EVALUATION OF PUBLIC TRANSPORT

Method for Application in Open Planning

Summary Paper*

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by: B. Flyvbjerg

SUMMARY

Rising vehicle costs and dropping real wages have led to new demands on public transport in Denmark. This is happening in a situation where urban and regional planning have been based on the car for decades, with the consequence that everyday life involves longer distances travelled more often and more randomized than earlier.

As a result, the planning capacity for public transport is in a need to be increased. This involves the development of planning methods, and if it is assumed that planning for public transport is to be carried out with openness toward users and other types of planning, special demands will be placed on method development. In this case the methods will have to work on the basis of simple assumptions and with a simple mode of operation. Their point of departure must be specific, local problems, and their results easily understandable. Finally, the methods must be quick and inexpensive in use, indicating less emphasis on comprehensive, formalized demand estimation and forecasting.

In order to satisfy these demands a method to evaluate scheduled, fixed-route public transport bas been developed. One major evaluation criterion in the method is total travel time, subdivided into walking time, waiting time, time on vehicle, transfer time, and concealed waiting time. The other major criterion is costs incurred by a given supply of transport. In contrast with conventional methods, this method operates with real measures, i.e. real location (instead of traffic zones), real time (instead of average travel time), and real costs (instead of proxy-costs, as for instance in cost-benefit analysis). The purpose is to produce relevant and easily understandable results suitable to open planning.

Simple assumptions and a simple mode of operation have been striven for by computing travel time on the basis of the same information as users face when travelling by public transport, namely the timetable. The computations of travel time are carried out by a computer model, simulating looking up individual trips in the timetable. This mode of operation should be easy to understand by any user of public transport. It also ensures that the results of model simulations can be checked manually by anyone. The only advantage of the computer model to manual calculation is the ability to look up thousands of trips in the timetable in a very short period of time, thus making possible a general description of the level of service in a given public transport system. Likewise, the basis for calculations of costs are simple measures such as the number of timetable hours and the number of vehicles. These, too, are calculated from the timetable.

The method was developed with an explicit view to a modest role in a more holistic, open political planning process. This role is sought by aiming the method at specific evaluations of well-defined partial aspects of the planning problem for public transport. The partial aspects then have to be evaluated against each other and against other, maybe more qualitative, aspects by the parties involved in the planning process.

Numerous test uses of the method on the public transport system in Aalborg, Denmark (150,000 inhabitants, ca. 150 buses) indicate, that the method may satisfy the posed demands. More detailed evaluations of the method would take a real test in practical public transport planning with citizen participation and openness toward other types of planning. The information-need of the method makes it most applicable under circumstances where planning of public transport is carried out as an institutionalized and continuous process. In Denmark examples would be the county transport authorities, the transport

authorities of larger municipalities, and the Danish Railway Administration. These authorities typically work with computer-based timetables, making extra data collections and extra coding unnecessary for the use of the evaluation method. In these cases the method is most likely to work as the aid to planning it is meant to be, and not as a further data-demanding drag on the planning process.

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INTRODUCTION

The planning, and to a large extent also the operation of public transport have in recent years been taken up by the public sector in Denmark as a task with a relatively high priority. The systems planned for have become more extensive and more complex with time, together with their institutional and organisational context. The common sense and local knowledge of former small scale transport operators, are no longer sufficient, even though they continue to be necessary. It can for example be difficult to grasp the options in a public transport system with only 15-20 vehicles, and already to-day many systems include considerably more.

It is no surprise, therefore, to find an increased interest in the development and use of more systematic methods of planning public transport. Methods by means of which it is possible to assess alternative plans with a view to contribute to achieving a plan which is 'good', in one sense or other.

The objective of the research project summarized in this paper has been to develop such a method. To be more specific, the objective has been to develop an easily understood and practically usable method for evaluation of public transport, as well as to test the method under realistic conditions with the public transport system in Aalborg Municipality as an example.

The method has been developed with the specific view to its application in open planning, i.e. open vis-a-vis the public, users, politicians, other planning and those changes in planning conditions which societal development creates. The aim is more coordinated, public-orientated and efficient planning.

The target group for the research project comprises people who work with planning of public transport, either in practice or in research and teaching.

OPEN PLANNING

Open planning can be characterised by openness to three sides. Firstly to all who may be expected to be affected by or who have an interest in a specific project. These may be the public in a broad sense, political parties, interest groups, or the specific target group for the project in question. Secondly openness vis-a-vis other types of planning is required, both physical (town) planning, economic planning (inter alia budget planning) and other sectors' planning. Finally open planning also means openness vis-a-vis general societal development and related changes of a economic, political and ideological nature. This last type of openness is often overlooked, because it does not necessarily involve a specific actor. It may nevertheless be important for the development of relevant and valid projects.

A paradigm of open planning has been used as a point of departure in the current work. Firstly from the normative consideration that planning should be carried out in a fashion more political and more akin to the classical democracy ideal than closed expert-orientated planning. Secondly because open planning can be assumed to be well suited to an area such as public transport, partly because the daily contact with the users is specific and direct here and therefore results in immediate reactions and dissatisfaction in the event of erroneous assessments of the users' requirements, and partly because coordination with other forms of planning, e.g. town planning, is extraordinarily important for a good result in the public transport field. Open planning can in other words also be expected to contribute to more comprehensive, coordinated and effective problem solving.

METHOD REQUIREMENTS

Now and then one may come across the view that there is no need for formalised methods in open political planning, perhaps that they are simply unwanted. As a result of the dominant role of formalised analyses and methods in rationalistic-comprehensive (cybernetic) planning, there is a tendency to identify methods with this type of planning. As a consequence the criticism of rationalistic-comprehensive planning (as opposed to open planning) and its methods is often regarded as a general criticism of methods, which easily results in method-hostility.

This conclusion from part to totality is, however, so general that it becomes misleading. There is also a need for formalised methods in open political planning. The requirements for methods in this type of planning will be significantly different from the requirements for rationalistic-comprehensive methods, however.

Open political planning assumes that the traditional rationalistic-comprehensive method conception is turned upside down. Instead of seeing (and subordinating) planning and politics in a complicated technical-economic framework, techniques and economics are subordinated to politics and political objectives (interaction). The methods are reduced to simple tools, so that quantitative analyses of important partial aspects can be linked together by more holistic and political assessments of the whole. The objective is to ensure that assessments and priorities, which are really political, also stand out as such and are not concealed in technical terms.

An initial method requirement will then be that it must be possible to produce results simply and readily understood. This requirement is principally linked to the involvement of the public in planning, but also plays a part in other forms of cooperation, e.g. in relation to politicians and planning in other sectors. In the case of quantitative analysis, aggregated proxy variables should be avoided, and measurement in real quantities should be aimed at.

A second - and equivalent - requirement is that the methods' assumptions and mode of operation should be simple and readily understood. "Black box" methods should be avoided, even if planners may believe such methods produce a better analysis of the problem. The requirement to avoid complexity and the resulting opacity also urges care vis-a-vis comprehensive formalised demand modelling and forecasting. Of course there will be need for estimates of demand in one form or another in all planning. What should be stressed, however, is the fact that detailed quantitative demand modelling, as found in many traditional transport studies, requires a modelling of complicated behavioural relationships that at best is resource-consuming and difficult to see through, and at worst also of dubious reliability. This is especially a problem in planning of public transport, as demand here is related to supply in a manner where greater supply (better service) typically results in greater patronage. Instead of formalised demand modelling, it will in many cases be both possible and advantageous to manage with more ad hoc style methods.

A third requirement is that methods must be aimed at evaluating specific problems, which will often be identical to local problems. Traditional traffic planning has been apt to focus on the advantages of high accessibility over long distances in overall traffic systems, e.g. systems covering cities or regions, and to put less emphasis on local effects which are often negative and socially biased. In open planning the methods should make it possible to take a local point of view and assess the local situation very specifically.

The all-to-all view on traffic planning should in this case be toned down and supplemented with assessments of the type one-to-all, few-to-few, and the like.

Finally, the methods in open planning should also be easily applicable, i.e. quick and inexpensive to use. This is important because openness will often entail an interplay between the parties involved, in which planning proposals change in appearance and effects must be re-assessed.

All in all, these considerations indicate a general requirement for methods with a limited scope aimed at evaluation of specific partial aspects of a more holistic planning process. This type of methods would be simple effect assessment methods constructed around easily understood and relevant assessment criteria.

METHOD FOR EVALUATION OF SCHEDULED PUBLIC TRANSPORT

Any public transport plan will, if carried out, have a long series of physical, economic and social effects on users, operating companies and the environment. Consequently, it seems logical to include all these effects in one comprehensive method for assessment. It is this logic which forms the basis of the rationalistic-comprehensive method conception. It is also this logic, however, that leads to methods which are complex and expert-orientated, contrary to the point of departure of the current project: That methods should be usable in open planning. It is necessary, therefore, to limit the scope of effects to be considered.

Against the background of the previous considerations, that effects and assessment criteria should be relevant to those affected, we have selected the users' level of service as the first principal criterion, around which the evaluation method is built up. Since it furthermore applies that the maintenance of a given level of service is linked to a series of costs, which are often defrayed by the planning authority, costs are selected as the second principal criterion in the method. The problem which the method consequently aims at assessing is what level of service is offered at what cost in a given public transport system, and consequently which system out of several - in the form of alternative plans - will result in the best possible service for the users, for a specified use of funds.

But what should be understood more specifically by level of service and by costs?

It applies once more that a long series of physical, economic, and social effects may be included in evaluation of the level of service. Or, put another way: The level of service is a concept comprising a wide variety of sub-components, ranging from waiting conditions at bus-stops, over travel time, to interior comfort in the vehicle. The problem is once more whether all these components should be modelled together into one quantity. And the answer is, as before, in the negative on account of the requirement for lucidness in open planning. As stressed above, aggregated proxy-variables should be avoided and real quantities preferred.

On the basis of studies of travel preferences and travel behaviour relating to the relative importance of the individual components within the service concept, it has been chosen to express the level of service in a specific public transport system by total travel time experienced by the users of the system, i.e. accessibility. Total travel time is divided up into the components walking time, waiting time, driving time (time on vehicle), transfer time and concealed waiting time.[1]

The assessment of costs can relate to different types of costs, e.g. direct gross costs, net costs or total social costs. Below, direct gross costs will be considered first and foremost, supplemented with calculation of net costs where possible.[2]

To be used for evaluation of each of the sides, level of service and costs, a travel time model and cost models have been developed (see Fig. 1). The results of model calculation are presented in real time and real costs, which are quantities that most people are assumed to know and be able to relate to ("time and money"). By this means an attempt is made to satisfy the requirements for simple assessment criteria and easily understood results.

TRAVEL TIME MODEL

Existing models for calculating travel times in fixed-route public transport systems typically calculate average travel time on the basis of information on vehicle frequencies on each route in a given period of time. It is, however, the real (as opposed to the average) travel time, to which a user is subjected in a public transport system. And the real travel time may be substantially different from the average travel time as the real time depends very much on the structure of the timetable as well as on other temporal and geographical constraints on the user, e.g. in the form of fixed working hours in a specific locality. In fact it is often the double temporal constraint in the timetable and at the destination which decides whether a journey can be carried out with public transport with an acceptable time use, or not.

If one anticipates the course of events for a moment and considers a result from an application of the travel time model, the significance of the difference between real and average travel time will, maybe, stand out more clearly.

Fig. 2 shows the proportion of the inhabitants of a suburb in the study area (Sulsted-Tylstrup) who can reach a central place (Nr. Sundby) within the travel times quoted. The two curves to the right of the figure show the total travel time with a requirement for a 07.50 arrival at the latest, e.g. with a view to a fixed working start at 08.00. The two curves to the left show the total travel time when the time of arrival is free, e.g. for work with flexible hours.

As far as accessibility and the options for using public transport are concerned, what is decisive here is whether the journey takes place to a time-linked activity or not. The average travel time is not relevant, either for the individual whose time is flexible (free arrival time) or for the person with a fixed meeting time. The travel time for the individual user thus varies in jumps which are larger the lower the vehicle frequency, and which can therefore be very different even for users within the same geographical journey relationship if they are subject to different time constraints at the endpoints of their journeys.

The average travel time will consequently often not be of particularly pertinent value for the individual user and can therefore not be applied as an expression of the accessibility in this context, where - as previously mentioned - it is a central method requirement that results shall be relevant and readily understood by users. It must, therefore, be demanded of the expression for accessibility that it is specific, both temporally as well as geographically: The accessibility of a specific geographical location from another is defined in the current context as the total travel time, given specific constraints on the timing of the journey. Example: The accessibility of the study area's largest place of work (Aalborg Shipyard) from the suburban area Sulsted-Tylstrup, with a requirement for arrival at 06.50 at the latest (with a view to starting work at 07.00), is expressed by a total travel time of 64 minutes - made up of 8 minutes' walking time, 3 minutes' waiting time, 32 minutes' driving time, 5 minutes' transfer time and finally 16 minutes' concealed waiting time. This is the actual time a user would have to spend on this travel relationship defined in time and space.

This definition means that the travel time model simply looks up in an existing or fictitious timetable a journey which will result in the shortest total travel time. This corresponds to a manual look-up in a timetable and should ensure that the model satisfies the requirement for simple assumptions and a simple mode of operation. With the travel time model, which is a computer model, it is possible to carry out quickly thousands of references and thereby define the level of service of a public transport system. It has been a basic consideration in the method-development work that computers are especially well suited to this type of task - repetition of simple routines a large number of times - and not e.g. to modelling complicated behaviour systems.

The travel time model's mode of calculation is shown in Fig. 3 in symbolic reproduction. The trips which can be made with direct connection are caught by the first filter. In the model this is equivalent to trip calculations for direct connections being carried out and printed out as a first step.

Trips which can be carried out with one transfer are calculated as a second step, and trip calculations with two transfers are carried out as a third step. The fourth step is for useless trips (scrap), namely those trips which could not be established as connections with up to two transfers.

Trips which have been calculated with satisfactory quality in one step in the travel time model are not considered at later stages. Poor quality is taken to mean in this connection trips in which transfer time + concealed waiting time is high.[3]

The individual travel time components (walking time, waiting time, driving time, transfer time and concealed waiting time) are made up separately, and they are allocated the same weight (unity) when combined in total travel time. Unity weights are used despite the fact that preference and behaviour studies show that the components of total travel time have different importance for the individual traveller, just as they vary from traveller to traveller. Transfer time is, for example, typically assessed as more troublesome (higher weight) than driving time, and older people assess walking time as more stressful than do younger people. Since, however, a satisfactory method of determining and combining weights for the many different user groups does not exist for practical purposes, it has been chosen in the current context to work with real time when calculating total travel time. This means, moreover, that any weighting (other than by unit weights) will have to be done externally in relation to the method, which should tend to make it more lucid. In addition it becomes clear that there is no single objective measure for accessibility, but that a specific accessibility measured in real time, has a different meaning for different user groups.

It should also be mentioned that, on the basis of calculations of real travel time, it is possible to aggregate into average travel time, whereas the reverse cannot be done. Similarly, it is possible to calculate travel times for non-time-linked activities. Finally, the accessibility concept's specific founding in both time and space makes it possible to evaluate both alternative transport systems and alternative locations.

COST MODELS

Since the adoption in 1978 of the law on local and regional public transport outside of Copenhagen it has been incumbent upon all county councils in Denmark to carry out planning of public transport. As a consequence the Association of County Councils, the Danish Railway Administration, and the National Association of Denmark's Bus Routes (LDB) have negotiated a standard cost model for calculating costs in connection with contract driving. Broad agreement has been reached on using this model in practice, and it is now used for cost calculations for most of the local and regional public transport outside of Copenhagen.

Since it has been an aim of the current research project to develop an easily understood method, which is generally applicable, it was decided to build up the method's costs side in accordance with the structure of the standard model. It would most likely create unnecessary confusion to introduce an evaluation method which deals with the cost side differently and there are no serious theoretical or practical arguments against using the structure of the standard model as a basis for cost calculations.

It should however be noted that the standard model's orientation towards accountancy settlement vis-a-vis individual contractors means a tendency towards a degree of detail which will not always be necessary or expedient in a planning context. For specific planning purposes various simplifications may therefore be helpful. It should also be noted that it is the model structure (the same variables) which are used. As far as the specific unit costs (parameters) are concerned, these should always reflect the actual outlays for the planning and cost-bearing authority. A distinction must therefore be made between two principal cases:

(1) Administrative authority: The cost-bearing authority is solely responsible for planning and administration, and buys the operation from private contractors and/or the Danish Railway Administration, which also operates buses. If the operation is paid for on the conditions of the abovementioned negotiated standard model, as must be expected in by far the majority of cases of this type, the negotiated rates are applied (perhaps with minor local modifications).

(2) Operating authority: The cost-bearing authority is responsible for both planning and administration as well as for operation. In this case the actual operating expenses must form the basis for the calculation of unit costs, i.e. the parameters of the model.

In practice combinations of the two types of authority may exist, as is the case for the study area, Aalborg Municipality: The town bus operation is looked after by the town council itself, whilst the operation of a number of suburban routes is contracted out to private operators. It has therefore been necessary to operate with two sets of unit costs, corresponding to each of the cases (1) and (2) above.

For case (1) the unit costs of the standard model are used directly:

$$C = 49.25 \cdot (K_T + P \cdot K_T) + 2149 \cdot B \cdot M + 59.46 \cdot K_T + 6.252 \cdot B \cdot M$$

where

C = total costs in kr. (1980)*

*) 1 US $ was equal to kr. 5.62 in 1980. (Annual average).

K_T = number of timetable hours
P = percentage supplement for the difference between drivers' working hours and timetable hours
B = number of operational buses
M = number of months

With a supplement to the basic wage rate for timetable hours occuring at particular hours of the day, a model as shown in Table 1 is obtained.

For case (2), a detailed analysis of the municipal bus company's accounts and vehicle timetables for the period October 1979 to September 1980 was carried out with a view to establishing the actual unit costs for the town bus operation. This resulted in the following model:

$$C = 58.86\cdot(K_T + 0.334\cdot K_T) + 2187\cdot B\cdot M + 62.55\cdot K_T + 6.375\cdot B\cdot M$$

where

C = total costs in kr. (1980)*
K_T = timetable hours
B = number of operational buses
M = number of months

With a supplement to the basic wage rate for timetable hours occuring at particular hours of the day, a model as shown in Table 2 is obtained.

In certain cases, where one only wants an initial rough evaluation of the costs linked with a given alternative, it will be expedient to work with simplified versions of the cost models. Two simplifications of each of the models have been made, firstly a conversion to pure hourly rates with variations over the day, and secondly a conversion to one generally applicable hourly rate (without variations over the day). The simplifications are not reproduced here for reasons of space limits.

A few examples from a fairly long series of test applications of the travel time model and the cost models for public transport in Aalborg Municipality are described briefly below. (152,000 inhabitants, approx. 150 buses).

EXAMPLE 1: CHANGES IN THE SERVICE OF A SUBURB

In conjunction with a comprehensive change in the public transport system in the study area in the winter of 1981, the service for a number of suburbs was changed. These changes have been analysed with respect to accessibility and costs.

In Tables 3 and 4 are shown two examples of application of the travel time model to describe the accessibility from the suburb Sulsted to important work places in the study area, with a requirement for a latest time of arrival of 06.50 (with a view to a meeting time of 07.00).[4] Table 3 shows the situation before the change in service, and Table 4 the situation after the change. It is possible, for example, to see in Table 3 that the total travel time before the change from Sulsted to the cement factory at Rørdal (1,900 employees) was 64 minutes, divided up into 11 minutes walking time (including waiting time at the initial bus stop), 41 minutes driving time, 5 minutes transfer time and 7 minutes concealed waiting time. It is also seen that the connection is made by taking route 36 from Sulsted to the terminus (banegaarden) and route 28 from there to Rørdal. From Table 4 it is seen that, after the

*) 1 US $ was equal to kr. 5.62 in 1980. (Annual average).

change in service, it was not possible to reach the cement factory at Rørdal from Sulsted in time.

Fig. 4 shows another mode of presenting the information in Tables 3 and 4, a mode which has been much used in presenting results from the travel time model. Fig. 5 shows a further aggregation and another mode of presenting the same information, with the travel times weighted with the number of work places reached within certain time limits.

In Fig. 6 is shown an example of change in accessibility internally in the suburb, namely to the local centre in Sulsted from its hinterland, with free time of arrival.

Finally Tables 5 og 6 show the gross costs before and after the change in service respectively, calculated for routes between Sulsted and Aalborg (the central business district) and for routes within the local area. The costs are calculated by means of one of the simplified versions of the cost models mentioned above (pure hourly rate with variation over the day).

It can be seen that the change in service comprised a considerable increase in funds used. At the same time it is evident from Tables 3 and 4 that the change entailed alterations which could be regarded - and in actual fact were regarded by a majority of local residents - as reductions in the area's public transport service. This peculiar situation led to local citizens protesting and demanding participation in the planning process. As a result of meetings between the municipality and the citizens, it was arranged that the service was changed again shortly after the initial change in a fashion more in accordance with the local needs.

It should be stressed that this situation was not typical for other suburbs. Several suburbs experienced considerable improvements in service as a result of similar increases in use of funds. The Sulsted case was of particular interest in the current context only because it involved citizen protest and participation and thus gave an opportunity of deciding whether the method's evaluation criteria correspond to the key elements in the public debate about the change in service, which proved to be the case.

EXAMPLE 2: COMPARISON OF LOCALITIES

Due to the fact that the accessibility concept used is symmetrical in time and space - i.e. embraces specific time as well as specific geographical locality - it is possible to compare both transport systems and localities. In the example above the evaluation method was used for a comparison of different transport systems. In this section its application for comparing different localities is illustrated, whilst the transport system is constant.

Fig. 7 thus shows the accessibility from a number of suburbs in the study area to concentrations of work places larger than 500 employees and with 06.50 as latest time of arrival. It can be seen that there are considerable differences in access from the individual suburbs to work places by public transport with the required time of arrival. Dall Villaby is in a particularly poor situation as it is possible to reach only approx. 45% of the work places quoted from this suburb. It is possible to reach almost all of the work places from Svenstrup, a significant section, however, only with comparatively long travel times.

Fig. 8 shows the accessibility from the same suburbs to residential areas larger than 1000 inhabitants with free time of arrival. It can be seen that the differences between the suburbs are smaller for this situation, which seems to indicate that the differences in accessibility shown in Fig. 7 are to a larger degree due to differences in the arrangement of the transport system in time than it is due to purely geographic conditions, e.g. distance or barrier effect.

Fig. 9 has been prepared with a view to illustrating differences in accessibility to the most important concentrations of work places from the whole of the municipality. It is evident from this that there are considerable differences in the chances of reaching the selected places of work by public transport at the latest time of arrival quoted. Test applications of the travel time model for other localities and at other times show corresponding results.

Comparisons like those shown in this example might be usable in town planning. For example it would be possible, from a public transport point of view, to pick out areas which are particularly well suited for the location of new work places. Correspondingly, it would be possible to evaluate potential residential areas and areas with other town functions in relation to one another. It is however important to keep in view the fact that localities which, with this type of evaluation, stand out with poor accessibility could often achieve improvements by changes in the public transport service. If, indeed, a number of advantages exist for the locality, from aspects other than public transport, the former should not, of course, be ruled out on the basis of poor accessibility. On the contrary such advantages may perhaps justify the disadvantage - in the form of increased costs - which an improvement in the accessibility by public transport to the locality would mean. What can be established, however, is the fact that assessments like those quoted should be made before a decision on a specific town development is taken. The consequences of omitting this is abundantly illustrated in many of the suburban developments of the sixties and seventies, which are difficult to service sensibly with public transport, both due to location in relation to other town functions as well as to internal physical structure. Many suburban areas are in fact transport traps which will slowly close, if the recent increase in fuel prices and decrease in real wages continues.

If all sectors with an interest in town development could produce assessments similar to those shown above, of advantages and disadvantages seen from their point of view, and if priorities between sectors were set in a political and locally anchored town planning, an important step towards truly comprehensive planning (as opposed to so-called rationalistic comprehensive planning) would have been taken. Town planning would hereby acquire less the character of simple follow-up planning looking after the land use consequences of sector planning.

EXAMPLE 3: EVALUATION OF ALTERNATIVE PROPOSALS FOR A CIRCULAR LINE

In the public debate about planning of public transport in the study area several different proposals have been put forward for the establishment of a circular line in the southern outskirts of the town area, running transversely to the existing radial lines. Common to the proposals has been the fact that they have as an objective improved accessibility to a number of important residential, service, educational, and working place concentrations in the southern area of the town.

One of the proposals is shown in Figs. 10 and 11 with examples of changes in accessibility (for 15 minutes intervals between buses).* These and other

*) Reproduced from test applications of the evaluation method in Lone P. Andersen and Finn Madsen (1981): "Public transport and town planning in Aalborg". Master's Thesis, Civil Engineering in Planning Program, University of Aalborg.

results indicate that a circular line would first and foremost mean shorter travel times for journeys with both the point of departure and the destination on the line. It would have a varying significance for journeys with either the point of departure or the destination on the line. And finally it would only in a few cases mean anything for journeys which have neither their point of departure nor their destination on the line.

The gross costs for the proposal are calculated in Table 7 for an operating period of 4½ hours during the peak periods on weekdays and for intervals between buses of 15 minutes.

From these and other evaluations of the bus network with and without a circular line respectively, it is concluded that a circular line to a wide extent fulfils its aim with regard to improvements in accessibility. Since it applies, furthermore, that a possibility exists to cover part of the costs for a circular line by eliminating certain departures on certain radial lines, it is recommended in the thesis quoted to establish the circular line.

EXAMPLE 4: FLEXIBLE HOURS VERSUS FIXED HOURS

It has already been mentioned that the double time constraint in the timetable and at the destination has a great influence on total travel time and consequently on the usefulness of public transport to potential and actual users. (See Figs. 2 and 12). The test applications of the evaluation method has shown that this applies even in situations with comparatively short intervals between buses. In general, the results typically show that individuals who are subject to double time constraints (e.g. scheduled public transport and work with fixed hours) experience a considerable lower accessibility than individuals with one or no time constraints. Abolishing either side in a double time constraint would therefore typically improve the possibility of using public transport, especially to work and education.

A possible procedure would be to abolish the time constraint in the public transport system, either by increasing the number of departures in the schedule until concealed waiting time and changing time are almost zero, or by introducing a demand-responsive form of public transport, e.g. dial-a-ride. The latter solution will perhaps be expedient in thinly populated areas and during sparsely used travel periods. On the other hand it is hardly well suited for meeting transport demands in fairly large towns during the peak periods.

The first solution - to increase the number of departures in the schedule - is more obvious for larger towns, but it will require large sums of money before the improvements are generally noticeable and before they correspond to the improvement that would be experienced if flexible hours were introduced instead of fixed hours (free time of arrival and departure). As an example, consider the change in service referred to under Example 1. The differences between the dotted and solid curves in Figs. 2 and 12 correspond to increases in gross spending of approx. 1 million kr. and approx. 5 million kr. respectively on an annual basis, and it can be seen that the corresponding improvements in accessibility are far less than the differences between the situation with and without a free time of arrival. Even though the situations before and after the change in service are not fully comparable due to an extension in the area covered by the bus network, this suggests that flexible hours could be a particularly cost-effective means of improving the accessibility in the public transport system and thereby perhaps also of increasing its use. These results call for specific investigations of which types of work and work functions (or activities in general) can be performed just as well with flexible hours as with fixed hours and for policy formulation for the area.

EXAMPLE 5: USER INFORMATION

As a result of the method requirement concerning specific and relevant results, the travel time model operates on a data base identical to that which users employ when selecting their journeys, namely the pertinent timetables. This means that the travel time model (together with various data processing programmes) can be used to structure and present the contents of the timetable in different ways.

Particular emphasis has been laid above on planning-orientated applications but, due to the nature of the data base, it will also be possible to work in other directions, e.g. with the aim of representing user information.

An example of this type of application is illustrated in Table 8, which shows part of a printout of the most expedient journey selections to the employment and educational centre Amtsgaarden (the county council and the university) from all other parts of the public transport system in the study area. Latest time of arrival is set at 07.50.

It is evident from the table, for example, that a user who lives in the district around Østervaenget, works/studies at the county council or at the university (Amtsgaarden), and must be there by 07.50 at the latest will achieve the shortest total travel time by taking bus No. 4 at 07.04 to Dyrskuepladsen and transfer here to bus No. 30 with departure towards the bus terminal (Rutebilstationen/Banegaarden) at 07.15. At the bus terminal the user must change again, this time to bus No. 911 which departs at 07.40 and arrives at Amtsgaarden at 07.49. If the user will not accept a journey with two transfers, there is an option to start a quarter of an hour earlier, at 06.49, for Nytorv, where he or she changes to bus No. 11 which arrives at Amtsgaarden at 07.45.

Printouts of this type (with an improved design) could perhaps be used by public transport authorities as a service vis-a-vis educational institutions, work places, etc., with a view to simplifying and increasing the use of public transport. For instance, one could imagine that information about which choice of journey is most expedient after a prospective change in service would make adjustments in travel habits less troublesome and result in fewer complaints.

It should also be mentioned in this connection that many other types of user information will be possible. The only limit lies in the fact that there must be a possibility of further processing of information already present in the timetable. Cost calculations will be of less interest in this connection.

CONCLUSIONS

The main conclusions from the research summarized in this paper have already been mentioned in the introductory summary. In closing the paper it should be added that the test applications of the evaluation method clearly shows that the accessibility side of the method (the travel time model) is most operational for all-to-few, few-to-all, and few-to-few assessments both with respect to computer time used and with respect to the ease with which results can be handled. This comes as no surprise, of course, as the evaluation method has been developed with an explicit view to this type of assessments. It is possible, however, to carry out all-to-all assessments with the model, but this would require the introduction of a geographical aggregation, i.e. traffic zones as in traditional transport models, as well as a temporal aggregation, e.g. average travel time. This would be possible but it would mean a departure from the basic idea of the evaluation method as the results would become more expert-orientated and less comprehensive and relevant to laypeople.

NOTES

1) The concealed waiting time arises as a result of a mismatch between the timetable and the times which the traveller has to comply with at the end points of the journey. For example, the timetable may mean that a home-work traveller is obliged to arrive at his or her work place several minutes, A, before actually required, if the person concerned is not to arrive too late for the start of the working hours. One then speaks of A minutes' concealed waiting time.

2) A prerequisite for calculating net costs is the knowledge of actual journey numbers as well as of what changes alternative planning proposals would entail for journey numbers. For the study area, Aalborg, knowledge of journey numbers did not exist in 1980-81, and it has therefore been impossible to carry out precise calculations of net costs.

3) For test runs of the model on the study area (Aalborg) a limit of 15 minutes was set for transfer time + concealed waiting time. If this limit was exceeded in a given calculation, the calculation process proceeded to the next step in an effort to find a better (quicker) connection.

4) All tests of the travel time model were made for the timetable weekdays 05.00-09.00.

FIGURES

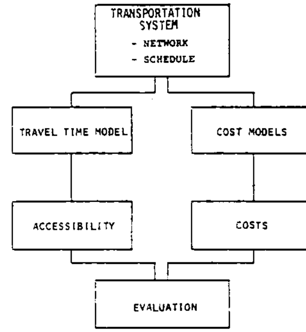


Fig. 1: Travel time model and cost models.

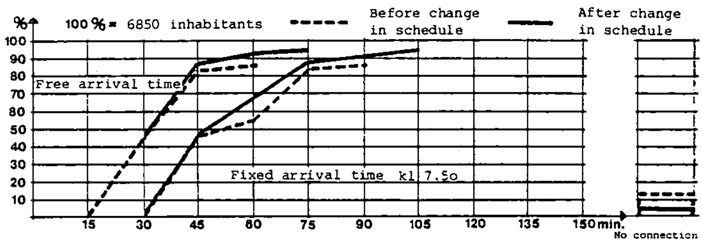
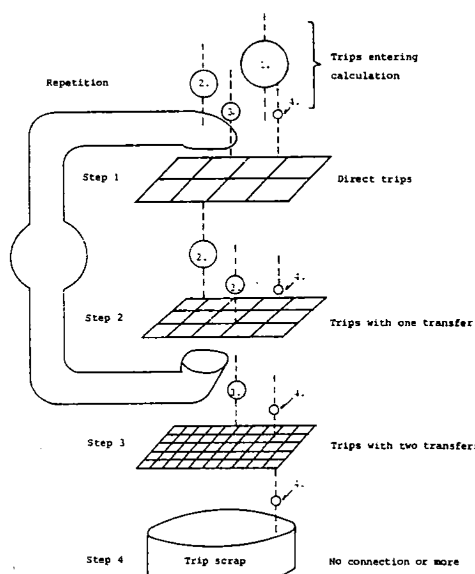


Fig. 2: Proportion of the population of a suburban area (Sulsted-Tylstrup) who can reach a central place (Nr. Sundby) within the total travel time quoted. Curves are quoted for the situation before and after a change of timetable (schedule) (January 1981), as well as for journeys with a latest arrival time of 07.50 and journeys with free arrival time respectively.

Fig. 3: Calculation process in the travel time model symbolised by a filter system with different mesh sizes. Trips are symbolised by grains of varying size. The grains 1, 2, 3 and 4 are "stopped" at the pertinent "filter" (step) in the model. (See description in text).



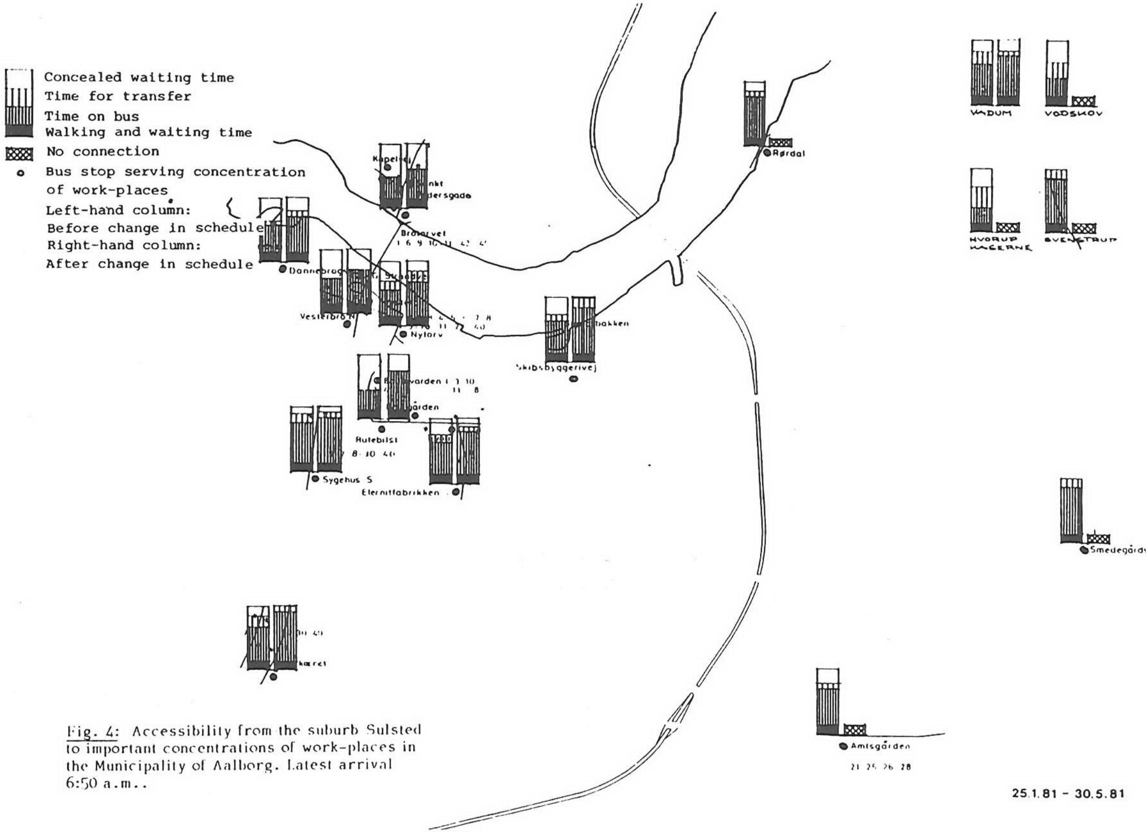
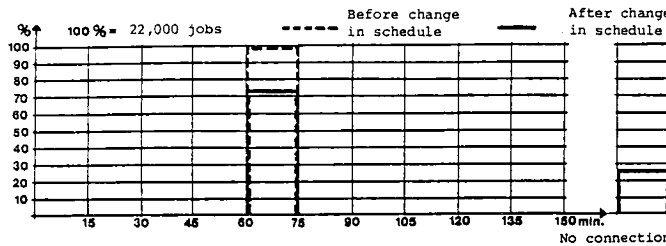
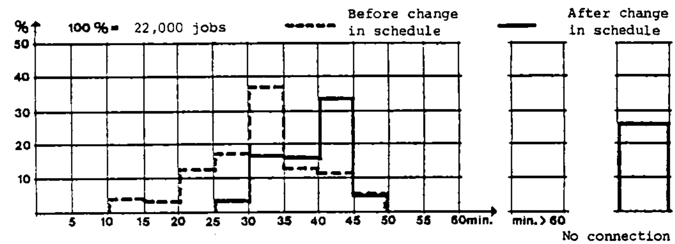


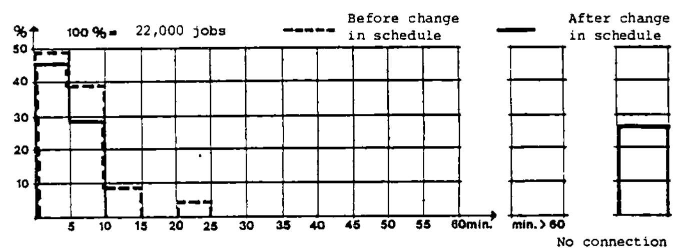
Fig. 4: Accessibility from the suburb Sulsted to important concentrations of work-places in the Municipality of Aalborg. Latest arrival 6:50 a.m..



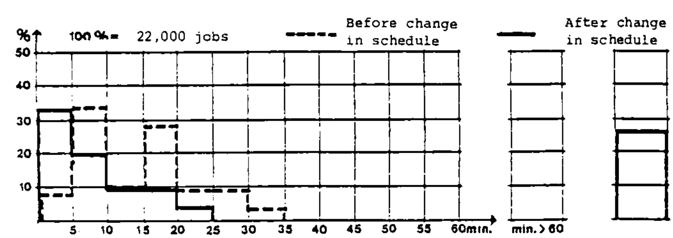
(a) Total travel time



(b) Time on bus



(c) Time in transfer



(d) Concealed waiting time

Fig. 5: The accessibility from Sulsted to work place concentrations with more than 500 employees, with latest time of arrival 06.50. Before and after the change in service respectively. The proportion of work places reached at the time quoted is shown.

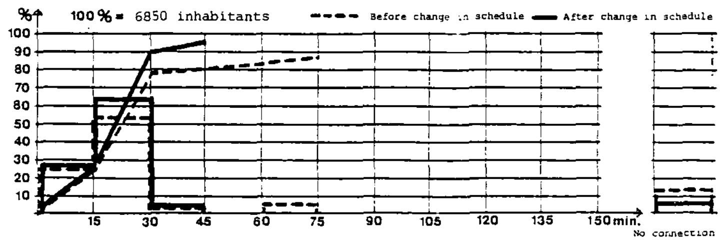


Fig. 6: The accessibility to Sulsted from its hinterland, with free time of arrival. Before and after the change in service respectively.

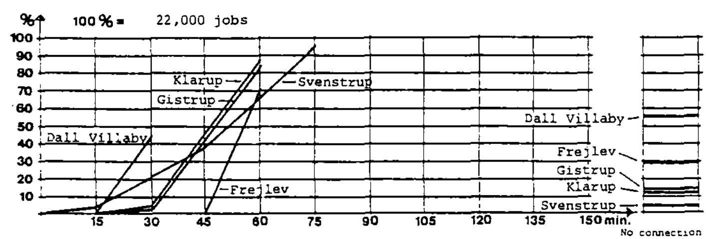


Fig. 7: The accessibility from selected suburbs to work place concentrations with more than 500 employees, with latest time of arrival 06.50. Proportion of work places which can be reached in the total travel time quoted is shown.

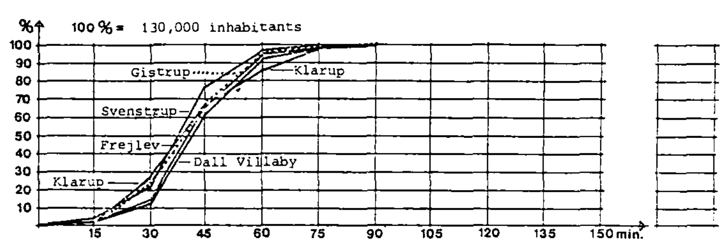


Fig. 8: The accessibility from selected suburbs to residential areas with more than 1000 inhabitants, with free time of arrival. Proportion of inhabitants reached in the total travel time quoted is shown.

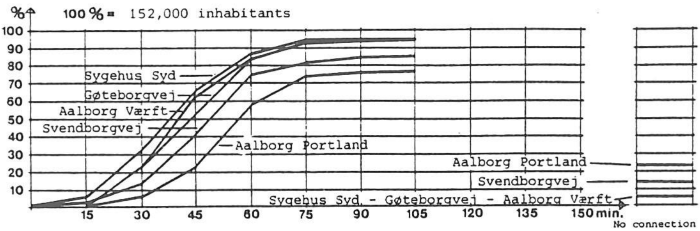


Fig. 9: The accessibility to selected work place concentrations with a latest time of arrival of 06.50. The curves show the proportion of the population of the study area which can reach the work place concentrations quoted within the total travel time quoted.

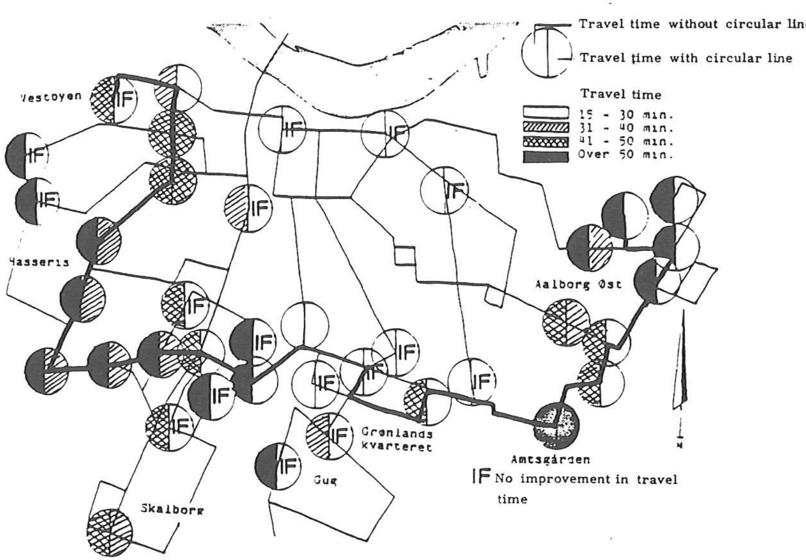


Fig. 10: Total travel time to the county council and the university (Amtsgården), latest time of arrival 07.55. With and without a circular line respectively.

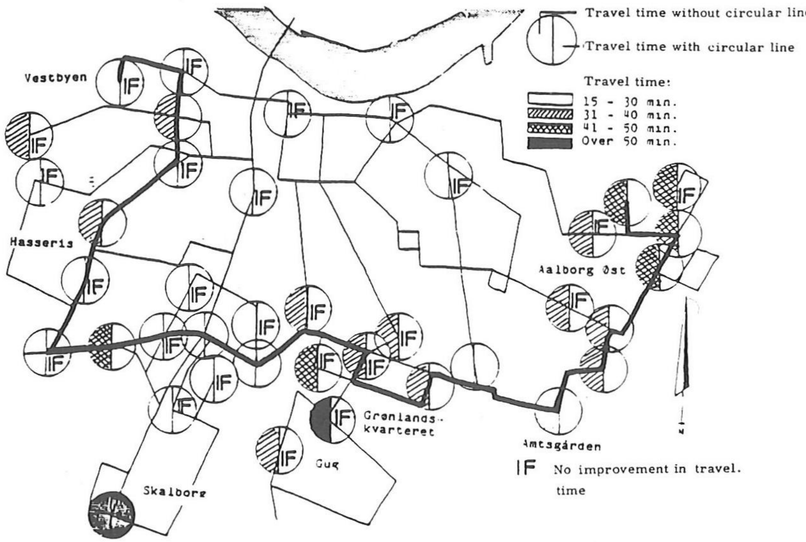


Fig. 11: Total travel time to Skalborg, latest time of arrival 07.55. With and without a circular line respectively.

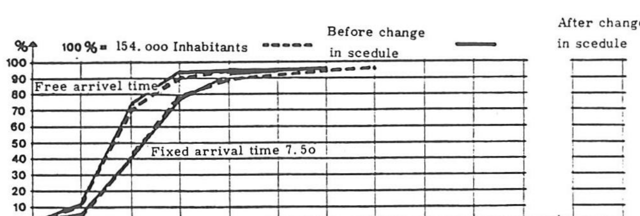


Fig. 12: Proportion of the population in the study area which can reach the CBD (Nytorv) within the total travel times quoted. Curves are shown for the situation before and after the change in service respectively, as well as for journeys with a latest time of arrival of 07.50 and journeys with a free time of arrival respectively.

TABLES

Driver costs per hour		
Mon-Fri	0600-1700	49.25 kr.
	1700-0600*	57.70 kr.
Saturday	0600-1400	49.25 kr.
	1400-1700	49.25 kr.
	1700-2400	57.70 kr.
Sundays and holidays	0000-0600	74.60 kr.
	0600-1700	62.53 kr.
	1700-2400	70.98 kr.
Supplement for driver work hours in addition to hours in schedule		Var.
Other operation costs		
Per vehicle-month		2,149 kr.
Per hour in schedule		59.46 kr.
Depreciation and interest		
Per vehicle-month (< 10 years)		6,252 kr.

Table 1: Cost model, standard model's structure and unit costs, January-August, 1980
*) Also applies for Saturday 00.00-06.00.

Driver costs per hour		
Mon-Fri	0600-1700	58.86 kr.
	1700-0600*	68.21 kr.
Saturday	0600-1400	58.86 kr.
	1400-1700	72.08 kr.
	1700-2400	81.43 kr.
Sundays and holidays	0000-0600	81.43 kr.
	0600-1700	81.28 kr.
	1700-2400	81.43 kr.
Supplement for driver work hours in addition to hours in schedule		33.4%
Other operation costs		
Per vehicle-month		2,187 kr.
Per hour in schedule		62.55 kr.
Depreciation and interest		
Per vehicle-month		6,375 kr.

Table 2: Cost model, standard model's structure, but actual unit costs for the bus operation in Aalborg. October 1979 - September 1980.
*) Also applies for Saturday 00.00-06.00.

DEPARTURE FROM: SULSTED, STOP NO. 804001

LATEST ARRIVAL 6:50 AM

EMPLOYED STOPS	STOP NO.	BUS NO.	LATEST ARR.	WAI+WAL	ON BUS	TRANSFER	CON.WAI	WALK	TOTAL
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	28							
SKIBSBYGGERIVEJ	965701		( )	7	32	5	16	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	7							
SYGEHUS SYD	325403		( )	7	39	8	6	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	28							
KORDAL	698502		( )	7	41	5	7	4	64
SULSTED	804001	36							
BROTORVET	83901	6							
VESTERBRO SYD	910602		( )	7	32	19	2	4	64
SULSTED	804001	36							
VESTERBRO NORD	910603		( )	7	25		28	4	64
SULSTED	804001	36							
VESTERBRO NORD	910603	2							
NYTORV	604001		( )	7	26	8	19	4	64
SULSTED	804001	36							
BROTORVET	83901	49							
VADUM (1)	837201		( )	7	31	12	10	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	8							
ØSTRE ALLE	74802		( )	7	31	7	15	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	7							
ETERNITFABRIKKEN	821601		( )	7	31	7	15	4	64
SULSTED	804001	36							
VESTERBRO NORD	910603	2							
DANNEBROGSGADE	398401		( )	7	27	4	22	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	9							
SMEDEGAARDSVEJ	864201		( )	7	46	7	0	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	7							
GØTEBORGVEJ	217101		( )	7	45	8	0	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	1							
OVER KAERET	325401		( )	7	34	10	9	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	6							
AMTSGAARDEN	577601		( )	7	35	5	13	4	64
SULSTED	804001	36							
BOUET	940001	6							
HVORUP KASERNE	362102		( )	7	15	21	17	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703		( )	7	28		25	4	64
SULSTED	804001	36							
BROTORVET	83901		( )	7	21		32	4	64
SULSTED	804001	36							
RUTEBILSTATIONEN / BANEGAARDEN	388703	1							
SVENSTRUP	325400		( )	7	43	10	0	4	64
SULSTED	804001	36							
BOUET	940001	8							
VODSKOV	940002		( )	7	15	15	20	4	64

Table 3: The accessibility from Sulsted to work place concentrations with more than 500 employees, with latest time of arrival 06.50. Before change in service.

DEPARTURE FROM: SULSTED, STOP NO. 804001

LATEST ARRIVAL 6:50 AM

EMPLOYED STOPS	STOP NO.	BUS NO.	LATEST ARR.	WAI+WAL	ON BUS	TRANSFER	CON.WAI	WALK	TOTAL
SULSTEO	804001	42							
BROTORVET	83901	10							
SKIBSBYGGERIVEJ	965701		( )	7	45	8	1	4	65
SULSTEO	884001	42							
BROTORVET	83901	40							
SYGEHUS SYO	325403		( )	7	45	5	4	4	65
SULSTEO	804801								
RORDAL	698502		( )		NO CONNECTION				
SULSTED	804001	42							
BROTORVET	83901	40							
VESTERBRO SYO	910602		( )	7	43	5	6	4	65
SULSTEO	804001	42							
VESTERBRO NORO	910603		( )	7	34		20	4	65
SULSTEO	804001	42							
VESTERBRO NORO	910603	2							
NYTORV	604001		( )	7	35	10	9	4	65
SULSTEO	884001	42							
BROTORVET	83901	49							
VADUM (I)	837201		( )	7	40	4	10	4	65
SULSTED	884001	42							
RUTEBILSTATIONEN / BANEGAARDEN	388703	21							
ØSTRE ALLE	74882		( )	7	41	5	8	4	65
SULSTEO	804081	42							
RUTEBILSTATIONEN / BANEGAARDEN	388703	4							
ETERNITFABRIKKEN	821681		( )	7	42	7	5	4	65
SULSTEO	884801	42							
VESTERBRO NORO	910603	2							
DANNEBROGSGADE	398401		( )	7	36	6	12	4	65
SULSTEO	8A4001								
SMEDEGAARDSVEJ	864201		( )		NO CONNECTION				
SULSTED	804001	42							
BROTORVET	83901	40							
NYTORV	604801	7							
GØTEBORGVEJ	217101		( )	7	49	10	0	4	78
SULSTED	804001	42							
BROTORVET	83901	40							
OVER KAERET	325401		( )	7	49	5	0	4	65
SULSTED	804001								
AMTSGRAROEN	577601		( )		NO CONNECTION				
SULSTEO	884001								
HVORUP KASERNE	362102		( )		NO CONNECTION				
SULSTED	804881	42							
RUTEBILSTATIONEN / BANEGAARDEN	388T03		( )	7	39		15	4	65
SULSTEO	804801	42							
BROTORVET	83901		( )	7	30		24	4	65
SULSTED	804801								
SVENSTRUP	325408		( )		NO CONNECTION.				
SULSTED	804001								
VODSKOV	940002		( )		NO CONNECTION				

Table 4: The accessibility from Sulsted to work place concentrations with more than 500 employees, with latest time of arrival 06.50.

	Hours in schedule	Driver work hours in add. to hours in schedule	Total costs
Before change in schedule	8.300	1.610	1.197.000
After change in schedule	17.620	3.310	2.551.000
Difference	9.320	1.700	1.354.000

Table 5: Gross costs on an annual basis (1980-kr.) for routes Sulsted-Aalborg. Before and after the service change respectively. 1 $ = 5.62 kr.

	Hours in schedule	Driver work hours in add. to hours in schedule	Total costs
Before change in schedule	7.650	1.480	1.108.000
After change in schedule	16.580	3.290	2.387.000
Difference	8.930	1.810	1.279.000

Table 6: Gross costs on an annual basis (1980-kr.) for routes within the local area of Sulsted. Before and after the service change respectively. 1 $ = 5.62 kr.

	No. of units	Unit costs	Total costs
Driver costs	6.804 hours in schedule	58,86 kr.	400.500 kr.
Supplement for driver work hours in addition to hours in schedule		29,6%	118.500 kr.
Other operation costs			
- per hour	6.804 hours in schedule	62,55 kr.	425.600 kr.
- per vehicle	6 vehicles	2.187 kr/month	157.500 kr.
Depreciation and interest	6 vehicles	6.375 kr/month	459.000 kr.
Sum total	-	-	1.561.100 kr.

Table 7: Gross costs for a circular line. Calculated on the basis of the cost model shown in Table 2. 1 $ = 5.62 kr. (1980 annual average exchange rate).

ARRIVAL AT: AMTSGAARDEN

LATEST ARRIVAL 7.50 AM

START BUS STOP	DEPARTURE	BUS NO.	TRANSFER 1	ARRIVAL	DEPARTURE	BUS NO.	TRANSFER 2	ARRIVAL	DEPARTURE	BUS NO.	END BUS STOP	ARRIVAL	LATEST ARRIVAL
LØVVANGSCENTRET	701	1	NYTORV	725	730	11					AMTSGAARDEN	745	753
NYHAABSVEJ	705	1	NYTORV	755	730	11					AMTSGAARDEN	745	757
NØRRE BRANDSVEJ	599	1	STRUBJERG VENDEPLADS	650	717	11					AMTSGAARDEN	745	750
KAPELVEJ	706	1	NYTORV	715	730	11					AMTSGAARDEN	745	750
LINDHOLMVEJ	715	11									AMTSGAARDEN	745	757
STRUBJERG VENDEPLADS	737	11									AMTSGAARDEN	745	750
STATIONSVEJ	716	11									AMTSGAARDEN	745	750
LARSENSVEJ	721	11									AMTSGAARDEN	745	753
LØVBAKKEN	555	38	NYTORV	710	733	11					AMTSGAARDEN	745	750
LINDHOLM HØJE	712	11									AMTSGAARDEN	745	750
NYRUP KASERNE	650	6	NYTORV	751	737	11					AMTSGAARDEN	745	750
NØRRE UTTRUP KASERNE	653	6	NYTORV	711	730	11					AMTSGAARDEN	745	750
NR SUNDBY GYMNASIUM	713	9	NYTORV	726	750	11					AMTSGAARDEN	745	757
BROTORVET	719	51									AMTSGAARDEN	745	753
NYTORV	730	11									AMTSGAARDEN	745	750
VESTERBRO NORD	720	42	RUTEBILSTATIONEN / BANEGAARDEN	735	740	911					AMTSGAARDEN	749	750
VESTERBRO SYD	723	39	RUTEBILSTATIONEN / BANEGAARDEN	725	757	911					AMTSGAARDEN	749	750
VESTERKÆRETS SKOLE	725	2	RUTEBILSTATIONEN / BANEGAARDEN	737	740	911					AMTSGAARDEN	749	750
LINDSKOVVEJ	715	3	VEJGAARD TORV	735	744	911					AMTSGAARDEN	749	750
JERNBANEHUSVEJ	712	5	NYTORV	725	737	11					AMTSGAARDEN	745	750
SØFRENDALSVEJ	711	7	NYTORV	725	736	11					AMTSGAARDEN	745	757
NØRHOTOFT	759	5	NYTORV	725	730	11					AMTSGAARDEN	745	750
BYSUMGAARDEN	705	4	NYTORV	715	737	11					AMTSGAARDEN	745	750
SYGEHUS SYD	727	30	RUTEBILSTATIONEN / BANEGAARDEN	725	740	911					AMTSGAARDEN	749	257
BAASEPIGEN	724	3	VEJGAARD TORV	735	744	911					AMTSGAARDEN	749	750
ØSTERVÆNGET	549	4	NYTORV	785	728	11					AMTSGAARDEN	745	750
ØSTERVÆNGET	704	4	DYRSKUEPLADSEN	706	715	30	RUTEBILSTATIONEN / BANEGAARDEN	725	740	911	AMTSGAARDEN	749	750
JOHAN SKJOLDBORGSVEJ	557	7	NYTORV	719	730	11					AMTSGAARDEN	745	757
DYRSKUEPLADSEN	715	38	RUTEBILSTATIONEN / BANEGAARDEN	[illegible]	740	911					AMTSGAARDEN	749	[illegible]
GØTEBORGVEJ	715	7	NYTORV	725	730	11					AMTSGAARDEN	745	750
NR KAERVEJ	714	1	NYTORV	727	730	11					AMTSGAARDEN	745	753
VESTRE MARIENDAL SKOLE	706	[illegible]	NYTORV	725	735	11					AMTSGAARDEN	743	750
HØJVÆNGET	709	4	NYTORV	725	730	11					AMTSGAARDEN	745	750
ØSTER VÆRKET	714	37	RUTEBILSTATIONEN / BANEGAARDEN	725	745	911					AMTSGAARDEN	749	750

Table 8: Extract from computer printout which shows the best connections from all parts of the public transport system in the study area to the county council and the university (Amtsgaarden) with a latest time of arrival 07.50. For each bus-stop are shown departure time, bus No. used, any transfer with arrival and departure times, any new bus No., and the time of arrival at Amtsgaarden