TRANSPORTATION RESEARCH IN GENERAL AND TRAVELLERS DECISION MAKING IN PARTICULAR AS A TOOL FOR TRANSPORTATION MANAGEMENT

by E. Asmussen, Director of the Institute for Road Safety Research SWOV, the Netherlands.

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1. Introduction

1. The road user problems have already been studied in specific contexts by various OECD Road Research Groups. The findings in these reports and the dearth of effective countermeasures served to highlight the need to examine the total road user system in a more fundamental way and from a multi-disciplinary standpoint. To this end the present symposium was organised by the Ministry of Public Works of Italy under the auspices of the OECD Road Research Programme and it was emphasised that a key theme throughout would be the applicability of present research knowledge to the design and evaluation of preventive action.

2. General theories and models of driver behaviour in practical research, either simple or sophisticated, in principle always contain perception, decision, response and feed-back elements. There are several theories and models for perception and decision processes directly suited to applied research. There are also models for the response and feed-back processes; but there appear to be no workable integrated models dealing with all the four elements, directly suited to application. The theory of driver behaviour has not reached such a level that complete operational manoeuvre models in the field of driver-roadway interface can be described. The more isolated perception and decision elements seem to give a workable basis for practical application.

3. There appears to be a real gap between driver behaviour research and the knowledge gathered from this research on the one hand and the practical rules and solutions of the transportation management, for instance, traffic engineers etc., on the other.

General knowledge as a result of research in the field of driver behaviour can ce applied, for instance, to the design of roads and road networks, the design of traffic situations in general, the design of vehicles, but also to education and training programmes.
In the design criteria for roads and road networks as used by the transportation management you will find hardly any input from driver behaviour research.
The same applies to the design criteria and regulations for vehicles, as laid down by the governments and international organizations and to traffic rules and regulations in general.
Education and training programmes are as a rule not based on knowledge of driver behaviour

obtained from driving task analyses. On this subject for instance Goldstein stated at the 1971 symposium*) "to-day there exists no single study or series of studies from which one can conclude with confidence that current driver education programmes do or do not have an effect on subsequent driving records of the graduates, compared with records of drivers who are informally trained." Planek, a representative of the National Highway Safety Council, responsible for the education programmes in the United States, presented in his paper at that symposium a first plan for assessing driver education on the basis of driving task analyses.
The above mentioned examples show how little use was made of the results of driver behaviour research. We must therefore conclude that from a society point of view the effectiveness of the research in this field is rather meagre. This must be considered as a serious problem, as the results of decisions in the field of transportation (positive and negative effects) have a great impact on the welfare of society and research results have to be important tools for transportation management decision making.

2. Transportation decision making scheme

The question is now, what can we do about this? One has to realize that the decision process for policy makers in the field of traffic and transport is in fact a difficult process. They have to deal with a complex problem with many aspects such as political, economic and social.

It would seem useful therefore to analyze the decision process related to transport and traffic in order to supply the right answer to the following questions.
1. What information is needed for the different stages of the decision process and how should research conclusions and results be presented for instance to the policy makers or to the transportation management?
2. How should research be structured and organized in order to yield the greatest efficiency?
3. What priorities should be given to research programmes in different fields and on different subjects?

Figure 1 visualizes the decision process relevant for the transportation system.
The quality of the transportation system can be described by the value of a number of production aspects, such as intensity, travel time (speed) and unwanted adverse aspects. such as unsafety, pollution, noise, and so on.
In Figure 1 these aspects of the system are given under the collective name "transportation quality characteristics". At the foot of Figure 1 the quality characteristics, as observed in the actual traffic situation, are indicated by C_{oi}, the subscribed i refers to each of the quality characteristics such as travel time, unsafety, etc.
Policy makers should make their views on the requirements of society with respect to these transportation quality characteristics explicit, if possible in terms of numerical values. These socio-economic requirements with respect to the transportation quality are indicated by C_{wi}.
It is the task of the transportation management to run the system in such a way that both in respect of the long-term and the short-term policy, the system meets these requirements.

*) The symposium on psychological aspects of driver behaviour organised by the Institute for Road Safety Research SWOV at Noordwijkerhout, The Netherlands.

The discrepancy between C_{wi} and C_{oi} is in fact the stimulus for activities. In this case we must realize that C_{wi} has not a constant value, but changes in time, depending on society conceptions. If there is a discrepancy - and there will always be discrepancies - measures have to be taken which will affect C_{oi} in such a way that the discrepancy is reduced.

These measures can be taken in the field of physical and socio-economic planning, in the field of system building and in the field of system operating, all instruments, indicated as labels on the lines of the transportation management decision making.

Measures on physical and socio-economic planning affect the existing provisions for socio-economic activities, as measures on system building influence the existing transportation networks and system operating measures influence the existing provisions for traffic control and regulations. These changes in the provisions in turn influence the transportation needs and the transportation facilities and limitations.

Transportation needs and transportation facilities and limitations, again indicated as labels, are the "input" conditions for the travellers system. It is in fact the travellers decision making process that finally determines the output of the whole system, described in terms of the transportation quality characteristics C_{oi}.

3. Contribution of transportation research

The task of the transportation researcher now is to assist the transportation management in selecting the right measures. In order to be able to do so he has to make objective and reliable measurements of the output C_{oi} in quantative terms and he has to make a prediction of the influence of all possible measures (M_j) on C_{oi}. A first selection of measures could be based on the sign (positive or negative) of the fraction $\Delta C_{oi}/\Delta M_j$ for each of the transportation quality characteristics as related to the socio-economic requirements. In this fraction ΔC_{oi} is a notation for the change of a specific quality characteristic as influenced by a specific measure. If one measure influences more than one quality characteristic, weighting factors have to be introduced in order to make costeffectiveness considerations possible as a further selection mechanism.

The transportation management have to make their decisions based on the above mentioned contributions of the research institutes. All measures are directed to influence the travellers system, and therefore the effect of these measures can only be predicted and interpreted if there is enough knowledge available of this travellers system and particularly of the travellers behaviour. That is to say, the prediction of the full effect of a measure is only possible if all intermediate effects and interactions in the processes in figure 1 are analyzed. This in not always understood by the transportation management. They are as a rule not interested in the intermediate effects and in the whole process between the measures and the effect of measures in terms of transportation quality characteristics. This probably is one of the reasons why the results of driver behaviour research have until now seldom been used in taking practical measures. In fact they are only interested in the prediction of the ultimate effect of their measures on the output of the system, for instance the ultimate effect of speed limits on road safety, while traveller's decision making often is assumed as a more or less constant component of the process.

Therefore it is the task of the research institutes to convince the transportation management that research into all the intermediate effects on the process is necessary in order to be able to interpret the full effects of measures on the output in terms of quality characteristics.
The following arguments may be of some help in convincing the transportation management:
1. The same measure may have different effects depending on different intermediate interactions in the same way as different measures may lead to approximately the same effects.
2. The lack of agreement in the relationship between measures and their effects on transportation quality characteristics forces research into a pure input-output model without analyzing the intermediate effects to study again and again the effects of the same measures in different circumstances and conditions. In practice facilities for such a laborious approach are not available.
3. A detailed study of the entire process and of all intermediate effects enables us to generalize the research findings of sub-processes of traveller decision making and behaviour in a much wider field and for more than one type of measure. It also enables us to predict the effect of new measures that have not been applied in practice. Basic knowledge of sub-processes therefore offers the possibility of a more conceptual long-term policy approach. The conclusion may therefore be drawn that in this whole process, traveller decision making and in the case of private transport, manoeuvre behaviour take up a central position.

Should a general division in research objects be necessary, it would seem logical to give a division as indicated by A, B, C and J in Figure 1.
The research objects of category A concern the relationships between all possible measures (M_j) in the field of transportation management and transportation needs, facilities and limitations. This kind of research is mostly carried out by physical planners, civil engineers (road constructors), traffic engineers, etc.
The research objects of category B refer to the effects of transportation requirements, facilities and limitations on travellers decision making and behaviour.
The research objects of category C cover the influence of travellers behaviour on the transportation quality characteristics C_{oi}. Integration of the isolated research objects (category J) will lead to a general relationship between measures and quality characteristics. If the results of research into category B objects (being travellers behaviour research) are not integrated in category J research, the practical value of category B research is very low for the management decision making process. This being quite often the case, is perhaps the main reason why the results of (driver)behaviour research have seldom been used for practical measures.

In the decision making process and the behaviour of travellers one can discern microscopic (individual) and macroscopic "sum total" behaviour. Both can be divided into four hierarchically arranged levels. This is elaborated in Figure 2.
The first behaviour level concerns the social activity that generates traffic. As far as individual travellers behaviour is concerned the selection of destination and the time schedule are relevant. At the second level, the selection of the mode of transport is relevant. The third level entails the more detailed selection of the route and itinerary, and the fourth level is related to the selection of manoeuvres by the driver. Of course

not only the selection process is important at all these levels, but also the realization of the choice.

Talking about the "sum total" behaviour we must realize that this is a kind of macro-product of very heterogeneous and individual travellers behaviour. It can therefore not be described in terms of group behaviour of a collectivity. As long as this is the case, research into individual behaviour is necessary in order to interpret the "sum total" behaviour and to predict the effect of measures on the "sum total" behaviour.
On the other hand prediction of the "sum total" behaviour is necessary to predict the influence of measures on the transportation quality characteristics. The "sum total" levels are described in Figure 2 as:
1. trip generation and trip distribution,
2. modal split,
3. assignment,
4. traffic flow.

The higher the behaviour level considered, the more the relations between transportation and society will be involved; the lower the behaviour level the more important the interaction between driver, vehicle and the road will be. In view of this it might be logical to structurize the traveller (driver)behaviour research according to the four above mentioned behaviour levels.

4. Elaboration and realization

Transportation research can be seen as a help and a tool for the transportation management. Therefore the aim of that research into the different levels should not only be the description and explanation of driver behaviour at each of the four levels, but is should also lead to the possibility of predicting all possible measures by which the behaviour can be influenced or manipulated. Transportation needs and transportation facilities and limitations are the input conditions for this driver behaviour research. Driver behaviour research, however important it may be, only functions as a link in the total process. The driver behaviour and the changes in that behaviour should be translated into terms of transportation characteristics (see Figure 1).
Transportation management tools or instruments can be divided into measures in the field of physical and socio-economic planning, system building and system operating. All these measures may influence the travellers behaviour at the four levels. Thus knowledge obtained by research into these four levels is necessary for the assessment of planning, building and operation measures as well as to predict their effects.
However, depending on whether the research results are applied to planning, building or operation, there is a difference in type of information and in the presentation of the results: The planning decision makers on the one hand have a greater need for general or basic principles etc., which they can use in their long-term programmes, the system operating decision makers on the other, especially require more detailed information, which they can use in their mostly short-term programmes and ad hoc solutions.

Research institutes have to make a systematic analysis of the practical problems, and they

have to carefully judge the decision process of the decision makers and their need of research information, in order to determine what the research institute can contribute to this process.

In a systematic approach the problems have to be stated and analyzed. It is the responsibility of the transportation policy makers to do so. In practice, however, it will be necessary that the problem analysis is carried out in co-operation with the researchers. In fact in general the problem is the discrepancy between C_{wi} and C_{oi}. We have to find out whether it is the difference between C_{w1} and C_{o1} relating to the capacity (intensity) of the system or C_{w4} and C_{o4} relating to safety or to a combination of quality characteristics. A stock-taking of all relevant solutions has to be made in the meantime.
On the basis of problem analyses and stock-taking as well as of the knowledge on research objects A, B and C, functional requirements for the solutions can be derived at. In the case of these functional requirements and long-term conceptions it is possible to evaluate a number of solutions with respect to cost-benefit considerations. The transportation management then choose on a basis of predictions of the effects one of several solutions or package of solutions. Finally the research institutes have to verify the effects in the actual world situation, in terms of changes in travellers behaviour and in transportation quality characteristics.

The research institutes can only do so, if there is a possibility to work in close co-operation with the policy makers as well as with the transportation management. In the entire decision process there is a stage that the decision makers and researchers join hands in the same way as in a relay race in athletics.
The stick symbolizes the information supplied by the policy maker to the researcher for problem analysis and by the researcher to the transportation management in the interpretation of the research conclusion and results.

In addition to this, the research institutes can also make long-term predictions on their own initiative about a possible development of the transportation system in terms of quality characteristics in the case of an extrapolation of the past policy. They may furnish the tools for long-term planning in terms of advising packages of measures that could lead to an improvement of the output of the system. That is to say, fewer accidents, less pollution, and so on. The research institutes should be in a position to publish this long-term advice without any restrictions by the policy makers.

5. Priorities for measures and their implication on driver behaviour research

As mentioned earlier, measures should be based on results of scientific research.
This conclusion has some implications on the quality, the scope and the priorities of the research to be carried out.

Measures to be discussed during this symposium are concerned with improvements in the driver-vehicle-roadway system, which may be discussed in terms of road users sensing, information processing, decision and operating capabilities.
Five classes of measures are to be distinguished:

1. Optimizing information displays (for instance traffic signs, road markings, vehicle lights);
2. Response and feed-back manipulation (automatic steering and guidance systems);
3. Introduction of decision assisting devices (for instance electronic route guidance system, passing aid system, car-following displays);
4. Automation of decision making (for instance traffic signals, ramp metering, and so on);
5. Response optimizing (vehicle control characteristics; the vehicle/roadway interface).

There are indications that the traditional control and regulation measures can only contribute in a limited way to a further improvement of the quality of the system. There is therefore a tendency to expect a greater effect from more non-traditional measures in this field, such as the aid of electronic equipment or systems.
However, it should not be forgotten, that these conclusions are based on the experience of present-day measures, mostly proposed by the transportation management. These measures are seldom based on driver behaviour research. They are only based on the impressions about the "sum total" behaviour and not on the results of individual travellers decision making processes and behaviour, carried out in research projects such as driving task analyses, etc. An interpretation of the observed changes in the "sum total" behaviour is therefore not possible. In fact a sound prediction of the influence of a measure on travellers behaviour is hardly feasible. If the introduction of non-traditional measures is not based on travellers behaviour research there is a great chance that the present optimism about the positive effects of these measures is not justified.

There is still considerable room for improvement with regards to the transportation networks in detail (for instance better roads) or as a whole (for instance better transportation networks). This is illustrated by considering motorways versus single carriage-way roads.

From accident statistics we learn that there are great differences in accident-rates on different types of roads, for instance the accident-rate of the well-designed motorways in the Netherlands is nearly one fourth the accident-rate of the single carriage-way roads with about the same traffic density per lane.
On the latter type of road the accident-rate is gradually increasing with the intensity. The total accident-rate for rural roads, however, is dropping. This could be explained by the fact that the greater part of the total mileage takes place on the motorways. Compared with the total network more motorways and dual carriage-way roads are built in the Netherlands.
One of the reasons that a motorway is so much safer and has a greater capacity per lane might be that the traffic flow is more homogeneous, there are fewer potential conflict situations. This would imply that the driving task is less complex. Task enlightenment seems to be a basic principle for a better performance.

As regards motorways, optimizing information displays such as traffic signs, road markings and so on might give some further improvement as the speeds are relatively high, therefore long distance information is necessary and the available decision time very short.
Especially in the field of vehicle lighting some important improvement is possible by

"quickening" the type of displays. The information needed is given explicitely in a form that does not require elaborate mental operations by the driver, for instance a specific signal for emergency braking in addition to the existing braking signal.
Introduction of decision assisting devices (for instance electronic route guidance system, electronic signalization, electronic traffic control, ramp metering, etc.) are also able to lower the frequency of multiple crashes (pile-ups).

As regards the single carriage-way roads with mixed traffic probably some gain may be obtained by improving traffic signs, road markings, and so on, particularly on rural roads with mixed traffic.
On these single carriage-way roads there are still so many difficult and hardly predictable traffic situations inherent to the type of road that the principle of task enlightenment can hardly be applied by only improving the road characteristics without changing the entire concept of these roads. Therefore a small gain was to be expected from improving traffic signs, road markings and other work on the road itself. Better display systems on the vehicles for rear lighting, especially for indentifying the category of vehicle, might be an improvement.
In addition more radical measures directed at uniformity of the traffic flow components based on the dynamical characteristics will also be fruitful, there will be less variation in the traffic stream, which leads to better predictability, for instance categorization of roads, vehicles, etc.
Introduction of decision assisting devices (such as passing aid systems, electronic route guidance systems, etc.) can certainly improve the situation on single carriage-way roads, but in practice this will appear to be too costly.

As far as electronic aids are concerned we are faced with basic questions related to the allocation of tasks, dependent on the ingenuity of man and the efficiency of the machine. In transportation system research this line of approach has to be specified according to different capabilities in sensing, information, processing, decision and operation in different driver tasks under different driving conditions and for often unknown driver population and vehicle (steering) characteristics.
The decisions of the transportation management to introduce electronic devices for decision assistance should actually be based on this kind of task analyses.
Special attention should be paid to the predicted effect on the behaviour of the road user, that is to say how and in what way can the behaviour be manipulated by the decision assisting devices and under what conditions.

As I mentioned earlier the research of sub-processes such as traveller decision making have to be generalized.
In experimental research into driver behaviour there are still essential questions unresolved concerning the generalization from
- usually highly motivated test persons in the experiment versus the less interested driving population in the actual world situation;
- optimal test conditions versus less optimal driving conditions;
- relatively simple perceptual motor tasks or isolated driving part tasks versus more complex driving;
- artificial risk versus hazardous situations.

The researcher should pay considerable attention to the validity of his experiments in actual world situations.
This is only possible if the researcher is in a position to verify the results of his research, as they are applied in real measures, to real world situations. We must not forget that the advice of the researcher to the transportation management on measures or aspects of measures functions as a prediction that has to be verified. This is a basic principal for empirical research. Again this shows that direct and close co-operation between researchers and the transportation management is essential, but also in order to give the researcher facilities to obtain the feed-back necessary for systematic research.

6. International co-ordination

Most motorized countries have to cope with the same kind of transportation problems, although there may be differences in the specificity or generality of problems and in the time they arize, probably as a function of differences between countries in the degree and kind of motorization. Research in the various countries has therefore to deal with the same problems.
From the viewpoint of the road user, but also from an efficiency point of view there is a need for uniform rules and regulations concerning the vehicle (for instance lighting system), the driver (for instance alcohol and driving rules), the road (for instance markings, signals and signs) within the uniform principles for classification or categorization of roads, vehicles, etc.
Therefore more and more transportation policy and management decision making have to be carried out at an international level. It is obvious that this calls for close co-operation between research organizations and decision makers at an international level.
Most of the international rules and regulations are prepared by ECE or CEMT working parties. This procedure does not, however, guarantee uniformly applied solutions in different countries, because of varying national needs. It is found that for most of the specific short-term actions contemplated, systematic treatment in terms of general and long-term goals is lacking. This does not create much room for a more conceptual and problem-oriented discussion, including the systematic assessment of alternatives for actions. The international decision making process, however, is apparently even more complicated than the national one, and can in fact also be analyzed and structurized in the above mentioned way.
Especially the systematic treatment of problems in terms of problem analyses, stock-taking of all relevant solutions, the drawing-up of functional requirements for the solutions based on the research findings and so on, is essential. As research results should play an important role in this process, international exchange of research findings is a sine qua non.

In the matter of international co-ordination of road safety and traffic research, OECD covers a wide field: documentation and information retrieval systems, co-ordination of research projects, enhancement of contacts between researchers especially on conceptualization of research, measurement techniques and design aspects of research.

7. Scope of this symposium

At the end of my introductory paper I should like to put forward some comments on the scope and substance of this symposium.

In the first place, the emphasis of this symposium is on (counter)measures, relating problems (regarding perception, information processing, decision making and operation) of road users to the driving tasks, the conditions and the environmental stimuli. This means that we have to take into account practical aspects associated with an introduction of improvements of systems already existing or with the introduction of newly developed systems.

Secondly, the papers presented at this symposium suggest that research on road user perception and decision making is in the fore-front of general perceptual and decisional research. This situation promises future research with research results that are applicable to the conceptualization of measures.

Finally, I want to mention that the present social interest is more and more directed towards the undesirable adverse aspects of the transportation system. These aspects call for a more society oriented approach of the transportation problem, as, in fact, the higher behaviour levels do (see figure 2).

On the other hand although research is carried out into the higher behaviour levels, this research is mainly non-experimental (survey research). Thus the conclusions are limited and only applicable to the existing situation.

A symposium concerning this subject would no doubt be very stimulating for the experimental research in this field.

Figure 1. Transportation decision making scheme

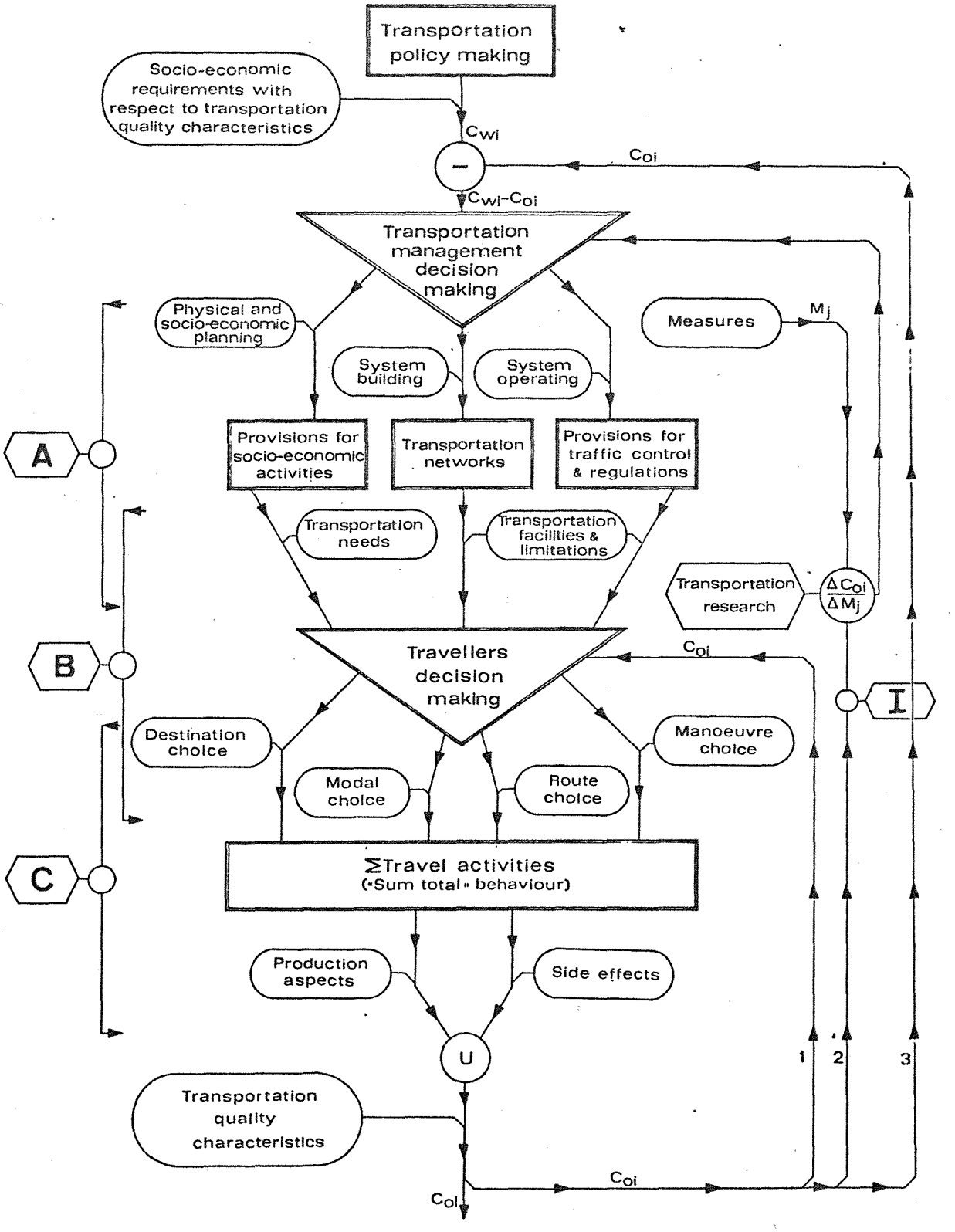

Figure 2. Decision- and behaviour levels and quality aspects