

Preface

This report summarizes the results of a major transportation research study that was performed for the Netherlands Ministry of Transport, Public Works, and Water Management by the European-American Center for Policy Analysis (EAC), which is a part of RAND. The study, called Freight Options for Road, Water, and Rail for the Dutch (FORWARD), examined the benefits and costs of a broad range of policy options for mitigating the negative impacts of the expected growth in road freight transport while retaining the economic benefits. The study was carried out during the two-year period from the end of 1992 through the end of 1994.

A complete description of the research carried out on the FORWARD project is contained in a main report and two supporting volumes. The main report is *FORWARD—Freight Options for Road, Water, and Rail for the Dutch: Final Report*, MR-736-EAC/VW, RAND, 1996, by Richard J. Hillestad, Warren E. Walker, Manuel J. Carrillo, Joseph G. Bolten, Patricia G.J. Twaalfhoven, and Odette A.W.T. van de Riet. The supporting volumes describe

- The PACE-FORWARD model that was used in the assessment of the policy options (*PACE-FORWARD: Policy Analytic and Computational Environment for Dutch Freight Transport*, MR-732-EAC/VW, RAND, 1996, by Manuel J. Carrillo).
- The policy options whose impacts were assessed using PACE-FORWARD (*FORWARD—Freight Options for Road, Water, and Rail for the Dutch: Tactic Definitions*, DRU-1385-EAC/VW, RAND, 1996, by Joseph G. Bolten, Patricia G.J. Twaalfhoven, Odette A.W.T. van de Riet, and Warren E. Walker).

Earlier, the project produced a report describing the various models of the Dutch transport system that were currently available and might be used in the project: *Characteristics and Capabilities of Dutch Freight Transportation Systems Models*, MR-382-EAC/VW, RAND, 1994, by Lóránt A. Tavasszy.

The policy analysis structure and conclusions should be of direct interest to freight transport policymakers in the Netherlands and elsewhere, and the methodology should be of interest to transport system analysts worldwide. Indeed, many of the conclusions and much about the methodology should be directly applicable to freight transport issues of other governments.

The EAC is located in Delft, the Netherlands, sharing resources with the Faculty of Systems Engineering, Policy Analysis, and Management of the Delft University of Technology. It operates as a foundation (Stichting), chartered in The Hague under Dutch law. The mission of the EAC is to conduct interdisciplinary analyses of public policy problems facing Europe and North America; to convey the results of these analyses to the policymaking community, the research community, and the public at large; and to foster cooperation among researchers in all parts of Europe and North America. Funding for the EAC's activities in 1992–1996 is being provided by the State of the Netherlands, the Delft University of Technology, RAND, and sponsors of individual projects.

For further information about the project, you may contact a number of persons. In the United States, please contact the principal investigator:

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For more general information about the project and how its results are being used by the government of the Netherlands, contact

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Contents

Preface iii

Acknowledgments ix

1. BACKGROUND 1
   The Research Problem 1
   The FORWARD Project 2
   FORWARD Used the Policy Analysis Approach 2
   Some Unique Features of the FORWARD Project 3

2. OVERVIEW OF THE FORWARD PROJECT AND ITS RESULTS 5

3. CONCLUSIONS AND OBSERVATIONS 11

4. A GLANCE INTO THE FUTURE 15

Appendix: NON-EAC/RAND PERSONS DIRECTLY INVOLVED IN THE FORWARD PROJECT 17

Bibliography 23

Acknowledgments

Policy analysis projects usually involve the assistance of many individuals and organizations. The FORWARD project required a great deal of such help and was fortunate to have received it. Help was needed because of the diversity of the topics considered, our dependence on other individuals and organizations for essential information, and the political nature of aspects of the process.

When help is received from so many sources, it is difficult to individually thank everyone who contributed in some way. We mention a few names here and provide a more inclusive list in the Appendix. Of course, acknowledging various individuals and organizations does not imply that those who assisted us are responsible for, or agree with, our findings. The responsibility for any shortcomings rests solely with us, the authors.

Some of the most important participants in the project were several members of the Netherlands Ministry of Transport, Public Works, and Water Management and its associated Transport Research Centre (AVV) who served as members of a joint EAC/Ministry project group. They met regularly to review the project's status, identify the next steps to be taken, assign responsibilities for the next steps, and provide liaison with the policymakers. Throughout the project, they participated in the research and gave helpful advice and information. They also read this document and suggested revisions to it. The non-EAC members of the project group varied over the course of the project. At some time or other, the following persons were members:

Drs. M. Klok (Leader, 1992–1993)

Drs. P.B. van der Gaag (Leader, 1993–1995)

Dhr. E. Baarspul, MBA

Drs. M.P.W. van Biezen

Mw. mr. B. Boschma

Dr. J.C. Gardenier

Drs. J.C. van Ham

Ir. J. van der Rest

A steering group was also formed. It provided guidance on the scope and emphasis of the research and had the policy conclusions presented to it. The

steering group was chaired by Drs. J.M.F. Diris, Director of Freight Transport for the Ministry. His dedicated support of our work was crucial to the project's success. The other members were

Mw. B.C.M. van Buchem, Ministry of Economic Affairs

Dhr. G.J. Hoekstra, Koninklijke Douwe Egberts BV

Dhr. mr. M.C. Kroon, Ministry of Housing, Physical Planning, and Environment

Mw. drs. S.M. Maier, Ministry of Transport, Public Works, and Water Management

Dhr. J. Mink, NEBAM BV

Drs. M. Muller, Ministry of Transport, Public Works, and Water Management

Dhr. J.Z.H. Stijnders, Hoogovens Groep BV

We acknowledge the assistance of our EAC colleague Henk Kloosterhuis and our RAND colleagues James Stucker, Dan Relles, and Judy Fischer. Although not co-authors of this report, they made valuable contributions early in the study. Two other RAND colleagues, Louis Miller and Stephen Brady, reviewed an earlier version of the report. Their comments assisted in improving the report's quality. Other valuable contributions were made by two other Dutch transportation research organizations: NEA, which was the source of the freight transport demand data used in our analysis, and the Netherlands Economic Institute (NEI), which developed the model that we used to estimate the macroeconomic impacts of the various policy options. NEI developed their model as part of a separate contract with the Ministry of Transport, Public Works, and Water Management.

As part of the process of understanding the problems related to the freight transport system, policy options that might be taken to mitigate those problems, and ways of estimating the consequences of those options, we met with many individuals. These persons worked for the government, for universities, for research organizations, for companies involved in freight transport, for truck manufacturers, and for groups concerned with mitigating the negative effects of freight transport. We are grateful for their assistance. The names and affiliations of these persons are included in the Appendix.

1. Background

The Research Problem

In 1990, the Dutch Minister of Transport, Public Works, and Water Management, and the Dutch Minister of Housing, Physical Planning, and Environment issued a policy statement on transport called the *Second Transport Structure Plan (SVV)* [Second Chamber of the States General, 1990]. This document described the current and projected problems associated with transport in the Netherlands and proposed adopting a number of specific steps to deal with them. With respect to freight, there were specific policy recommendations designed to maintain the Dutch market share, improve freight hauling efficiency, and develop additional infrastructure.

Although the *SVV* was fairly comprehensive in its policy recommendations, there has been continued debate about the importance and effect of specific policy options. The debate focuses not only on the predictions of effects, but, depending on the interest group involved, which effects are most important. It has also been argued that there may be more attractive alternatives to a number of the plan's options.

The continuing public debate about the alternatives to deal with freight transport in the Netherlands and the importance of this transport to the Dutch economy motivated the Ministry of Transport, Public Works, and Water Management to commission a broad study of freight policy options and their impacts and costs.

The problem originally posed to the project team was to find the best ways to shift freight off the highways and onto other modes. However, this was soon realized to be too narrow and more of a solution statement than a problem statement. Asking the client why freight should be shifted off the highway revealed a desire to reduce the negative effects of road freight transport. But there are other ways of dealing with the negative effects of road freight transport besides shifting it off the highways, such as making better use of the existing infrastructure and truck fleet, or employing cleaner diesel engines.

It was also realized that there were likely to be many policy actions for coping with the negative impacts of road freight transport, and that preferences among these actions would depend on the relative importance placed on their effects.

People concerned about environmental effects are likely to evaluate the policy options differently than people concerned about economic effects. A major component of the problem was how to provide some rationale for choosing among a large number of policy options and making tradeoffs among many measures of effectiveness.

The goal of the research was eventually defined as

> Find the best strategies to mitigate the negative impacts of the growth of freight transport while retaining the economic benefits.

This was done for alternative economic scenarios for the year 2015. The study was to look at as many policy options as possible and to evaluate each policy option's effects on a broad range of performance measures, including emissions, noise, safety, congestion, costs, and the national economy. The remainder of this section and Section 2 provide an overview of the project and the approach it used. Readers who wish to find the project's major conclusions and observations should skip to Section 3.

The FORWARD Project

The Freight Options for Road, Water, and Rail for the Dutch (FORWARD) project was commissioned by the Ministry of Transport, Public Works, and Water Management to perform this broad study of freight transport alternatives. Begun in December 1992, the project was carried out by the European-American Center for Policy Analysis (EAC), part of the California-based RAND Corporation. The project team was composed of researchers from the EAC, RAND, and the Faculty of Systems Engineering, Policy Analysis, and Management of the Delft University of Technology. A Ministry *project group* provided support and coordination for data collection and work with other contractors, as well as tactical guidance for the project. In addition, a steering group composed of representatives from industry, other government ministries, and various offices within the Ministry of Transport, Public Works, and Water Management periodically reviewed the research progress and offered strategic guidance.

FORWARD Used the Policy Analysis Approach

The research was performed using a structured approach developed at RAND to evaluate public policy options (each of which is called a *tactic* and combinations of which are called *strategies*) specifically for situations involving complex systems with multiple measures of performance and involving competing interest groups with different and frequently conflicting goals. The approach is

simply called *policy analysis*. It has been applied successfully to such different problems as national water policy, drug policy, educational policy, and national defense planning and budgeting.

Policy analysis is an *iterative* process. When the first batch of strategies is presented to the policymakers, they may ask whether it is possible to design a strategy that emphasizes, for example, modal shift a bit more. Or new tactics may be suggested, which may help to shore up weaknesses in the strategies initially presented. The analysis and planning team must then design new strategies and return for further direction.

Properly applied, this approach helps policymakers do their jobs better. At various stages, the policymakers are asked to participate and advise. They are shown the effects of a number of different strategies. They are then asked for their preferences, or to suggest areas in which they would most like improvement or could best tolerate degradation. The end result is not only a set of promising strategies, but a deeper understanding of the rationale for why certain strategies and tactics perform as they do, and a set of results that the policymakers and stakeholders have helped develop. This is the approach that we used in the FORWARD project.

Some Unique Features of the FORWARD Project

There have been many studies of policy options for transport in the Netherlands and Europe, including those related to the Ministry's own *SVV* [Second Chamber of the States-General, 1990]. The natural questions are how the FORWARD project differs from the others, and what unique insights it provides for making informed policy decisions. The differences are in both approach and outcomes.

Generally, transport projects, even policy projects, have been narrowly defined to look at one or two specific policy actions and to focus on a particular impact category, such as the economic impacts, environmental impacts, or safety impacts. Thus, one finds, for example, studies on the "cost of time" for transporters, on the environmental impact of a dedicated rail line for freight, and on the effect of road pricing on traffic intensity.

The FORWARD study took a *broad perspective* in terms of the policy actions investigated and the impacts of those actions. The attempt was to consider as many tactics as possible and to compare their impacts on the measures of interest to the broad spectrum of stakeholders. The project was *integrative* in that it attempted to bring together multiple tactics to provide robust strategies that would mitigate the negative impacts of freight transport on all of the measures.

FORWARD was also integrative in the sense of utilizing existing Dutch research (e.g., research by DAF on cleaner diesel engines and *Trendbreuk* results [Werkgroep `2duizend, 1993] on certain efficiency options) and existing Dutch models. The computer program that was used to estimate the impacts of the various tactics (which is called PACE-FORWARD, for Policy Analytic and Computational Environment for FORWARD) [Carrillo, 1996] was largely based on traffic conversion and impact models developed by other groups in the Netherlands. The freight demand data were obtained from NEA, and were based on research NEA had done with respect to origin and destinations of freight as affected by the Central Planning Bureau scenarios of economic growth. In its breadth, FORWARD was also *multimodal* in that it considered the interactions among modes (e.g., how shifting freight from highway to rail decreases road emissions but increases rail emissions), the elasticities of demand for the various modes (i.e., how demands might be affected by changes in costs), and actual intermodal freight transport. The project treated each tactic as a separate research project, and, in some cases, went into considerable depth to understand how to represent and quantify a tactic. In other cases, cursory examination was enough to eliminate an option. Thus, we *used variable amounts of analytic effort to create the necessary knowledge/insight/understanding for this project.*

FORWARD did not attempt to find a single solution; instead it *produced alternative promising strategies and conclusions,* together with their evaluation and rationale. The research and the final results were developed *through iterations with the stakeholders and policymakers,* thus providing important inputs and more assurance that the conclusions and recommendations would be understood and accepted.

The project *developed PACE-FORWARD,* which is expected to have a usefulness beyond this research effort. Given appropriate support and data, this model and its architecture provide the Ministry a capability for reevaluating the policy actions investigated in this project as more information on tactics becomes available or as changes in scenario projections of demand occur. It can be used to investigate changes in the relative emphasis applied to the various impact measures, and it can be used to evaluate new tactics and strategies once they are fully defined and implemented in the model and data structure.

Finally, the FORWARD project *demonstrated a policy analysis methodology* that can be applied to other policy areas, such as civil aviation, passenger transport, and infrastructure priorities, in the Netherlands and elsewhere. Indeed, the methodology provides an approach that can be used to address high-level, cross-cutting issues when there are large numbers of policy options and when there are competing objectives and measures.

2. Overview of the FORWARD Project and Its Results

One of the key elements in the FORWARD project was to develop a detailed picture of transport and traffic in the current situation and for several future situations. The Netherlands Central Planning Bureau (CPB) has outlined three scenarios for the development of the Dutch economy to the year 2015: the balanced growth (BG) scenario, the European renaissance (ER) scenario, and the global shift (GS) scenario. Based on the freight demand data developed by the Dutch research institute NEA, we developed freight demand scenarios for the year 1990 ("current situation") and for the three CPB scenarios for the year 2015.

The performance measures considered in the FORWARD study were divided into six categories: emissions, noise, safety, congestion, costs, and the national economy. The emissions category consisted of six types of emissions: CO_2, NO_x, C_mH_n, CO, SO_2, and aerosols. The effects on the noise nuisance were measured by the average distance from the highways to the 55 dB(A) noise contour.[1] To measure safety, the impacts on the number of truck-involved accidents, injuries, fatalities, and accidents related to the transport of hazardous goods were estimated. Total congestion severity (number of incidents * average length of backup * average duration of incident) was taken as a measure of congestion on the Netherlands highways. The net incremental cost of a tactic (that is, its net additional cost over all stakeholders) was taken as a measure for the cost. The cost of a tactic was split into four parts: delay costs, investment costs, operating costs, and maintenance costs. For the macroeconomic impacts, the changes in employment and value added for the transport and production sectors were estimated.

The tactics evaluated fell into three main categories:

1. *Direct Mitigation Tactics.* These tactics seek specifically to reduce one or more of the negative impacts at their source. Most of them are technical improvements to trucks to reduce their emissions and noise or to increase safety on the highways. Examples are the use of soot filters, cleaner engines,

[1]The 55 dB(A) is a measure of noise. The 55 dB(A) contour shows the distance from the highway at which noise drops to this level. The closer to the highway this contour lies, the fewer people affected by unacceptable noise.

low-noise tires, and electric vans, and the reduction of the power/weight ratio of trucks. Tactics that change the road infrastructure in order to reduce congestion, such as using a separate lane for trucks, are also included in this category.

2. *Transport Efficiency Tactics*. These tactics seek to use the truck fleet and transport infrastructure more efficiently. Examples of efficiency tactics include the use of city distribution centers and larger trucks.
3. *Mode Shift Tactics*. These tactics are specifically designed to stimulate the shift of freight off the roads and onto other modes of transport. They include various ways to make rail and waterway transport of freight more attractive by making these modes faster and more reliable (e.g., using a regional dispatching system at ports and having the railroads give priority to freight transport over passenger transport). They also include ways to improve transshipment capabilities (e.g., building multimodal centers) and ways to provide regulatory or price incentives for modal shift (e.g., introducing tolls on roads and making rail transport free). Besides shifting freight to rail and waterways, the project considered possibilities for transport of freight by alternative modes, such as moving sidewalks for containers, short sea transport, and pipelines.

To assess the impacts of the tactics, a microcomputer-based spreadsheet model called PACE-FORWARD was developed. The user can directly interact with the program to gain insights into the effects of the various tactics on emissions, noise, safety, congestion, costs, and the national economy. PACE-FORWARD is integrative in that it uses data, factors, and relationships from existing Dutch transportation models and databases. PACE-FORWARD is designed for use by policy analysts knowledgeable about the freight transport policy area; its use requires little training for an analyst already familiar with spreadsheets. It was used to assess the impacts of the various tactics and strategies on a range of performance measures.

The FORWARD project had planned to use existing analytic tools to estimate the effects. A substudy was performed to identify the characteristics of existing Dutch freight transport system models and some other models for which documentation was readily available [Tavasszy, 1994]. This substudy concluded that no existing model or combination of models could satisfy the requirements of the project. As a result, PACE-FORWARD was developed. It uses equations and data from existing models, as well as new equations and data that were developed as part of the FORWARD project to fill the remaining gaps.

In trying to use the output of PACE-FORWARD (*scorecards*, which contain the estimated impacts for each of the tactics for each of the scenarios), we had to deal with a number of complexities in order to create strategies:

- The large number of tactics provided many different ways of achieving certain goals.
- There were numerous impact measures, and tradeoffs had to be made among them. The best tactics to include in a strategy differed depending on the weights assigned to the various impacts.
- There were constraints on the tactics to be combined into a strategy.
- It was not possible to simply add tactics together; related tactics interact in nonlinear ways, and some tactics cannot be implemented together.

In the FORWARD project, we developed an approach to deal with these complexities. The approach is based on a cost-effectiveness model (CEM) that uses the scorecard for a particular scenario and a given set of weights on the impacts to rank the tactics based on their cost-effectiveness. The outcome of this approach is not only a set of strategies, but also strategy design tables that can be used by policymakers to design their own strategies based on their own goals, constraints, and specific wishes.

We used the CEM to develop a broad range of strategies. We thought that the ranked components of the strategies would depend on the scenario for 2015 because of different demands on the freight system. But, with only a few minor exceptions, the ranked lists did not change as a function of the scenario. The ranked lists of tactics produced by the CEM did depend on the importance weighting of the tactic impacts,[2] on the subset of tactics considered, and on various nonlinearities in the combination of tactics (some tactics interfere with other tactics, and many do not provide strictly additive effects). Thus, there is a strategy for focusing on NO_x emissions, a strategy for focusing on mode shift, etc. Figure 1 shows how PACE-FORWARD and the CEM were used within the project to identify promising tactics and strategies. In all, we designed twelve illustrative strategies. To determine the effects of a particular strategy, we used the CEM to produce graphs of the cumulative effectiveness and the cumulative costs of a given set of tactics that were part of that strategy.

[2]It is important to recognize that the CEM uses subjective weighting in that the user is asked to provide his own importance weighting of impact measures. We initially utilized weights derived from discussions with various stakeholders, but we later varied these weights considerably to understand how the rankings of tactics changed or did not change.

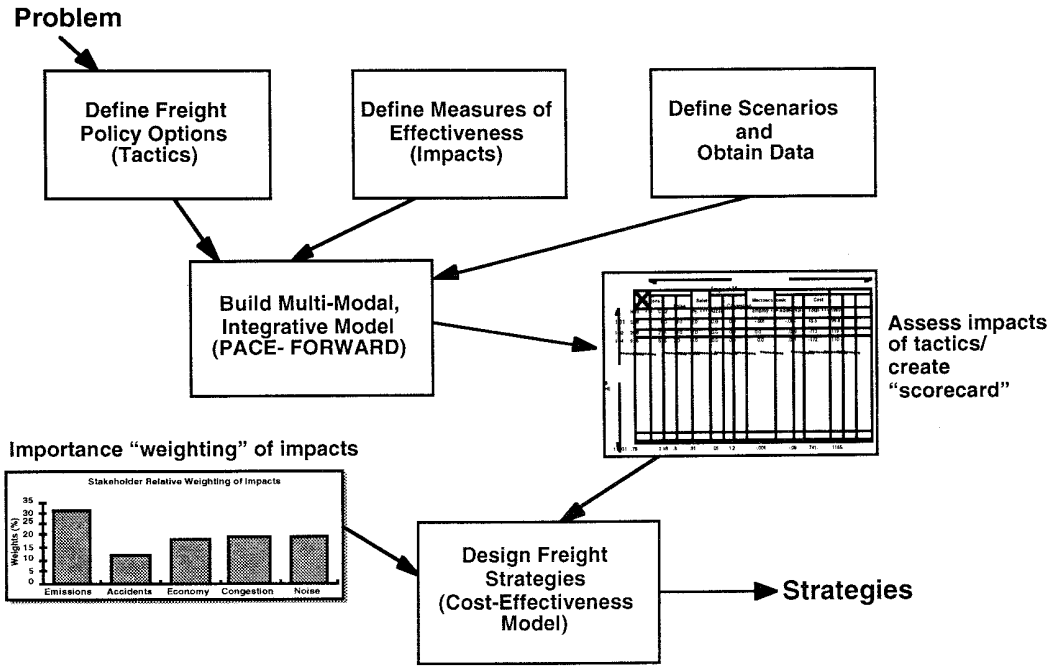

Figure 1—Use of Models in the FORWARD Project

One of the illustrative strategies was a "uniform strategy," which focused equally on all impact measures without making a selection among them. Figure 2 presents results from running the CEM for this strategy. The horizontal axis shows the number of promising tactics from the ranked list (after removal of the alternative and interfering tactics) that are included in the strategy. In the example shown here, the strategy includes 17 separate tactics.

The "maximum % reduction impacts" graph in Figure 2 is an upper-bound estimate of the cumulative percentage reductions in truck-related emissions, noise, safety, and congestion. The "minimum % reduction impacts" graph shows the estimate of the impact measure with the lowest cumulative reductions. As the strategy is built up by including additional tactics, the percentage reductions across the set of negative effects tend to increase. We regard the largest reduction over the weighted four truck impacts at each step as an upper bound on effectiveness. Likewise, the lowest reduction over the four impacts is a lower bound, with the reductions in all other effects falling in between. The cumulative reductions of the other impact measures are between the minimum and the maximum graph. The reduction increases as the number of tactics included in the strategy is increased. For example, in Figure 2, the lowest cumulative

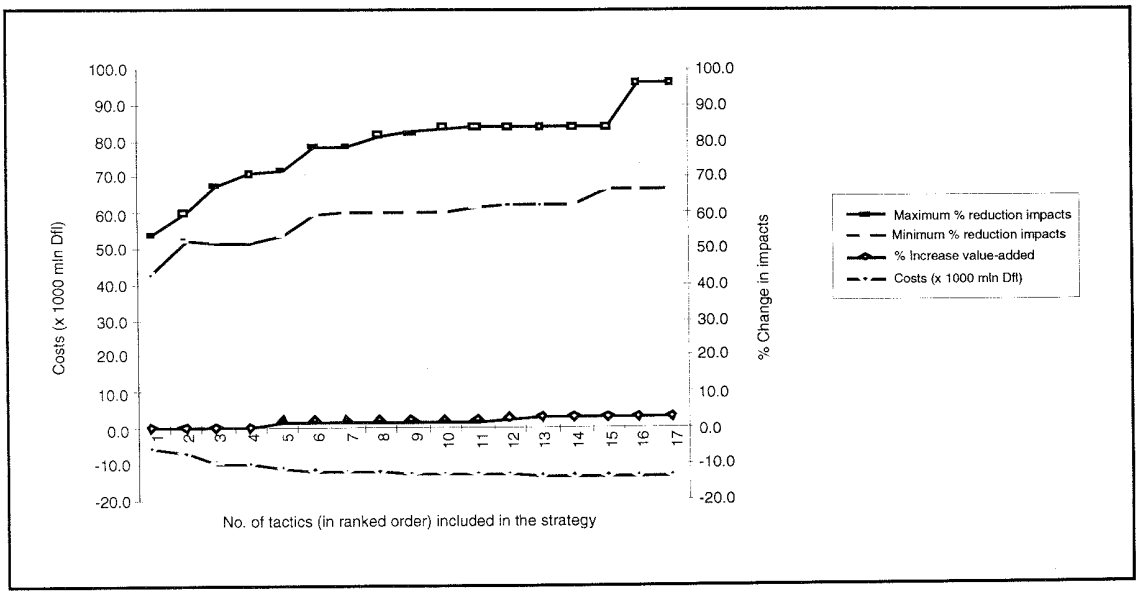

Figure 2—Costs and Impacts of a Uniform Strategy

reduction increases from about 45 percent with one tactic in the strategy to about 65 percent with all 17 tactics included.

The "costs" graph in Figure 2 is an estimate of the cumulative annualized cost (in Dutch florins) of implementing the tactics. Most of the tactics in this strategy actually save money, so the cumulative annualized cost of the strategy is negative. The remaining graph, "% increase value-added all," gives an indication of the effects on the economy; it shows the percentage increase in value added. All reductions are given relative to a European renaissance (ER) scenario base case in which none of the tactics is implemented. Note that there is a net cost savings for the strategy. Also note that all impact measures are improved dramatically.

The 17 tactics included in the uniform strategy depicted in Figure 2 are listed in Table 1. Twenty-four tactics were included in one or more of the 12 illustrative strategies. Those 24 tactics are listed in Table 2.

Table 1

Tactics Included in the Uniform Strategy (in ranked order)

No.	Name
6.041	Transporters use telematics to locate freight to be transported
6.011	Permit 50-tonne trucks in the European Union
6.08	Equalize rules of transport on own and professional account
1.02	Make trucks more fuel efficient
4.06	Provide free transport of goods by rail
1.05	Improve truck tires to reduce road friction and noise
10.02	Expand the use of city distribution centers
1.09	Build electric vans for urban use
7.14	Reward truck drivers for driving more fuel-efficiently
1.04	Reduce air resistance of trucks
7.02	Use speed limiters on trucks
4.01	Expand competition with the Dutch railways
4.05	Speed exchange of freight between road and rail
4.10	Reduce time trains spend at international borders
7.04	Use separate lanes for trucks
1.01	Build cleaner engines
1.14	Use vapor reduction systems on gasoline pumps

Table 2

Tactics Included in One or More of the Illustrative Strategies (in numerical order)

No.	Name
1.01	Build cleaner engines
1.02	Make trucks more fuel efficient
1.04	Reduce air resistance of trucks
1.09	Build electric vans for urban use
1.14	Use vapor reduction systems on gasoline pumps
2.01	Transport international freight via rail or boat
2.02	Settle new firms near water and rail
2.06	Create multimodal centers
4.01	Expand competition with the Dutch railways
4.04	Build new spurs
4.05	Speed exchange of freight between road and rail
4.06	Provide free transport of goods by rail
4.10	Reduce time trains spend at international borders
6.011	Permit 50-tonne trucks in the European Union
6.041	Transporters use telematics to locate freight to be transported
6.08	Equalize rules of transport on own and professional account
7.02	Use speed limiters on trucks
7.04	Use separate lanes for trucks
7.14	Reward truck drivers for driving more fuel-efficiently
1.05	Improve truck tires to reduce road friction and noise
9.03	No trucks during congestion hours
10.02	Expand the use of city distribution centers
11.022	Expand network of pipelines
11.032	Moving sidewalks for containers

3. Conclusions and Observations

It is possible to reach some general conclusions about an overall approach to mitigating the negative effects of road freight transport based on the strategies generated by the FORWARD project. And these conclusions, which are scenario independent, are unlikely to change as the result of more detailed analysis or consideration of different tactics. We were able to identify common tactics among all the various strategies. We were able to determine which strategies or types of tactics are relatively robust among a range of importance weights on impacts. And we were able to identify which types of strategies and tactics offer the greatest improvement in benefits at the lowest possible cost.

The major conclusions from the FORWARD project are as follows:

- **The most important tactics focus on transport efficiency improvements.** Transport efficiency tactics are disproportionately represented at the top of all lists of cost-effective tactics for a very broad range of weights. They improve many impact measures (e.g., reducing the amount of truck movements affects all impact measures), and by their nature they tend to save money because of their efficiencies. In other words, if you can reduce the number of kilometers traveled, many negative impacts are reduced and you save money (because of a reduction in the investment and operational costs, including labor cost). In fact, in the list of cost-effective tactics in a strategy that takes into account the full range of impacts, four of the first seven are transport efficiency tactics, and all four lead to a reduction in the overall cost of freight transport. Two of the best tactics in this set are the use of telematics in road transport[1] and permitting 50-tonne trucks in the European Union.

  There are other reasons why transport efficiency tactics tend to be important in most strategies. Most of the top-ranked transport efficiency tactics can make dramatic improvements in many of the impacts. And since many of them do not rely on future technological developments, they can be implemented in the near term. (Of course, the political feasibility of certain regulatory changes may imply a longer-term change for some.) Finally, these

[1] In this tactic, telecommunications are used to improve routing of trucks and to provide better real-time planning of pickup and delivery to reduce empty trips and partial loads.

tactics call for the involvement of many stakeholders, so the burden of implementation does not fall on a single agency or group.[2]

- **Certain direct mitigation tactics are cost-effective and are complementary to transport efficiency improvements.** Certain direct mitigation tactics are cost-effective and either produce net reductions in the overall cost of freight transport or produce only small increases. Two examples of such tactics are the use of quieter tires and the use of electric vans in urban areas. These tactics, although sometimes showing dramatic improvements for the measures on which they focus, generally rank lower in cost-effectiveness than the transport efficiency tactics because they focus on only a few impacts and have net positive costs. The importance of these tactics is that they can "fill in" for gaps in improvement by focusing on particular impacts not addressed by the transport efficiency tactics.

  However, because these tactics focus on particular negative impacts, whether they are promising or not depends to a great extent on the importance weighting of the impact measures. For example, someone who cares only about NO_x emissions would favor the clean engine tactic, while someone who cares only about CO_2 emissions would not. Furthermore, although direct mitigation tactics tend to cost more than the transport efficiency tactics, the costs might be made manageable by targeting the largest contributors to an impact. For example, the tactics could be selectively implemented to target urban vehicles, international (or national) trucking, or even certain regions for haulers of specific commodities. In addition, most of these tactics would be implemented in the mid to long term, since they generally require some technological change. This would make the cost impacts easier to bear, but would also mean that benefits would be realized only gradually.

- **Mode shift tactics are either not cost-effective or make little difference.** Our analysis showed that in both absolute effectiveness and cost-effectiveness, mode shift tactics tend to be inferior to the combination of transport efficiency and direct mitigation tactics. This result stems from the fact that waterway and rail improvements are relatively expensive and do not realize very much mode shift for a number of reasons. First, there is only limited opportunity for mode shift. The average distance traveled by national freight is less than 50 kilometers, so it is unlikely that rail and waterway transport, which usually require before-and-after road transport

[2]Of course, the dependence on many groups can also be a deterrent, but in this case results do not depend on complete compliance. Each group of stakeholders can have an impact even if not all comply.

and transshipment anyway, will be attractive to forwarders for national goods movement. Second, the quantity of longer haul, international trucking is much smaller than the quantity of national trucking, whether measured in terms of tonnes or tonne-kilometers. Thus, the quantity of road haulage that can be affected by mode shift tactics tends to be smaller than that affected by other tactics.

Mode shift tactics that attempt to focus on the international movement of goods between specific regions affect even a smaller quantity of transported goods, because these goods are already shipped mostly by water.

We note that we have not considered the port competition effects of the various tactics. The consideration of port competition is not likely to change the set of promising tactics, but some tactics having to do with port improvements or improvements in the movement of freight from the port would likely become higher ranked.

A qualification, however, is that improving the service characteristics of rail and waterway transport could make mode shift more attractive to freight forwarders and thus more promising.

- **The economic effects of most of the promising tactics are small.** The macroeconomic module of PACE-FORWARD shows the effects of the freight tactics on national value added and employment in the production and transport sector. Almost all of the promising tactics show only small macroeconomic effects because they involve low costs or even cost savings. There is likely to be little effect on market share from implementation of any of these promising tactics, since they either save money or would have to be implemented internationally.

In addition to these conclusions, we offer the following observations:

- **Freight cannot do it all.** Changes to the freight transport system have only a limited ability to reduce the negative effects of road transport on such things as the environment, congestion, and noise. Freight causes only a part, and in many cases only a small part, of the impacts relative to passenger transport.
- **Reducing the negative impacts of road transport is everyone's business.** An important characteristic of the promising set of tactics is that it shows that reducing the negative impacts of road transport is everyone's business, not just that of the government or the truckers. Businesses, railways, inland shipping, and passengers must all do their part. For example, rail and waterway transporters must improve their service characteristics, and businesses must adjust to some changes in transport policy to reduce environmental impacts.

- **The tactics in this study can now be compared in a common framework.** One of the most important contributions of the FORWARD project is that it enables many of the freight transport tactics being discussed in the Netherlands to be compared on a consistent quantitative and logical basis through the use of PACE-FORWARD and the FORWARD results. The user of PACE-FORWARD can directly interact with the model to gain insights into the effects of the various tactics. The FORWARD results show which tactics are the most effective on various measures, as well as the conditions and assumptions under which the tactics are important. The project has also shown that many tactics do not appear to be effective or cost-effective. These results can be used to focus future deliberations on the most promising tactics and strategies.

The study of any individual tactic or impact could go deeper, and some of the tactics will change their rankings in various strategies as implementation aspects are considered. However, we believe that the above set of conclusions will hold up to such further study, and that the overall approach outlined here for reducing freight impacts while retaining economic benefits will continue to be valid.

4. A Glance into the Future

The FORWARD project made major strides toward enabling a broad range of policy options to be compared on quantitative and logical grounds. These findings can be used in support of major freight transport initiatives in the Netherlands. However, there are still a number of things that need to be understood better.

This study focused on freight, but there are substantial interfaces with passenger transport in the use of infrastructure and in terms of impacts. It would be desirable to study these interfaces in the future by expanding PACE-FORWARD and developing an integrated set of tactics for freight and passenger transport.

This project was a study of freight transport in the Netherlands. We did not consider the international movement of freight beyond the Dutch borders, except in terms of destination and distance traveled. Many tactics would have to be implemented in the European Union rather than solely in the Netherlands, so a broader, European Union-based study of freight (and passenger) transport similar to this study would be useful and important.

The development of PACE-FORWARD and the analysis of the tactics were based primarily on current knowledge and existing models in the field of freight transport. New and/or better knowledge could be integrated into PACE-FORWARD relatively easily to update the different modules and to examine new or modified tactics. For example, an elasticity module for mode choice is part of PACE-FORWARD. But this module may not predict mode shifts correctly if service improvements in rail and inland waterways are made. It would be desirable to update this module based on a better understanding of likely future changes in the service provided by these modes.

There is a need for a port competition model to evaluate the economic importance of a number of the tactics involving the port of Rotterdam and transport to and from that key facility.

Finally, many implementation aspects of the tactics have not been considered in this study, particularly in terms of dealing with costs and cost transfers. These and the other considerations must be studied as the government prepares its overall strategy for reducing the negative impacts of road freight transport.

Appendix

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