TRANSPORT SYSTEMS' DEPENDENCE UPON OIL: A LONG TERM SYSTEM DYNAMIC POLICY ANALYSIS

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NEW TRANSPORTATION – AND ENERGY-MODEL INDICATES: "ACTION SHOULD BE TAKEN NOW TO PREPARE FOR FUTURE OIL CRISES"

ABSTRACT

A new system dynamic transportation model deals with important aspects of passenger transport and communication which interact with other aspects of society. The model's analyses indicate substantial reduction of the vulnerability of transport systems to increasing oil prices on the world market as a result of taking certain measures. However, it is important to introduce the new policies as early as possible. It is not rational to wait and see how the oil market develops. The long-term effects of measures taken are, however, only slightly dependent on oil price developments in the first few years.

INTRODUCTION

At the Institute of Transport Economics in Oslo, we are working on a new system dynamic transportation model. The investigations are carried out under two extreme alternatives for the price development of crude oil products. These alternatives are combined with different oil production rates on the Norwegian continental shelf.

Rapidly increasing oil prices and oil production will increase our economic activity and thereby the amount of travel and communications in the country. Increased fuel costs will produce only a slight reduction in the growth rate of transportation.

So far, only four transportation sectors have been included in the model: these are; private car, bus, pedestrian/bicycle and telecommunications. Several other sectors should also be included, for example railways, coastal shipping, air transport and mail. Ten different policies have been tested so far. (See the list of policies further on in the paper). Several hundred combinations of these measures were also investigated. Other policies should be tested by new model runs later.

Until now we have obtained a wide range of interesting results for the effects of different policies. The vulnerability of transport systems under future oil crises is used as a performance indicator of these policies. However, the inverse notion is currently being used, this so called "preparedness" or "robustness" is defined as the relation between the following two properties:

Property 1:

– The annual amount of travel and communications carried out in the country by the transport means included in the model

and

Property 2:

– The annual national fuel consumption for the operation of the motorized transport means included in the model.

The ratio of these two properties can be defined as "communications per litre of fuel".

The measures investigated also affect the level of national economic activity. This performance indicator we measure by:

– The Gross National Product (GNP)

The goal in this investigation is to combine quantitative and intuitive knowledge in one model to give a better view and understanding of the interactions in the transportation sector.

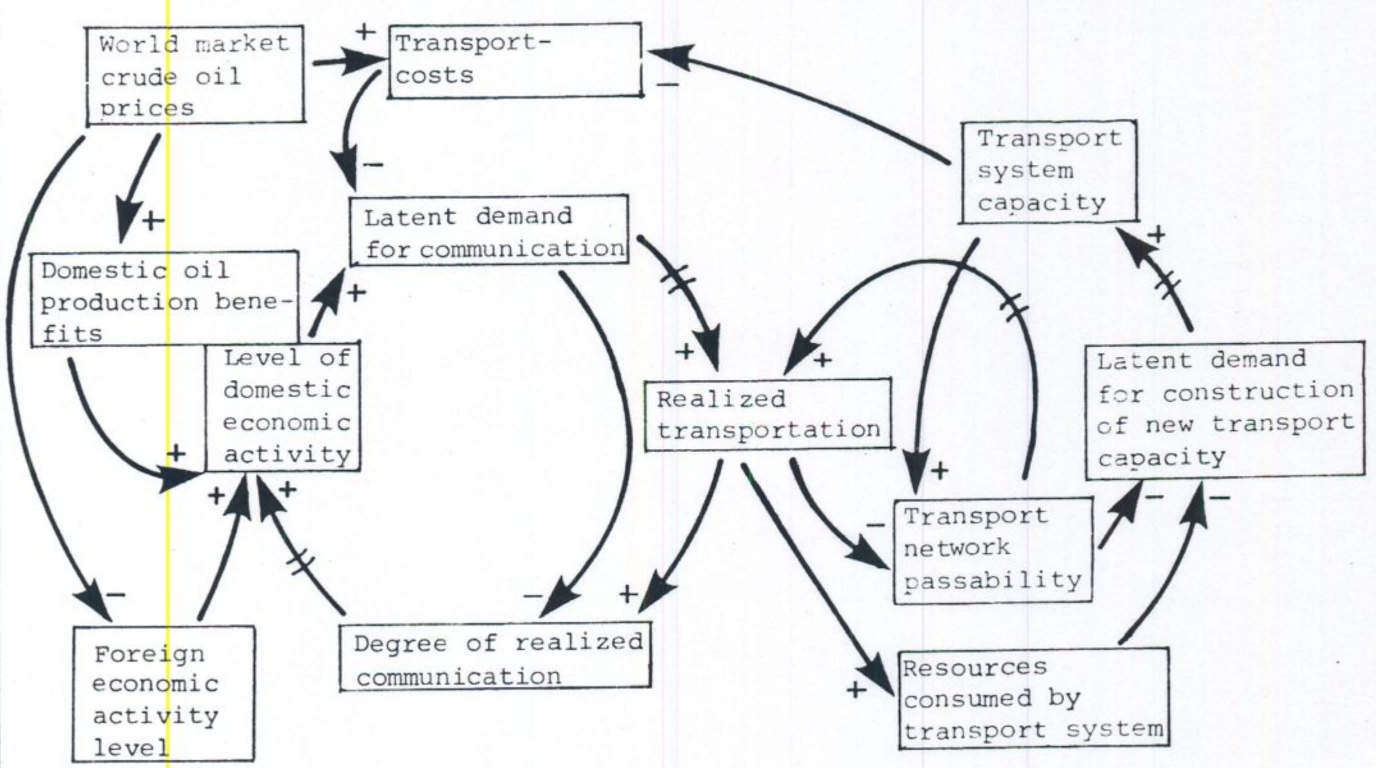
PRINCIPLES BEHIND THE COMPUTER MODEL

The interaction between the different transportation sectors and between transportation and other aspects of society is very complex. No single person can hope to obtain an overall view of this complex set of cause-effect relationships without making simplifications.

Our model is also based on a simplified picture of the real world. However, it contains several hundred concepts.

We shall discuss a few of these concepts in order to give an impression of how the model works and can be used.

To simplify the description we have aggregated all transportation of passengers and information in the figure into a single concept, namely: "Transportation". In this way transportation in the figure is what is necessary to provide communication between people and between people and nature or machines.



The figure (1) shows how changes in the economic activities in the country will influence realized transport and the demand for new transportation capacity. This in turn will have feedback effects on the economic activity level of the community. In real life we have a network of such feedback forces.

In this paper the expression "communication" is meant to have a very wide meaning. We defind all personal travel and transfer of information as a realization of latent demand for communication.

Figure 1

Realized transport is central to the model, and is accordingly found in the middle of the figure. The right hand side of the figure represents the supply part of the transportation sectors. The left hand side represents the demand parts of the model; economic activity and the demand for transport this creates.

In the figure (1) the arrows express the influence between factors. For example as the community's economic activity level increases, we think that the latent demand for communication also will increase.

Two dashes across an arrow in the figure mean that this effect will be more delayed than for other causal relations.

There are positive feedback loops. If the level of realized transport is reduced this may have a restraining influence on the level of economic activity in the country. This in turn will reduce the level of latent communication demands. After some time this will give further reductions in the realized transportation.

There are also negative feedbacks. For example, if the economic activity in the country increases it will, as mentioned, give an increase in the latent communication demand level. But this again will immediately reduce the degree of realization of communication. Furthermore, this will reduce the mentioned growth in the level of economic activity.

THE DEVELOPMENT OF DEMAND FOR COMMUNICATION IS INFLUENCED BY EXTERNAL FORCES

The increase in Norwegian economic activity is determined to a large extent by economic growth in the rest of the world. Our large foreign trade has the consequence that an increase in global economic activity will give an increasing demand for Norwegian products and services. This will increase domestic activity. In addition we have the new and very interesting Norwegian oil resources. Increased oil prices and oil production may increase our domestic economic activity. On the other hand, the increase in crude oil prices will reduce economic activity in the rest of the world and also increase domestic transportation costs. These factors may reduce economic growth in our own country.

THE TRANSPORTATION SECTOR HAS ITS OWN INTERNAL DRIVING FORCES

An increase in the realized transport will at first reduce the passability which indicates increasing demand for development of new road capacity. After some time this may cause an increase in road construction. New roads usually also increase road standards allowing higher traffic speeds, shorter travel time, saving of time costs and thereby reduction in transportation costs. This again will stimulate the latent demand for communication, resulting in turn in a new increase in realized transport.

There are also several negative causal loops in the transportation sector. Two of them try to keep the passability on a constant level. The one is the loop through realized transport and the other through a transport capacity.

In the future the development of transportation will probably be strongly influenced by environmental and resource consumption factors. These forces will try to reduce growth in transport capacity. This effect will be stronger as the consumption of resources in transport increases. Therefore, the effect will b[illegible]e important in the future, but we have already clearly [illegible] this increasing power.

The four transport sectors which are built into the model are represented by four fairly equal model parts. Each part is in principle a copy of the right hand side of figure (1). The four transport sectors of the model are coupled by adding up the traffic volumes to one grand total realized transport volume.

THE INTERACTION BETWEEN TRANSPORT SECTORS IS IMPORTANT FOR TRAFFIC DEVELOPMENT

The transport volume in one sector may increase at the expense of other sectors. The growth of transport in one sector may therefore be much larger than the general increase in the level of transportation. That is probably one of the main reasons for the rapid growth of private car traffic in the 1960's in Norway.

Better conditions for car traffic make it possible to travel longer distances between one's home and place of work and services. This results in extra growth in car traffic, which again increases demand for road capacity.

POLICIES INVESTIGATED

In the model we have tried out several different policies. The public can directly control some of these policies, for example, by charges and dues. Others can only be indirectly controlled. We have analyzed the following policies:

1. Measures to increase the number of passengers in private cars.
2. Increasing fuel taxes and thereby the operating costs of private cars.
3. Measures for direct influence (reduction) of average fuel consumption for new private cars.
4. Improved supply of new telecommunication services and increased telecommunication network capacity.
5. Measures to improve facilities for pedestrians and cyclists.
6. Decreased road capacity development in traffic problem areas.
7. Measures to give bus traffic priority over private cars.
8. Reduction in bus fares.
9. Improvement of travel comfort for bus passengers.
10. Rationing of fuel in the private car sector.

Many of the measures are generally formulated. They may be given effect in different ways. We may use information, propaganda, obligations, prohibition, physical restrictions, fares, subsidies or rewards.

RESULTS OF MODEL SIMULATIONS AND POLICY EXPERIMENTS

The figure (2) will be gradually built up through figures (3), (4) and (6). It shows the *effect* of single policies, that is the so-called robustness (or number of communications for each litre of fuel used for operating cars), and the value of the Norwegian Gross National Product.

Point B in the figure denotes the basic value in year 2005. Points 1 to 10 give the similar value in year 2005 if the respective policies are introduced today. Policies 8 and 9 are not shown because they are at the same point as B.

All the other policies improve robustness, but policies 1 (more passengers), 4 (improved telecommunications) and 5 (better pedestrian systems) which improve transportation and communication will also increase GNP.

On the other hand policy 6 (decreased growth of road capacity), 7 (bus priority) and 10 (rationing fuel) which worsen the situation for private cars will reduce the GNP.

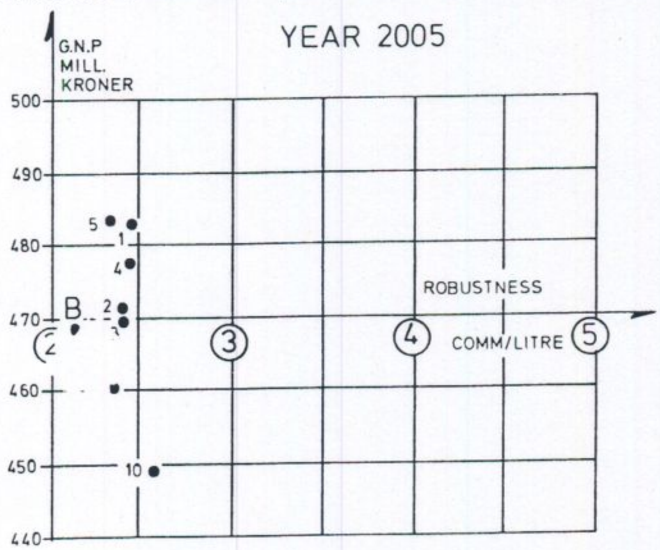


Figure (2) Results of Basic Simulation and Single Policy Experiments show Influence on Both Robustness and GNP for Norway in Year 2005.

The additions made in figure (3) show the effect of introducing stronger measures of the same type as before. The effect is seen to be approximately proportional to the intensity of the policy introduced. The effect of a policy on both robustness and GNP is proportional to its strength, that is the points in the figure all move in straight lines out from the basic point B.

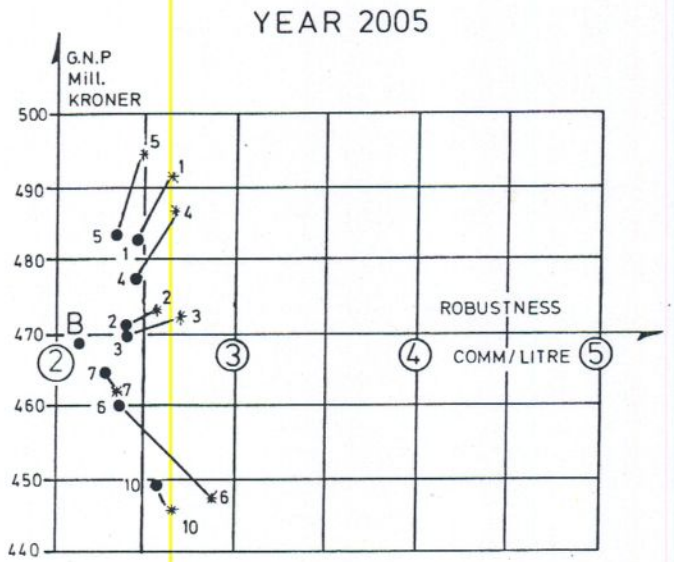


Figure (3). Stronger Measures moves the Performance Indicators Radially out from the Basic Value

The additional points in figure (4) show the effect of combining two policies. Point 45 gives the effect of simultaneous introduction of policy 4 and 5 (improving both the telecommunication and the pedestrian system). All these points are results from different model simulations, but they look like adding up vectors.

Actually the effects of policies do not only add up, but there is also mutual amplification and damping.

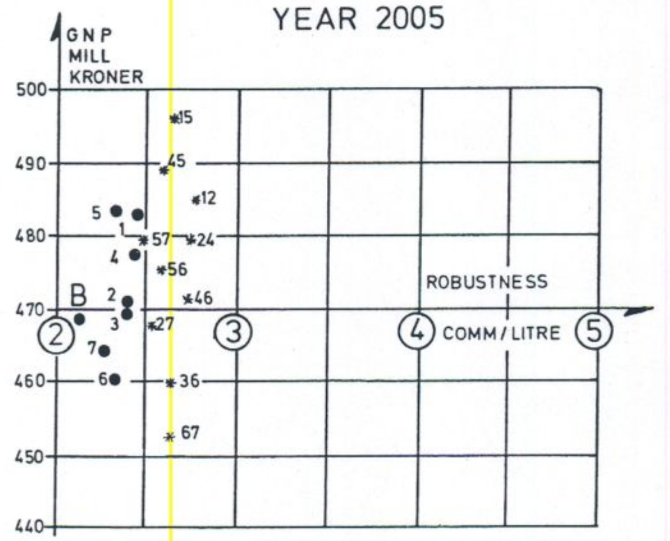


Figure (4). Points with Double Digits Show the Results of the Combination of two policies

The figure (5) shows this amplification phenomenon. At the origin we have no amplification or damping for either robustness or GNP. Point 46 indicates that policy 4 (better communication) and 6 (less growth in road capacity) amplify both robustness and GNP. But for the earlier mentioned combination of policy 4 and 5, both the effects on robustness and GNP are reduced.

The amplification effect varies, but it can be up to +100% of a single policy effect. It means that a combination of policies may very much pay off, and one should take care to combine the right policies.

By combining more than two policies, model simulation experiments show that it is best to combine pairs with high amplifying effect. The resulting amplification may then be higher than the sum of the amplifications of the pairs. For example, combination of policy 4 (improved telecommunication), 6 (decreased growth in road capacity) and 7 (bus priority) into a policy 467 gives a higher amplification than adding the amplification of the three pairs 46, 47 and 67.

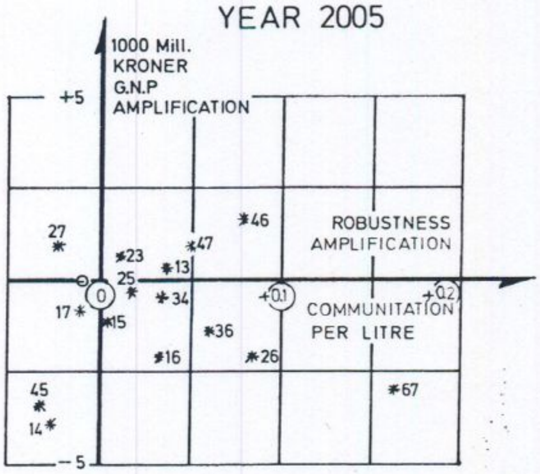


Figure (5). Amplification and Damping Effects by Combining Two Policies are Important Results of the Model Simulations

We will take a look at the final effect to combining more than three policies.

The four digit numbers in figure (6) show the result of simulations with simultaneous introduction of four different policies. We see that the difference in effect of combinations is larger the more policies we combine. Actually the amplifying – and damping – effects will be more important than the original effects. For example, the four best single policies 1, 2, 3 and 4 will not give the best combination of four policies.

The point *12345* shows the result of combining the five first of our policies and the point *123457* shows an example of the result of combining six policies. Finally, the point *1234567* combines the seven first policies.

It seems to be important to combine policies which *restrict* the development of gasoline consuming transport and at the same time to offer new possibilities for transport by systems not consuming gasoline.

Preliminary sensitivity analysis has shown that many of the results presented today are not dependent on uncertainties of the model. But much work remains to be done in this field.

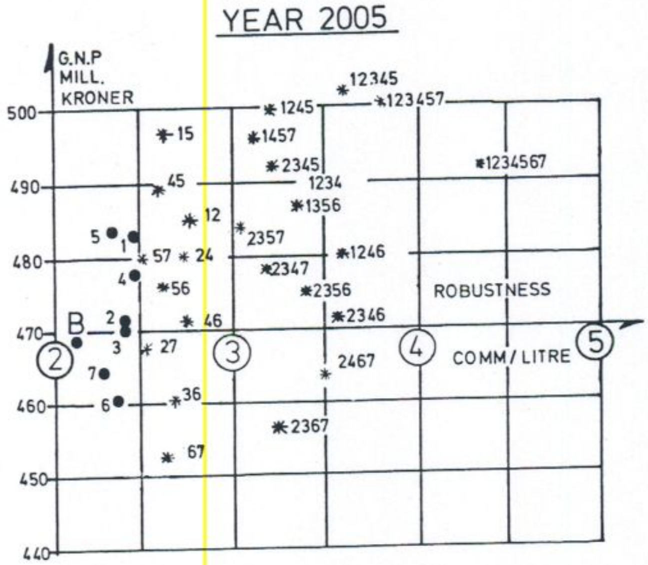


Figure (6). Combination of Policies Originally Intended to Decrease Gasoline Consumption will in the Long Run Also Increase GNP in Norway

MEASURES CAN GIVE THE TRANSPORTATION SYSTEM PROTECTION DURING FUTURE OIL CRISES

By combining the seven first measures the vulnerability of the transportation system by the end of the century may be reduced to half of base future value. This result is dependent on the measures being taken immediately.

The effect of the measures are nearly independent of the rate of increase of oil prices. This makes it unnecessary to wait and see how the oil market develops before taking action.

As mentioned the combinations of several measures can have a stronger effect than the sum of the effects of the single policies. One of the best combinations of *four* policies relating to Norwegian conditions is:

- Measure No.2 (Increased gasoline prices)
- Measure No.3 (Reduced gasoline consumption in new cars)
- Measure No.4 (Increased supply of telecommunication services)
- Measure No.6 (Reduction of road capacity development)

This combination of policies we may call a typical "give and take" combination, where all the policies are saving energy. Policy 2 and 6 reduce traffic and thereby energy consumption by the motoring sector. Policy 3 also reduces gasoline consumption, in combination with the reduction of car operating costs. Policy 4 may give alternative means for those who suffer from bad road conditions. The improved telecommunication service will thereby also save fuel for the transportation.

MEASURES IN ONE SECTOR ALSO INFLUENCE OTHER SECTORS

Policies introduced in one sector usually also affect other sectors.

- Increased number of passengers in private cars makes transportation cheaper. This increase the total demand for transportation which in the long run also implies that the bus traffic also increases. Similar effects also result from a policy of reduced fuel consumption.
- Increased fuel prices reduce private car traffic in the short term. But this effect is reduced over time. The reason is that the high fuel prices influence our purchase of new cars so that we buy more fuel economical vehicles. In addition as time goes by fuel prices will play a less important role in total travel expenses.
- Supply of more and better telecommunications services will increase total demand for communication and transport. The demand for passenger transport is thereby only slightly reduced by new telecommunication services. Private car transportation in particular will remain at a high level while bus- and pedestrian/bicycle-traffic will lose most in the competition.
- Similarly the pedestrian/bicycle-improvement policies will cause substituion of traffic, especially from the bus and telecommunications sector.
- When less road capacity is constructed in traffic problem areas, the energy consumption of the private car sector will be greatly reduced. The vulnerability of the total communication system under future oil crises will not be reduced to the same extent.
- Reserving lanes for the bus sector and otherwise giving priority to buses greatly increases bus passenger traffic. Furthermore this measure have approximately the same effect as the reduction of road capacity.
- Rationing of fuel for the private car sector will increase the bus passenger traffic in the same manner as reserving lanes for the bus sector. By rationing petrol we may, of course, save approximately as much fuel as we want. But this measure also reduces the growth rate of economic activity in the country.

THE NEED FOR FURTHER RESEARCH

Sensivity analyses may indicate the need for further research in different fields. Typical examples are:

- The economic activity growth generation and reduction effect from the degree of traffic and communication realized.
- Similar effect on latent demand for communication from economic growth and crude oil prices.
- The road capacity development resistance effect from environmental and resource preserving pressure groups.
- The effect of change in traffic volume and transport capacity on passability and vice versa.
- Delay of causal effects as those marked by double dashes across arrows in the figure.

In its present form the model shows interesting results. In principle, the conditions in other countries are similar to the Norwegian, but with different weight on the relationships in the model. Analyses for other countries could be carried out by changing the input data, i.e. by varying many of the constants and table functions in the programme.

Minor changes in the programme logic might also be necessary, but that should not be difficult. The main task would be the analysis of the nation's economics and transportation statistics to establish a new set of input data and the calibration of the model coefficients to make the model reproduce historical development.