

CAPACITY AND USE OF INFRASTRUCTURE NETWORKS: CRITICAL SUCCESS FACTORS

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INTRODUCTION

This paper summarizes major findings of a recent study (Kreutzberger and Vleugel, 1992) in which capacity and use of infrastructure are elaborated using the so-called pentagon model (see section 2). Both capacity and use of infrastructure are constrained in various ways, a lot of them having a non-technical nature. So, the traditional view on capacity and use bottlenecks should be enhanced to include these non-technical 'barriers'.

This means that an alternative view on network capacity (and hence network expansion) should also include issues like organization/management, financing, ecological sustainability and information systems access.

In line with this view, the most proper way to improve the current problematic situation of transport planning is not a straightforward expansion of conventional physical infrastructure, but either to upgrade existing infrastructure or to develop new transport systems without violating the constraints incorporated in our pentagon model. If we concentrate on this option, the main strategies (and research questions) are:

- How to use existing capacity reserves of infrastructure networks by relaxing various (non-technical) constraints?
- How to improve the use of the existing capacity of networks?

The implications of these two strategies include inter alia:

- avoidance of any unnecessary physical transport.
- operation of necessary physical transport systems against lowest social costs.
- (in the medium and long term) reducing the need for transportation by means of physical planning.

This paper has the following content. In Section 1 a general introduction into infrastructure planning and management is given, while Section 2 concentrates on the use of scenarios of preconditions (constraints) for

infrastructure capacity and its use. Section 3 is of a more practical nature, since this section contains various applications of the scenarios. Section 4 gives an overview of major conclusions.

1. INFRASTRUCTURE AS A SOURCE OF CONFLICTS

Network infrastructures have to serve the needs of a mobile society in which mobility/interaction of goods, persons and information are the clear exponents of a modern network economy (see ECMT, 1986; Nijkamp et al., 1990). In the past decades new infrastructure expansions and investments have by and large followed the demand requirements; transport policy was mainly demand driven and investments in transport infrastructure followed mainly the demand trends. Only the 'jumps' in the system (e.g., airplanes, high speed trains etc.) were also caused by technology push motives.

However, the question facing us nowadays is more complicated: if we take for granted the politically advocated and largely accepted objective of ecologically sustainable economic development, are then the needs of an extremely mobile network society for a drastic expansion of infrastructure compatible with the constraints imposed by environmental concerns, safety considerations and socio-economic equity objectives? The answer to this question has far reaching consequences. The conflicting nature of a demand driven transport system provokes immediately the question as to the role of supply in terms of managing and expanding infrastructure. Here the fundamental question is: are ecological, safety and equity considerations prohibitive regarding network expansion? If so, then the question of capacity use of the existing material infrastructure in Europe has to be given due attention. If not, the question remains nevertheless whether a better use of existing capacity may not be an economically more viable option than an uncritical investment effort in conventional physical infrastructure.

Furthermore, the problem of capacity constraints should not only be considered from the viewpoint of separate bottlenecks in a given infrastructure component, but also - and even more important - from the viewpoint of the functioning of a network as a whole. Thus also the relationship between infrastructure development and its use on the one hand and the modal split on the other hand is at stake here. This question also leads to complex trade-offs between investments and disinvestments at the same time in the transport sector. Transport policy should - in this context - serve to enhance efficiency and sustainability from the viewpoint of network operations (see also ERT, 1991). Thus an important related question is: what kind of network policy can be feasibly developed so as to serve simultaneously the needs of a mobile society, the ecological paradigm and the socio-economic needs of the mobility-deprived?

The previous questions make it evident that the notion of capacity and the idea of network management are critical parameters for a policy analysis of new infrastructures in Europe. In this paper we will in particular call attention for the need for effective, efficient and creative capacity management of existing material infrastructure (including the need for a high-tech upgrading of and a more market-oriented view on such networks).

2. MOBILITY AND INFRASTRUCTURE; CAPACITY AND USE UNDER PRECONDITIONS

Mobility and transport are not an aim in itself, but serve the goal of economic growth and welfare increase. However, there is not a linear correlation between mobility and transport on the one hand and economic development on the other. There is essentially a conflict between three major policy orientations:

- economic development, requiring infrastructure efficiency
- environmental sustainability, caused by the 'ecological paradigm'
- network access, imposed by the needs of mobility-deprived.

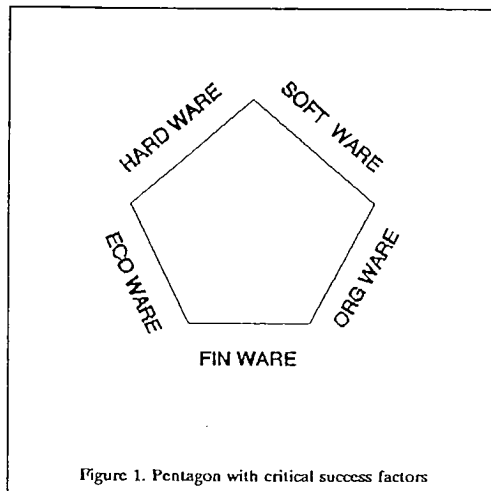
Depending on the size of transport flows, the specific modal split in a network, the vehicle technology used and the type of regulations, this conflict is more or less present in actual situations.

It is evident however, that the above conflicts are becoming more serious, as more traditional infrastructure investments - in combination with more traditional mobility processes - are allowed and realized. Whether or not this is politically acceptable, is a different question which apparently is given different answers in European countries.

In order to come to grips with the above mentioned conflictual issues, it seems plausible to investigate the critical success factors for the planning and implementation of transport systems. In this context reference can be made to the so-called pentagon model which has been used elsewhere to analyze and evaluate new European transport plans (see Maggi and Nijkamp, 1991, and Vleugel and Nijkamp, 1991). The edges of the pentagon (see Figure 1) represent five critical success factors for designing and operating transport systems.

This prism model may be particularly useful in evaluating new transport policies. Today several projects concerning transport infrastructure or transport systems are being executed. An example in the field of transport infrastructure is the Channel Tunnel (Chunnel), linking the transport infrastructure of Western Europe with that of England. The quality of the latter link, when finished, can be evaluated in the light of the light of the five critical success factors mentioned above. With respect to the hard ware, the value of the Channel Tunnel would be greatly reduced when through-trains from the continent to e.g. London would

be impossible. Partly, this reduced value might become reality when the French TGV is not allowed to attain its high speed on the English tracks due to the lack of compatible infrastructure on the English side of the Channel. As the Channel Tunnel will be used by through trains and by shuttle services, org ware is a very important factor too. The time tables must be organised in accordance with the time tables of the French and the English railways, while the shuttle services must be performed with a frequency that is sufficiently high to ensure its efficiency, which depends largely on the advantage of a strongly reduced travel time. Similar observations can be made regarding the fin ware (where the private financing of this project has caused major concerns), the eco ware (in terms of protection of vulnerable areas crossed by new tracks) and soft ware (in terms of sophisticated information systems).



Legenda

- Hard ware (e.g., efficient technological standardisation)
- Soft ware (e.g., use of compatible information systems)
- Org ware (e.g., existence of effective management structures)
- Fin ware (e.g., presence of private or public financial institutions)
- Eco ware (e.g., environment-friendly or regulated systems).

Infrastructure expansion is usually advocated on the basis of lack of capacity of existing infrastructure. And normally the claim is made that new infrastructure investment would lead to a rise in capacity (even though we know that - according to Say's law 'supply generates its own demand' - after some time most new infrastructure will again manifest congestion phenomena). Therefore, the question is opportune: what is essentially capacity? And is it conceivable that capacity management, technologically upgraded capacity and intermodal flexibility contribute more significantly to the solution of capacity problems than straightforward expansion? And last but not least: are we able to assess - and charge to the user - the right price of capacity use?

In the context of searching for a new concept of capacity the following reflection seems plausible: Capacity of infrastructure refers to the maximum volume of persons, goods, vehicles or messages that can use a given (part of) infrastructure in a given time period.

The main question however is: what is maximum? This is not easy to answer, as for instance a road segment may already have reached its environmentally sustainable maximum, before it has reached its technical maximum. Consequently, the notion of capacity as a maximum use can only be delineated, if the criteria determining a maximum are specified. Following the pentagon approach, the following indicators are possible:

Max-scenarios: the maximum traffic/transport volume that

- Technomax*: is possible, given the technical constraints on infrastructure.
- Enviromax*: is allowable, given the sustainability constraints.
- Orgmax*: is possible, given the regulatory system for the infrastructure at hand, and considering the quality expectations of travellers, transporters and shippers.
- Economax*: may be expected, given the economic efficiency and financial criteria.

Table 1. Max-scenarios on infrastructure capacity and use

These concepts are elaborated in more detail in section 3.

3. CAPACITY AND USE MANAGEMENT; FOUR CASES

3.1. Introduction

From the foregoing it becomes apparent, that capacity should be treated in the context of one or more (scenarios of) preconditions (constraints). Capacity is

therefore not unique or constant; 'the' capacity of networks does not exist. Capacity has been defined in section 2 as the maximum number of vehicles, persons or freight transported (in a certain time interval) between two or more destinations on a given infrastructure (segment).

Capacity has also a different meaning to the user and the network manager. For instance, levelling off peak use is beneficial for the network as a whole (the community of users, society), but the single user will not be pleased if he is prevented from using infrastructure at any time he or she wishes.

So there exists a potential dilemma between the wishes of the individual user (in terms of transport costs, time, routing etc.) and society, which may prevent the success of the two strategies before mentioned.

In the rest of this section a brief introduction into the use of max-scenarios for capacity and use management will be given for four transport systems; air-, road-, rail transportation and inland shipping. For each transport system we will present major elements of max-scenarios, together with tentative indications - based on calculations - of their impact on capacity and use of infrastructure. Side-effects are also described.

3.2. Air transport

Air transport differs from other modes of transport because it has the pattern of a chain; both arrival and exit of passengers and goods must follow strict routing. At most European airports capacity limits have been or are being reached in the near future. As physical extensions of capacity (e.g., more runways or new airports) are in most cases not a realistic option because of financial¹ and other restraints, (implicit) capacity management is one of the policy options.

Capacity management may take various forms. We will consider the capacity effects of homogenizing the fleet of arriving and departing airplanes, and enlarging the scale of the fleet (e.g., larger airplanes). Homogenizing means that airplanes with unequal flight characteristics are replaced by planes with more or less equal ones without loss of transport capacity. Putting a small airplane behind a larger one on a runway requires more distance, because of (tailwind) turbulence. Therefore separation intervals (time) between two larger airplanes are less than those between a large and a small one. Global calculations show that homogenizing might lead to using at least 15 % lesser airplanes, when using exclusively medium or large air planes (Amsterdam-Schiphol Airport).

In practice, full homogenizing and scale increase are not always feasible, but partial developments cannot be judged as completely unrealistic. The side-effects of homogenization include, inter alia, investments in fleet replacement and in other parts of airport infrastructure (e.g. terminal capacity). For airlines,

another major problem is how to reach the optimal (economic) percentage of airplane-load on all destinations, if a certain airplane type would be more or less prescribed or imposed by airport managers.

3.3. Road transport

Capacity restraints are very common in road transport. There is a number of ways to relieve this problem. Well-known measures include, inter alia, traffic management, road pricing and parking restrictions; these are all infrastructure-related. Another option is vehicle-related, namely increasing the weight of lorries. Caff (1988) indicates, that "In Britain, following the increase in the maximum gross vehicle weight from 32.5 tonnes to 38 tonnes in 1983, it is estimated that 5 000 fewer heavy lorries are now used. This has meant a reduction of about 250 million miles travelled through Europe by goods vehicles (..) ". Increasing the vehicle weight may therefore increase the transport capacity of roads, because less vehicles are needed. A negative side-effect of using heavier vehicles is the higher road maintenance costs. The same impact may be achieved by increasing the vehicle length. An important negative side-effect of increasing the vehicle length however, is the fact that longer trucks are hard to manoeuvre - especially in cities - and therefore may cause extra accidents.

Interesting, but not surprising, is also the comparison of normal and capacity-maximizing express way usage by travellers. Homogenizing and scale increasing of the vehicles by introducing bus transport as the exclusive transport system on express ways pushes up the transport capacity of express ways. According to Bexelius (1989), the capacity of express ways would rise by a factor of eight if big buses were chosen. Of course, exclusive bus-transport does not respond to all the needs of passenger transportation.

3.4. Inland shipping

Inland shipping in the Netherlands has not been confronted with capacity constraints on the lockless waterways yet. However, this can easily change during the next decade, if the transport forecasts become reality. On waterways with locks - common in most European countries and also in parts of the Netherlands - the locks are the most important bottlenecks, as their capacity usually is only a fraction of that of the surrounding waterways.

In contrast to the other transport systems, research and planning activities are hardly focused on capacity issues; in stead, they are restricted to the relation between vessel size and waterway characteristics. Nevertheless, the restricted information about the capacity factors enables us to give the following

indications on the effects of a more efficient use of waterways. The capacity of an existing lockless link can be doubled or more (depending on the current water levels of waterways) by homogenizing vessel traffic, increasing vessel size, and changing the other conditions of use (e.g., the introduction of advanced traffic management systems, increased manoeuvrability of ships and higher speeds of ships). On waterways with locks other factors determine the possible capacity. The aim is to maximize the use of a lock in a certain time interval. This implies that not the biggest vessel, but the vessel size which fits best in the lock without causing too much entering and leaving time leads to the highest increase in capacity.

An important strategy for a better cost-benefit relation of waterways implies using it more efficiently without changing the capacity. This may include a spread of transport in time, thereby lifting off capacity constraints and using existing capacity reserves, or to avoid navigation with a low percentage of ship-load or empty ships.

3.5. Rail transportation

The support of public passenger transportation by governments and - in the future also of rail freight traffic - has made it necessary to increase the capacity of rail infrastructure in the Netherlands. This is done by physical expansion of the network, incurring huge investments. Nevertheless, it is not clear whether the extra capacity is sufficient to meet all transport requirements. In parts of the Netherlands physical expansion of the network (wider profiles or new links) are also difficult to integrate in the existing urban and natural landscape. In sum, there are plenty of reasons to think about alternatives for expanding the network. Using the infrastructure more efficiently and increasing the rail capacity by means of rail management are likely to be very attractive alternatives.

Rail capacity depends on the loading and riding characteristics of trains, the degree of homogeneity among train types used, the quantity and quality of the installed signalling systems, the distance between facilities where trains can overtake each other, the quality of operation systems (e.g., maintenance), the speed, acceleration and brake characteristics of trains, the functionality of pedestrian areas in railway stations, and the loading capacity of wagons and trains.

Homogeneity means that all or most trains have the same number of stops and the same speed in order to avoid the necessity of passing each other. A high capacity might be attained by admitting only one train type with an optimal acceleration and brake performance, by reducing incident reserves (by increasing the quality of maintenance), and by promoting a higher loading capacity of trains. If all these conditions for using the rail infrastructure were realized, then

it would be possible to increase the capacity of rail infrastructure to about 40 trains per hour (both directions). These figures are the results of a restricted simulation. The advantages of such a high traffic intensity are significant, if one considers that the present capacity in the Netherlands varies between 8 (mixed mode), 12 (stopping trains only) or 16 (intercity trains only) trains per hour and direction. Of course, this high capacity requires high investments, inter alia in new traffic management systems (including new signal systems in cabins). It may also lead to the closure of some stations, which calls for compensating investments in local public transportation. However, the costs of these changes should be compared with the investment savings in physical expansion of the railway network, and with the possible advantage of a higher quality of life when avoiding physical expansion.

4. STRATEGIC CONCLUSIONS

In this paper we have examined the use of so-called max-scenarios in capacity and use management of infrastructure; capacity is a constraint-related phenomenon. It became clear that these scenarios may be important planning tools. Both types of management may become increasingly important as a replacement for the usual - but increasingly socially and ecologically unacceptable - way of physically expanding infrastructure networks.

This concept does not only hold true for uni-modal networks, but could also be extended towards multi-modal networks. For example, capacity problems (such as peak hour congestion) in some modes may - to some extent - be overcome by inter-modal substitution and complementarity. The identification of the optimal mix of necessary infrastructure modes in view of reaching given objectives (the so-called packaging problem) is a major issue in this context.

From the viewpoint of system-wide network optimization, it makes sense to pay particular attention to specific bottlenecks, such as transit points, variety in interaction/communication speed, intermodal connections, information systems regarding network operation, peak load and peak use, flexible working hours, new logistic systems, the position of mainports, standardisation in transport systems technology, hierarchical function decision in networks etc. This allows also a much better use of existing capacity, so that through chain connections the above mentioned socio-economic equity problem of limited network access can be relaxed.

In this study specific attention was given to relaxing part of the constraints on uni-modal network capacity and its use. Further research should also include multi-modal networks. This would also shed a new light on the (potential) successes and failures of transport policy in different regions and nations in Europe.

5. EPILOGUE

The optimization of capacity and traffic efficiency by varying the conditions of using infrastructure brings us to the environmental or background conditions of the functioning of infrastructure. This is because the presented possibilities for changing infrastructure use require great amounts of investments in the vehicle fleets, possibly also in the shipping business, distribution and logistics and even in housing and working locations. Next to that, operational costs of transportation may increase, for example, because of raising the speed of vessels. A higher efficiency by means of spreading transport in time also forces to changes in socio-economic structures (e.g., reducing sectoral privileges or abolishing national protective policies). In other words, the balance between actors who benefit and lose is likely to change. Success in saving investments by increasing the efficiency of infrastructure with less physical expansion of the networks requires equalization of advantages and disadvantages between actors. This of course, is not the easiest challenge for politics, since it may for instance lead to the use of user pricing schemes.

NOTES

1. For instance, the latest plans for doubling the capacity of Amsterdam Schiphol Airport imply investing some 23 mld. Dfl.

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