DECISIVE CONDITIONS FOR AN EFFECTIVE AND EFFICIENT MULTI-MODAL FREIGHT TRANSPORT NETWORK IN EUROPE: A META-ANALYTIC PERSPECTIVE

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1. Europe as a Midas

The recent developments in Europe show the signs of a Midas: a beast with many heads. There is European integration, and even a strong trend towards a coherent European network [1]. There is at the same time an unprecedented rise in mobility which causes so many social costs that the basis for integration benefits are gradually eroded. And finally, there is an overwhelming interest in Trans European Networks (TENs) which favour the economic-geographical centres of Europe, but which deprive the less accessible regions [8]. Consequently, the development of Europe leaves us with some ambivalent feelings which will concisely be discussed now.

First, a rapid extension and/or improvement of transportation and communication infrastructures are becoming a vital prerequisite for the competitiveness of the European economy [2]. This also provokes issues of effective transportation and regional policy. This is once more needed, given the changing role of governments in the transport sector (deregulation, devolution etc.). A really European transport policy will only become successful, if it takes a network view on the whole of European transport and communication infrastructure [3]. This means that missing networks, competing networks and complementary networks are key concepts in developing fresh ideas on European transport and communication policies [4].

Second, the increased emphasis on transport and communication will provoke a rapid rise in mobility which may be at odds with spatial sustainability. Mobility levels are increasing across all European countries as more travel is undertaken by road and air, and as the new informatics infrastructure is established. Communications in Europe have never been easier or cheaper. Each major innovation in transport and communications in the past has resulted in more efficient links between people, organizations and countries, and this in turn has led to increases in levels of interaction. Society is in transition from one based on manufacturing and services to one based on information and leisure. This move to a post-industrial society is reflected in the major new investments in the existing infrastructure (e.g., in high speed railways and air traffic control systems) and in new infrastructures (e.g., logistics networks and fibre optic networks). But the net result of this mobility is an unprecedented destruction of natural environments and landscapes, a drastic reduction in quality of life (e.g., noise annoyance) and a rapid rise in air pollutants affecting the global climate.

Finally, there are many regional disparity issues involved in current transportation policies in Europe. The large-scale investments in TENs are often favouring the less central areas. Thus, we are facing a situation where regional development objectives may conflict with an efficient operation of the transport market. In recent years we have observed that various Community Support Frameworks have been designed based on the policy view that investments in infrastructure are not necessarily made in those sectors or locations where the greatest economic benefits will be obtained, but for other development reasons to assist peripheral or underdeveloped areas. Even if investment is made for non-economic reasons, good connections from the periphery to the centre may still be to the advantage of the centre.

A major challenge is now to identify policies which would ensure a compatibility between the above mentioned major concerns. In this context, there is an increasing interest in Europe in multimodal transport, through which the benefits of the European network can be maximized, the environmental burdens reduced and the spatial accessibility issues mitigated. Seen from this perspective, the present paper aims to map out various recent issues in integrated European network policy with a particular view on the complementary and competitive roles of road and rail as the backbone of the European transport network. A major part of our analysis is based on views obtained from European experts. This empirical application is based on specific methods for qualitative data analysis, viz. rough set analysis and factor analysis.

In the present study, we focus on the success condition for a properly functioning freight transport network in Europe. A network is defined here as a cohesive set of infrastructure links (edges) connecting concentrations of people or economic activity centers (so-called nodes), with a view on the utilization of these infrastructure links by transport actors. As noted above, the present study is mainly concerned with the rail-road multi-modal freight transport network [7]. There are three main characteristics of such a network. First, the interoperability which refers mainly to operational and technical uniformity which allows actors and operators to use a network for different simultaneous or sequential purposes. Second, the interconnectivity which is in particular concerned with horizontal coordination and access to the network from different geographical areas. And thirdly, the intermodality which addresses the issue of a combined use of different transport modes in the chain of freight transport [7] [8].

The present study aims first to evaluate the current state of the rail-road freight network in Europe and then to trace the properties of a properly functioning network and finally to define relevant success conditions. In this perspective, the study adopts a European view on infrastructure networks as seen by relevant decision-makers who have to design a policy towards the improvement of the present system. The network will be assessed from the viewpoint of three main dimensions: environmental, economic and services (customers' satisfaction).

2. Evaluation of European Network Performance

2.1 Evaluation of the current performance and state

In the paper, an evaluation framework will be designed for assessing the efficiency and the state of each mode separately and of the network as a whole. This will be pursued at two levels. First, the technical elements of transport systems and their operational aspects will be evaluated. Secondly, the operational-managerial characteristics will be considered. The crucial relative advantages and disadvantages of each mode will be identified and assessed and the relevant trends will be assessed. This approach leads to the determination of the characteristics (environmental, economic, service/network) of a «proper» or satisfactorily operating freight transport network. Such desired attributes will be defined for each mode and for the entire system. The information that will be used at this stage of the study originates from existing European statistics as well as from a questionnaire addressed to a broadly composed panel of transport experts in Europe.

2.2 Identifying and assessing the current barriers and success factors

In this step the study will trace, identify and assess the decisive barriers that prevent a well-functioning operating of the freight road-rail network. These factors will be traced at two levels: the supply side and the demand side. The issue of achieving a satisfactory freight transport network will be examined. For designing the necessary policy the crucial success factors have to be carefully studied and their relative importance systematically assessed. For the identification of both current barriers and success factors the so-called Pentagon model will be used. This model distinguishes the relevant barriers into five main categories: financial, organizational, hardware, software and ecological barriers[7][9].

2.3 The evaluation framework for the current performance and state of road-rail freight transport

Freight transport, and transport in general, is a logistic system performing a specific economic task that is useful for individuals and society as a whole. This man-made system operates in the environmental, economic and institutional framework of society and it is interrelated with other man-made and natural systems [9]. An evaluation framework should consider all such physical, economic and institutional perspectives of the system. An ideal evaluation would be to define a reference point of benchmark by means of which the system might be characterized as "good". This might also be done separately for the main aspects of the system. However, such an absolute evaluation is hardly achieved in open partial and small systems. For the freight transport sector, we cannot define reference-point levels at which the system can be said to be environmentally sustainable, economically efficient and socially appropriate. All we can do is to assess the relative environmental, economic and social performance of the system. Relative evaluation means to compare the system's performance with the respective performance of another system of a similar type or with its performance in the past or future (i.e., a benchmark approach).

As a result, this evaluation basis leads to a number of indicators that are able to systematically operationalize it; indicators reflecting the efficiency of the system will have the form of ratios (quotient indicators). The numerator will be the useful outcome (transport service) of the system, expressed in either physical units or in monetary values. The denominator will be the natural inputs and the waste in the case of environmental efficiency, and economic cost of the inputs in the case of economic efficiency. In fact, these indicators form a suitable basis for analyzing specific case studies, since the conditions differ significantly between European countries.

2.4 The evaluation framework for the barriers preventing the development of a «desired» multi modal (rail-road) network

The identification and the assessment of the relative importance of the barriers in a transport system is faced with considerable difficulties, since the relevant literature and available statistics are limited; in particular, when the analysis concerns all European community countries, each one presenting particular characteristics and specific problems. Therefore, in the present study a survey approach among European transport experts will be used. It aims at identifying the crucial barriers at the national and international European level.

2.5 Description of the survey

Several policy reports suggest that intermodal freight transport incorporates considerable advantages in comparison to single mode transportation. The question is now whether multi-modal transport reaches a sufficient or desired level in Europe; and if not, which the main barriers are that prohibit such a development. Clearly, the direct assessment of the state of multi-modal transport as well as the identification of the relevant obstacles face incommensurable problems, since both relevant studies and empirical statistics are scarce. In order to cope with this problem, a survey study has been designed in the framework of the present research. Its basis is a comprehensive questionnaire among European experts which deals with two classes of issues. Part 1 asks for an assessment of the gap between the current intermodal transport and the corresponding desired level. Since a critical factor for an effective multi-modal network is the existence of intermodal terminals, Part 1 assesses also their present availability in relation to the respective desired level. All assessments take place at both the national and the international (European) level. Part 2 of the survey questionnaire deals with the main barriers preventing the development of effective multi-modal transport. These barriers are classified into the five Pentagon groups: financial, organizational, software, psychological and hardware.

3. Methodology of Rough Set Analysis

The questionnaire was held among freight transport experts in all Western and Central European Community countries plus Switzerland. The opinion of each expert was asked for separately for the respective national and (European) international level. A concise presentation of some findings is given in Annex 1.

The total response to the questionnaire was 60 (response rate 75%). Clearly, this sample is entirely not sufficient for applying standard statistical methods. Therefore, a recently developed nonparametric statistical method concerning data analysis is used. This is rough set analysis developed by Pawlak (1991) and Slowinski (1993). We will first give a concise introduction to rough set theory (see also [11] [10] [12] [5].

A rough set is a set for which it is uncertain in advance which objects belong precisely to that set, although it is in principle possible to identify all objects which may belong to the set at hand. Rough set theory takes for granted the existence of a finite set of objects for which some information is known in terms of factual (qualitative or numerical) knowledge on a class of attributes (features, characteristics). These attributes may also act as equivalence relationships for these objects, so that an observer can classify objects into distinct equivalence classes. Objects in the same equivalence class are - on the basis of these features concerned - indiscernible. In case of multiple attributes, each attribute is associated with a different equivalence relationship. The intersection of multiple equivalence relationships is called the indiscernibility relationship with respect to the attributes concerned. This intersection generates a family of equivalence classes that is a more precise classification of the objects than that based on a single equivalence relationship. The family of equivalence classes that is generated by the intersection of all equivalence relationships is called the family of elementary sets. The classification of objects as given by the elementary sets is the most precise classification possible, on the basis of the available information.

The indiscernibility relationship and the equivalence classes generated by this relationship make up the basic concepts and building blocks of rough set theory. A set is now coined rough if it is impossible to build it up from one or more elementary sets. In other words, a set is rough if it is not equal to a union of elementary sets. In this framework, two new concepts are introduced, viz. the lower and upper approximation in order to identify a range of uncertainty for the assignment of objects. The lower approximation of a set V is the union of all elementary sets that are a subset of V. The upper approximation of a set V is the union of all elementary sets that have a non-empty intersection with V.

This approach leads thus to an imprecise representation of reality due to the 'granularity' of knowledge; in other words, reality is represented by 'granules', corresponding to the elementary sets, i.e. subsets of the universe whose elements are indiscernible (indistinguishable) by the set of attributes used, because they present the same description in terms of the values of these attributes. The 'granularity' of knowledge representation is used to define the key concepts of rough set theory. The size of these 'granules' depends, naturally, on both the number of attributes used for the description of the objects and the domain of each attribute. With a suitable variation in these two quantities it is possible to obtain a variation in the dimensions of the 'granules': an increase in the number of attributes and in the number of values which each attribute can assume, results in more 'granules'.

Next, lower and upper approximations can be determined on the basis of the typology ('granules') generated by the available information on the elements of the relevant set (indiscernibility relation), that is, on the ability to observe some real phenomena (objects), classify them and distinguish them on the basis of the information obtained from real-world observations or of prior knowledge from an expert. The representation of reality by means of rough sets is therefore based on the knowledge (objective or subjective) on reality and the capacity to classify the information obtained.

Now we may introduce the concept of a reduct. A reduct is a subset of the set of all attributes with the following characteristic: adding another attribute to a reduct does not lead to a more accurate classification of objects (i.e. more granules), while elimination of an attribute from a reduct does lead to a less accurate classification of objects (i.e. less granules).

Finally, the core of a set is the class of all indispensable equivalence relationships. An attribute is indispensable if the classification of the objects becomes less precise when that attribute is not taken into account (given the fact that all attributes have been considered until then). The core may be an empty set and is, in general, not a reduct. An indispensable element occurs in all reducts. The core is essentially the intersection of all reducts.

Based on the previous concepts, rough set theory is now able to specify various decision rules of an "if then" nature. For specifying decision rules, it is useful to represent our prior knowledge on reality by means of an information table. An information table is a matrix (objects rowwise, attributes columnwise) that contains the values of the attributes of all objects. In an information table the attributes may be partitioned into condition (background) and decision (response) attributes. A decision rule is then an implication relationship between the description of the condition attributes and that of a decision attribute. Such a rule may be exact or approximate. A rule is exact, if the combination of the values of the condition attributes in that rule implies only one single combination of the values of the decision attributes, while an approximate rule only states that more than one combination of values of the decision attributes correspond to the same values of the condition attributes. Decision rules may thus be expressed as conditional statements ('if then').

In this way one may analyze in greater depth the information contained in the original table and to enrich it, specifying additional decision rules directly by means of suitable interviews or discussions with experts. In other words, it is possible to acquire information also directly in the form of decision rules supplied by experts, thereby enriching the original information contained in the decision table.

In practice, therefore, it is possible to use both the decision rules obtained by elaborating the data contained in the decision table and, if necessary, in further rules supplied and suggested by experts. The former may be accompanied by an indicator of their "strength", for example, the frequency (absolute or relative) of events in agreement with each decision rule. Moreover, both the former and the latter may be based on suitable and different sets of condition attributes, containing a larger or smaller number of attributes (even a single attribute). This last case implies that the value assumed by an attribute is sufficient to guarantee that the decision attribute (or attributes) will assume certain values, whatever the values of the other condition attributes. This consideration assumes particular importance when incomplete information is used, that is, when some values in the decision table are missing or are uncertain (empty cells). Decision rules which do not use condition attributes containing imperfect information assume particular importance in such cases, since they make it possible to operate without the knowledge of these values.

Decision rules, which constitute the most relevant aspects of rough set analysis, may be applied immediately in order to offer recommendations and advice in problems of multi-attribute sorting, that is in the assignment of each potential action to an appropriate pre-defined category according to particular aims. In this case, the classification of a new object may be usefully undertaken by a comparison between its description (values of the condition attributes) and the values contained in the decision rules. These are more general than the information contained in the original decision table and permit a classification of new or additional objects in larger numbers and more easily than would be possible using a direct comparison between these and the original examples. In general, such decision rules allow to make conditional transferable inferences, as the 'if' conditions specify the initial conditions, while the 'then' inference statements highlight the logical valid conclusions. In this way, rough set analysis can also be used as a tool for conditional transferability of results from some case study to a new situation. The mathematics of rough set is rather complicated, but has been properly described in the literature [10] [11].

4. Results of the Rough Set Analysis for Road-Rail Systems

4.1 Introduction

This section presents the results of the rough set method on the survey questionnaire of our study. Although rough set analysis may be used for identifying decision rules and performing multi-attribute sorting, we will rely on particular in the concepts of a reduct and the core of attributes which are used in our analysis. Each expert questionnaire is now considered as an object in a rough set method. There are four independent variables (decision variables):

- the gap of current intermodal transport with respect to the desired level at the national level
- the gap of current intermodal transport with respect to the desired level at the European level
- the gap of current intermodal terminals with respect to the desired level at the national level
- the gap of current intermodal terminals with respect to the desired level at the European level.

Therefore, the analysis will be subdivided into four cases, each one considering one dependent variable in relation to the relevant independent and explanatory variables.

As explanatory variables (attributes) we consider all the remaining questions-entities of the questionnaire. For a more detailed presentation we refer to Annex 1, where the main structure of the questionnaire is given. The explanatory variables are classified into five pentagon groups: financial, organizational, software, psychological and hardware.

In all cases, three meta-variables are added to the analysis in order to test their importance for the development of an effective multi-modal transport. These meta-variables are the following: population, surface of the country considered, and the geographical position of the country (central or peripheral in the European territory).

In each case, rough set analysis examines which are the subsets of explanatory variables/barriers that lead to the same accurate classification with all variables considered. In this way, reducts of barriers are estimated; each reduct presents a set of important explanatory variables (barriers). Next, the core of all reducts, if it exist, consists of all -and the only ones- important barriers.

The analysis initially identifies the reducts within each one of the five groups of barriers (financial, organizational, software, psychological, hardware). This process allows to identify the most important barriers of each group. Next, the sum of the most important variables is considered, while next the reducts are estimated. These reducts and the respective core, if they exist, may be interpreted as important barriers for European networks.

4.2 The gap between existing and «desired» intermodal transport at the national level

The independent variable is the gap between existing intermodal transport at the national level in relation to the relevant «desired» level; in rough set theory terms this is the classification/decision variable. So each expert's opinion is classified into one of the five groups (non-existing gap, very small, small, high, extremely high) according to his answer to the dependent variable. In order to identify the relative importance of each barrier variable for the classification of the answers - which in fact means to identify the relative importance of each barrier for the gap between existing intermodal transport at the national level in relation to the relevant «desired» level - we apply rough set analysis. First, we examine the relative importance of each group of barriers (financial, organizational, psychological, software, hardware, meta-variables,) as a whole and then we examine the relative importance of the barriers within each group.

The group of financial barriers has a relatively high importance for the classification, since the barrier variables of this group alone suffice to give an accurate classification of high quality - they form a reduct in rough set analysis -. In reality this means that the financial barriers are a critical obstacle for the development of an effective intermodal freight transport at the national level. Within this group the relative importance of the «user cost in intermodal transport» and the «user cost at intermodal terminals» are very high, although they do not form a reduct in rough set analysis. The «investment cost of intermodal infrastructure» and the «investment cost of rail infrastructure» follows with a relatively lower importance which nevertheless remains at a considerable level. It is noteworthy that in rough set analysis there is no core of attributes/barriers within the financial group.

The group of organizational barriers presents also a high importance, since the organizational barriers alone lead to an accurate classification of high quality for the objects: they form again a reduct in rough set analysis. As far as the relative importance within this group is concerned, we may conclude that the «institutional barriers which prevent intermodal transport between different countries» and the «bureaucratic organization and management in rail mode»are the most important barriers. The «lack of express delivery in intermodal transport» and the «lack of just in time delivery in intermodal transport» are of secondary importance. We note that there is no core of attributes/barriers within the organizational barriers group.

Next, both the groups of software and psychological barriers, when considered each one alone, appear to have a very low importance, similar for both groups, and therefore their explanatory power for the classification of the objects is low. If these groups are considered together, then their importance increases; however, it still remains far lower compared to the financial and organizational groups; still they do not form a reduct in rough set theory.

The group of the hardware barriers is of great importance, since this group alone leads to an accurate classification of the objects: the barriers of this group form a reduct in rough set theory. It turns out that among the variables of this group the most decisive barrier is the «lack of intermodal terminals». The «lack of lack of rail infrastructure» then follows, while the remaining barriers have almost the same (lower) importance.

Finally, the group of the meta-variables appears to have the lowest importance among all groups.

At this point of our analysis, we are able to select the most important barrier variables of each group and to check their importance at a more general level. It appears that the financial and hardware barriers are the most important ones. Specifically, the «lack of interoperability of railways at the European level» alone, the group of «investment costs for intermodal infrastructure» together with «investment cost for rail infrastructure» and the group of the «user cost at intermodal terminals» together with the «user cost in intermodal transport» appear to be the most decisive ones. It is noteworthy that there is no core of attributes neither for the whole set of attributes considered nor for the set of the most important ones.

Another general conclusion, which may be drawn from the analysis up to this level, is that the barriers prohibiting the development of an efficient intermodal freight transport at the national level differ considerably between countries. It seems that the decisive mixture of variables is different in each country. For instance, in one case we find that the financial barriers together with software barriers prevail, while in another case a combination of hardware together with organizational barriers is the main obstacle.

Nevertheless, the analysis up to this point indicates that the importance of hardware and financial barriers are the most common and severe obstacles for the development of an effective and efficient intermodal freight transport at the national level.

4.3 The gap between existing Intermodal and «desired» transport at the European level

In this second step of our analysis, the independent variable is the gap between the existing intermodal transport in relation to the «desired» level, at the international (European) level.; in rough set theory terms, this variable stands for the classification/decision variable. The question now is to identify the relative importance of the independent variables/barriers for the classification. This, in turn, means to identify the contribution of each barrier in the gap. Following the same mode of analysis as in the previous section, the importance of each group of barriers is examined separately.

The group of financial barriers leads to a classification of high quality and therefore it presents a relatively high importance: the barriers of this group form a reduct in rough set theory. The most important barrier variables are the «investment cost for rail infrastructure», the «investment cost for intermodal infrastructure» and the «user cost in rail mode» which form also the core of the attributes-barriers according to rough set analysis [12].

Next, the group of organizational barriers alone cannot establish an accurate classification and hence is of secondary importance: these barriers do not form a reduct. Nevertheless, among the barriers of this group, the barriers «lack of express delivery in intermodal transport», «lack of just in time delivery in intermodal transport» and «delays at intermodal terminals»appear to emerge with the relatively highest importance.

The group of software and the group of psychological barriers appears to have also a relatively low interest. Even when both groups are examined together, they do not lead to an accurate classification of the objects, and therefore their explanatory power is low.

The hardware group has clearly a high explanatory power: the barriers of this group do clearly form a reduct. The barrier «lack of interoperability of railways at the European level» appears to be the most interesting. The subgroup consisting of the barriers «lack of specific rail vehicles suitable for intermodal transport» together with «lack of specific track vehicles suitable for intermodal transport» offers a considerable explanatory power, while the barrier «lack of rail infrastructure» comes third in the importance ranking.

At this point we are able to select the most important variables from all groups and to examine the relative importance between them. It appears that the barrier «lack of interoperability of railways at the European level» is the most decisive one, while the barrier «investment cost for intermodal infrastructure» and «investment cost for rail infrastructure» follows next. The barriers «lack of specific rail vehicles suitable for intermodal transport», «lack of specific track vehicles suitable for intermodal transport» and «lack of rail infrastructure» have also a high importance.

Consequently, it appears that the most powerful explanatory barrier variables belong to the groups of hardware and financial barriers. This result is more evident at the international (European) level compared to the national ones. Moreover, in contrast to the national level it seems that the prohibitive obstacles for the development of a European intermodal freight transport network are perceived to be rather common at the European level.

4.4 The gap between the existing and «desired» intermodal terminals at the national level

It is an almost common perception among the European scientists and the experts that the role of the intermodal terminals is decisive for the development of an effective multi-modal freight transport system. In this context, the dependent variable is the gap between the existing intermodal terminals in relation to the «desired» level, at the national level. Then, we have to explain the existence of this gap by the relative power of the relevant barriers as explanatory variables. We apply the same type of analysis as in the previous two subsections.

It should be mentioned at the outset that no group of barrier variables alone leads to an accurate classification. Therefore, the identification of the most decisive barrier should take place at a general level where all variables are considered simultaneously. By applying roughset analysis, it appears that the most important barriers are related to financial and hardware issues. Specifically, the «lack of suitable rail infrastructure» and the relevant investment costs composed of «investment cost for rail infrastructure» and the «investment cost for intermodal terminals» emerge as the most serious prohibitive barriers.

In contrast to an intuitive expectation, our analysis shows that the meta variables (population, surface, location of the country) show up as irrelevant factors.

Here again, the mixture of the decisive barriers differs significantly between countries (our rough set analysis results in a weak accuracy of classification when a subset of barriers is examined).

4.5 The gap between existing and «desired» intermodal terminals at the European level

Here, the dependent variable is the gap between existing intermodal terminals in relation to the «desired» level, at the European level. The problem of explaining this variable on the basis of the relevant barriers, functioning as the explanatory variables in our analysis, is dealt with in the same way as in the previous part of the analysis.

The financial and hardware barriers, considered together, give an account for the lack in the development of intermodal terminals at the European level. Specifically, the «lack of rail infrastructure» and the «lack of interoperability of railways at the European level» emerge as the barriers with the most decisive power. Similarly, the financial barriers «investment cost for rail infrastructure» and «investment cost for intermodal infrastructure» stand for strong barriers. We also note that the above mentioned four variables offer a classification of the same accuracy as the classification resulting from all variables: they form a reduct in rough set theory terms. Besides, the organizational barriers «institutional barriers which prevent intermodal transport between different countries» and «bureaucratic organization and management of railways» give a significant explanation for the classification and therefore they may be considered as important barriers.

In this framework, we may conclude that at the international level the analysis, concerning the lack of intermodal terminals, leads to more rigid results in comparison with the same analysis at the national level, since the experts consider that there exist common barriers at the European level. In this respect, rough set analysis leads to a better approximation of the relevant classification compared to the analysis at the national level.

Table 1: Survey of the results

	Crucial Barriers	Medium Barriers	Low Barriers
Gap between existing and «desired» intermodal transport. <u>National</u> level	financial hardware	organizational	software psychological meta-variables
Gap between existing and «desired» intermodal transport. <u>European</u> level	financial hardware		organizational software psychological
Gap between existing and «desired» intermodal terminals. <u>National</u> level	financial hardware		software psychological organizational meta-variables
Gap between existing and «desired» intermodal terminals. <u>European</u> level	financial hardware	organizational	software psychological

5. Complementary Results of Factor and Regression Analysis

5.1 Introduction

This section presents the results of the application of some standard statistical methods to the survey questionnaire. Evidently, the size of the sample is not entirely sufficient for applying exclusively standard statistical methods. However, we may use them as a kind of an additional experimentation on the robustness of the results of rough set analysis. Specifically, we will use a standard factor analysis, viz. principal components analysis, and regression analysis [13, 14]. We will only concisely present the results here.

5.2 The gap between existing and "desired" intermodal transport at the national level

By using principal components analysis, in each group of the explanatory variables (financial, organisational, software, psychological, hardware) we can identify a smaller number of 'combined' explanatory variables which appear to have a statistically sufficient explanatory power. Then, by applying standard regression analysis on all combined explanatory variables we are able to trace their relative explanatory power and hence the relative explanatory power of the five groups of the explanatory variables.

For each group of the financial, organisational, software, psychological and hardware variables, factor analysis appears to determine two 'combined variables' factors. Then, we are able to apply regression analysis for the eight 'combined' variables. The linear regression model demonstrated that the financial barriers and especially those ones related with the infrastructure cost have the highest explanatory power. These variables are able to exclusively explain the variation of the dependent variable.

5.3 The gap between existing intermodal and "desired" transport at the European level

Our factor analysis appeared to identify two 'combined' variables or factors, for each group of the financial, organisation, software, psychological and hardware variables. Using again these eight 'combined' variables, we can apply regression analysis. The result indicates that the financial and hardware barriers are the most decisive ones, while organisational barriers play also a significant role which is, however, statistically less important than the former ones.

5.4 The gap between the existing and "desired" intermodal terminals at the national level

The factor analysis determines three 'combined' factors, for all groups of the explanatory variables examined altogether. Then, the results of our regression analysis showed that the organisational and financial barriers are statistically the most powerful ones.

5.5 The gap between existing and "desired" intermodal terminals at the European level

Finally, our principal component method was able to compose three 'combined' variables out of all explanatory variables. However, the application of regression analysis did not lead to a robust result. It seems thus that the size of the sample plays a disturbing role in this case.

In general, the results of these standard statistical methods are rather similar to those obtained by rough set analysis. Especially, for the first two dependent variables the decisive explanatory variables determined by both methodologies are the same. For the third dependent variable, the standard statistical methods indicate a marginally different outcome, while for the fourth dependent variable the standard statistical methods did not yield relevant results. The limitations imposed by the size of the ample appeared to be very important for our statistical analysis. On the other hand, its use as a reference point for the robustness of rough set analysis may be considered as an acceptable endeavour, at least on an experimentation basis.

6. Retrospect and Prospect

Commodity transport is critical for the European integration benefits. Given the limited capacity and the social-environmental costs of unlimited mobility, it is necessary to use all European networks and modes in an efficient and environmental-benign way. This calls for the need for intermodal transport policy, as this may increase efficiency and the use of greener modes of transport.

The European integration will only materialize, if there is an efficiently operating network connecting all nodes of the European network economy. A network is not just a set of links and nodes, but an infrastructure configuration aiming to provide services in an efficient way through one or several operators. A network is thus a value added configuration taking advantage of an essentially passive physical infrastructure.

Transportation planning is often associated with physical movement, with infrastructure configurations, with logistic management and with regulations. Far less attention is paid to the way the transport market is organized, and how this organization uses and shapes transport modalities. Especially the transaction theory of firms has shed new light on the interesting link between firm behaviour and network development (e.g., hub and spokes systems). Even though transport systems exhibit fragmented networks, various operators (e.g., forwarding agencies, logistics suppliers) - through multi-modal shipping, integral logistics and neo-fordist customized delivery - are able to exploit transport networks for generating added value, not only in a local-regional, but also in an international context. Globalization of markets, new forms of competition, more client orientation, integration of production and warehousing, and transport innovations are shaping new opportunities for creative actors in the transport market reflected in joint ventures, 'filières', vertical integration etc.

The European integration has created interwoven networks of international trading and industrial relations, in which firms located in different countries produce goods and service components of the same final product. In the last two decades, the internationalization and intensified competition in world trade has not only emerged from the liberalization of trade policies in many countries, but also from major advances in communication, transport and logistics technologies. The 'extended' firm - or the network firm - including formal and informal links (merging or partnership) is mainly driven by economic forces and prevailing market dynamics, but fails to take into consideration environmental effects and socio-cultural impacts of internationalisation. Therefore, it also necessary to take account of sustainable development criteria in the transport sector.

Our analysis has demonstrated that in the view of many European experts the most severe barriers to an improvement of the present systems are the financial aspects (new investments in sophisticated infrastructures, user charge principles and involvement of the private sector, e.g.), and the technical hardware aspects (not only logistics and telematics, but also more sophisticated terminals). More policy support and more European competition would be needed to improve the competitive edge of European freight transport while staying within sustainability limits.

We will present here some elements of a future research agenda addressing the above mentioned issues.

Economic accountability

Economic concepts are clear in that the user and the polluter should pay the full costs of travel including all externalities. However, there are many problems with the implementation of such concepts, as public acceptability is low and international agreement is difficult. Any such implementation would have to be fiscally neutral, otherwise the policy would be inflationary and could lead to increases in unemployment.

Functioning of transport markets

Transport markets should function to cover the question of efficiency and equity in the different transport markets, including the links between the different modes of transport. Many European countries have different traditions, some based on strong central intervention and others allowing much greater market freedom. These different forms of regulation relate to national policies, to European policies, and to appropriate policies for the emerging countries of the Old East Europe.

Barriers in transport

Barriers to the operation of the market are numerous, covering fiscal barriers, physical barriers and technological barriers. The European Community is committed to reducing these barriers to allow the free operation of the Single European Market. At the more local level there are also barriers to the operation of transport markets with collusion between operators, predatory practices, incumbent advantages and monopolistic operations.

Sustainable transport

Environmental costs imposed by the transport sector are high and increasing, despite extensive legislation at the European and national levels. Clear policy directions need to be given to the transport industry, so that production processes can be cleaned up and more environmentally benign transport modes can be encouraged. The private sector contribution would complement that of the public sector in giving priority to public transport and cycling within cities, and in encouraging energy efficient urban forms.

Private-public cooperation

Private sector contributions have an important role to play in supplementing the public sector investment in transport and communications infrastructure. Various forms of partnership must be established between funding agencies, between sources of European capital (e.g. the European Investment Bank and the European Bank for Reconstruction and Development), and between national governments, as the levels of capital required for investment in Europe are often too large for a single agency.

Regulatory reform

Institutional, organisational and legal frameworks for the efficient operation of European transport networks need to be established, as an increasing proportion of decisions are taken by international agencies. The institutions have evolved over the last thirty years, together with an increasing number of organisations and legal agencies involved with implementation. The issue at stake here is to ensure such an evolutionary process produces the most efficient and appropriate structure for pan-European decisions.

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Annex 1. Tables of Data and Results

TABLE A1. The frequencies of the dependent variables

	Current intermodal transport compared to the desired level. National	Current intermodal transport compared to the desired level. European	Current intermodal terminals. National	Current intermodal terminals. European
nonexisting	0	0	2	0
very small	2	0	3	0
small	10	12	16	12
high	28	22	18	22
extremely high	3.5	10	8	10

TABLE A2. The questionnaire and the relevant answers (in percentages)

	no (barrier)		light		intermediate		strong		extremely strong	
FINANCIAL BARRIERS										
intermodal infrastructure investment cost	2.3%		18.6	**27.9**	39.5	**37.9**	25.6	**23.3**	14	**11.6**
rail infrastructure investment cost	2.3		20.9	**20.9**	30.2	**32.6**	30.2	**32.6**	16.3	**16.3**
user cost at intermodal terminals	4.8	**4.8**	19	**23.8**	52.4	**52.4**	19	**14.3**	4.8	**2.4**
user cost in intermodal transport	4.8	**4.8**	21.4	**19**	52.4	**57**	19	**16.7**	2.4	**2.4**
user cost in rail transport	7.1	**2.4**	28.6	**42.9**	38.1	**31**	26.2	**23.8**	0	
ORGANIZATIONAL										
lack of express delivery in intermodal transport	9.5	**9.3**	26.2	**18.6**	26.2	**44.2**	28.6	**20.9**	9.5	**7**
lack of just in time delivery in intermodal transport	2.3	**4.7**	23.3	**16.3**	27.9	**30.2**	30.2	**39.5**	16.3	**9.3**
delays at intermodal terminals	2.4		31.7	**26.8**	22	**36.6**	34.1	**26.8**	9.8	**9.8**
institutional barriers that prevent inter-modal transport between different countries	7.5	**9.5**	20	**9.5**	32.5	**38.1**	25	**23.8**	15	**19**

	no (barrier)		light		intermediate		strong		extremely strong	
bureaucratic organization of rail mode	2.4	**2.4**	16.7	**7.1**	19	**33.3**	35.7	**21.4**	26.2	**35.7**
SOFTWARE										
insufficient informatics system in rail mode	2.4		29.3	**29.3**	36.6	**31.7**	14.6	**26.8**	17.1	**12.2**
insufficient informatics system used by freight transport operators	2.4		26.8	**26.8**	39	**41.5**	22	**29.3**	9.8	**2.4**
PSYCHOLOGICAL										
unjustified prejudice against rail mode	15	**15.4**	25	**17.9**	35	**41**	15	**15.4**	10	**10.3**
justified prejudice against rail mode	2.4	**4.9**	17.1	**12.2**	39	**46.3**	22	**24.4**	19.5	**12.2**
HARDWARE										
lack of inter-modal terminals	7		23.3	**20.9**	25.6	**44.2**	32.6	**27.9**	11.6	**7**
lack of rail infrastructure	14	**11.9**	20.9	**28.6**	34.9	**23.8**	20.9	**31**	9.3	**4.8**
lack of specific rail vehicles suitable for inter-modal infrastruct	7.3	**4.9**	48.8	**41.5**	24.4	**34.1**	9.8	**14.6**	9.8	**4.9**
lack of specific truck vehicles suitable for inter-modal transport	17.1	**17.1**	41.5	**34.1**	19.5	**31.7**	19.5	**17.1**	2.4	**0**

	no (barrier)		light		intermediate		strong		extremely strong	
lack of inter-operability of railways at the European level	5.4	**2.3**	16.2	**7**	24.3	**27.9**	37.8	**37.2**	16.2	**25.6**

Note that the bold numbers in the table refer to the European level, while normal numbers refer to national levels.