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Name of responsible: **Prof. Francesco Filippi**

Name of the institute DITS
Address Dipartimento di Idraulica Trasporti e Strade (DITS)
Università degli Studi di Roma "La Sapienza"
Roma

Abstract: The main goal of the CyberMove project was to demonstrate the effectiveness of Cybernetic Transport Systems (CTSs) in solving city mobility problems, proving that they have now reached high levels of reliability, safety and user friendliness. To do so several sites in Europe carried out field trials and feasibility studies for the implementation of CTS applications.

The sites were evaluated with a common methodology and the lesson learnt from them allowed to synthesize a guideline, this deliverable, for those cities willing to become a "City of Tomorrow" by installing a CTS. At a whole city level, this final evaluation report is complementary to the report "General process of urban transport planning and integration: where and how do cybercars fit?", D2.4, also called "VOLTair's methodology" aiming to initiate the link to the urban management and planing level.

The guidelines are written in three almost independent layers:
- the first, conceived to be read by politicians, city authorities and whoever is interested in CTSs, is the quantification of CTS main features and factors for success derived directly from the site evaluation;
- the second, drafted for city technicians and transport experts, provides a handy method to pre-design the right CTS for the city and to roughly quantify its costs and benefits;
- the third, written for those technicians who will make the detailed design of the CTS, provides a number of suggestions on how to design effectively, and differently from a conventional transport system the CTS.

Keyword List: Guidelines, CTS, performance, cost, evaluation

Foreword

This deliverable has been drafted under the guidance of Professor Francesco Filippi by DITS CyberMove staff: Dr. Adriano Alessandrini and Daniele Stam.
It is the main outcome of CyberMove evaluation to which all the Project partners contributed.
Sections 4.4 and 4.6 were respectively written by Thierry Chanard (GEA) and Marten Janse (TNO).

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EXECUTIVE SUMMARY

The main goal of the CyberMove Project was to demonstrate the effectiveness of Cybernetic Transport Systems (CTSs) in solving city mobility problems, proving that they have now reached high levels of reliability, safety and user friendliness. To do so, several sites in Europe carried out field trials and feasibility studies for the implementation of CTS applications.

This is the fifth and final evaluation deliverable which, on the basis of the site results, synthesizes a CTS design methodology and provides a guideline for those cities of tomorrow willing to study, design and implement a CTS.

CyberMove evaluation methodology has been organised in three phases: initial, ex-ante and ex-post evaluation. Derived from MAESTRO, it was adapted to the scopes and needs of CyberMove. Initial evaluation selected impacts and indicators to measure them and defined expectations and thresholds for success of each site. The ex-ante evaluation made a first financial and economic assessment of CTS implementation in each site. Ex-post revised these results on the basis of the outcomes of field trials and more detailed studies. This deliverable, after the completion of the last phase, makes it possible to transfer to other cities the CyberMove results.

CyberMove studied and evaluated CTSs in ten sites: Antibes, BAB, Coimbra, Copenhagen, EPFL, Nancy, Ouchy, Rivium, Technion Campus and Werfenweng.

Antibes will use the CTS as a park shuttle to push visitors to park further away from the city centre. The line studied is along the harbour, one and a half kilometres long two ways, and it links four car-parks to one of the city centre entrances (Porte Marine).

BAB CTS is a park shuttle too. Its aim is to reduce “search-traffic” around the centre of Bayonne. The city has several car-parks but people, instead of parking in the first car-park they meet on their way, try to park in the one nearest to their destination. The CTS is designed to push people to leave their car in the first available car-park.

Coimbra CTS will be a two weeks experiment in a newly refurbished zone of the city along the river and just under the city centre, which is on the hill. The CTS line, 2 kilometres long, will link a new car-park and a train station with the city centre entrance.

Copenhagen is the only city-wide application study in CyberMove. It studied the construction of a network of monorails where specially designed cybercars can run. The vehicles, either public or private, need a driver when driving outside of the monorail and are fully automatic on the monorails.

The proposed CTS for the EPFL campus, Ecole Polytechnique Fédérale de Lausanne, is meant to ameliorate internal campus mobility. The campus is linked to Lausanne by the light metro TSol and it has several car-parks, but the total extension is high and to go on foot from one corner to the other may require a long time. The system is conceived to be used as a way to “walk faster”.

Ouchy is the lake side of Lausanne. The CTS is conceived to be a public transport system linking the metro station with the CIO museum and with the “promenade”.

Rivium CTS is a shuttle linking one metro station of the Rotterdam network, Kralingse Zoom, to the business park of Capelle aan den Ijssel in the Netherlands. The new system will substitute another CTS that worked there as a pilot project until January 2001.

The Technion, I.I.T., is a university in Haifa (Israel). The CTS proposed for its campus is a line linking the eastern gate with the campus centre and the future cable car station.

Werfenweng is a winter resort in Austria and the CTS would be the only inner city transport system once it is completely closed to private cars ensuring internal mobility as well as the connection with the ski runs.

All the sites completed at least two evaluation rounds and allowed, by comparing the findings of the different sites, to define some general CTS outcomes transferable to other sites which were synthesised in these guidelines.

The whole of these planning and experiments made it possible to establish a methodological guide, intended to integrate the CTS in the policies of territorial development and urban mobility. In addition to the use of the CTS, it was indeed of primary importance to show its role and place in the city. This guide thus constitutes a tool of decision-making aid for the political authorities; that makes the strategies of transport and parking coherent, while replacing the private car at its right place.

As a general remark, from CyberMove studies it emerged that CTS can be most successfully employed for two short distance transport services: as feeders for the main public transport network and as park shuttles linking car-parks to one or many destinations.

The commercial speed for short distance CTS is strongly dependent on whether the route is shared or segregated: in the first case it ranges between 5 and 13 km/h whereas in the second it ranges between 15 and 20 km/h. The route of the long distance CTS must be segregated and the commercial speed can increase up to 44 km/h which is more than the commercial speed of cars.

The average waiting time significantly changes with the network extension, the demand and the number of the vehicles employed and ranges between 0.5 and 5 minutes.

Depending on waiting and travel times CTS does attract more or less demand: lower and more reliable waiting times and shorter travel times increase the attracted demand.

CTS can theoretically reach any capacity by using the platooning technique which allows the vehicles to form a “train” and therefore lowering the average headway distance to keep for safety reasons: in short distance services such techniques are usually not necessary and the system capacity can be increased only by increasing the size of the vehicles, whereas in long distance services the platooning is a must.

The average consumption per passenger·kilometre measured for the CyberMove sites is strongly influenced by many factors as maximum speed, average speed and occupancy and ranges between 0.05 and 0.5 kWh/p·km, much less than that of a normal 100 passenger bus which consumes 0.4 litres of diesel per kilometre that, considering a 30% average occupancy, would result in a consumption of 0.89 kWh/p·km.

Even if the number of kilometres travelled all together by all CTS vehicles in the world does not allow any significant statistics on safety, no accidents ever occurred to a CTS and not a person was injured neither there were any casualties.

The total investment to start up a CTS varies from 0.5 M€/km to 4 m€/km for short distance services, lower than 11 M€/km required for a tramway service, and grows to 9.3 M€/km for long distance services, much lower than 50 M€/km required for a metro service. The yearly operation costs vary between 2 and 0.05 M€/km per network kilometre.

Even if the Financial NPV for a CTS is almost negative, ad hoc mobility policies that would push people to use it could make CTS financially neutral. Furthermore CTS is usually socio-economically viable and the community would benefit in its installation.

The guidelines are organised in three sections with an introduction explaining who should read them and why:

- First, reporting the CTS features and critical success factors emerging as general findings from the entire CyberMove evaluation process and specifically from the ten Project sites;
- Second, providing a handy method to have a first idea of how many vehicles of what size would be necessary to provide a transport service in a given area with a known demand and what transport performances can be achieved with that many vehicles; and
- Third, indicating and describing the necessary steps to design and evaluate a CTS namely investigating the demand, building consensus among users and non-users, dimensioning the system, ensuring its integration in the urban environment and in the transport network and ensuring the system safety.

CYBERMOVE FINAL EVALUATION REPORT

1 INTRODUCTION

This is the final CyberMove evaluation deliverable; it gathers the results of the Project and use them to provide guidelines for any city whishing to think of, design and implement a CTS.

This brief introduction replies to four questions the readers may ask. What is the purpose of these Guidelines? Why are the Guidelines needed? Who should use the Guidelines? How are the Guidelines organised?

What is the purpose of these Guidelines?

These guidelines will help the cities:

- to understand whether they need a CTS or where they would benefit more from a CTS installation;
- to quantify the benefits and the costs connected to the CTS with respect to a conventional transport system; and
- to guide them through the CTS design process.

Why are the Guidelines needed?

To design a conventional transport system is a fairly standardised process; each transport system has been designed so many times in so many places that average figures of performances and costs are available. For example a metro line has a capacity of about 20 000 passengers/hour, a frequency of 5 minutes and a cost that, depending on many factors, may range between 50 and 100 M€/km bidirectional.

Such figures are not available for CTSs for two main reasons: there are only few systems built so far and the CTS are so flexible that their performances and costs may vary in a much wider range.

These guidelines provide the average benefit and cost figures for CTSs deriving them from the CyberMove sites, which are all together the widest CTS design and evaluation experience made so far, plus they provide a handy methodology to pre-design the CTS according to the site characteristics thus reducing the benefit and cost range, and finally they give a step by step procedure to guide a detailed CTS designing to be made and evaluated before the implementation.

Who should use the Guidelines?

These guidelines have been written for cities. They are not oriented to technology or technology providers but to the authorities of the city and their transport and urban planners.

Three layers of reading exist:

- politicians, city authorities and general readers, who are interested in the main features of a CTS, the benefits it could provide, how much it would cost and the key factors to make the CTS a success in the city, should read section 2 of these guidelines “CTS Main Features and Success Factors”;
- transport and urban authorities of the city, willing to have a preliminary assessment of a specific site in which they believe a CTS may be useful, who want to determine how many vehicles of what size would they need to provide what kind of service and what benefits such system may have at what costs should read section 3 “CTS Pre-design Method” after reading section 2;

- technicians, engineers and architects in charge of designing the CTS the city authorities believe could solve some of the mobility problems should read all this report and follow the section 4, “CTS Design Method”, procedure step by step.

How are the Guidelines organised?

In three sections other than this introduction:

- first reporting the CTS features and critical success factors emerging as general findings from the entire CyberMove evaluation process and specifically from the ten Project sites;
- second providing an handy method to have a first idea of how many vehicles of what size would be necessary to provide a transport service in a given area with a known demand and what transport performances can be achieved with that many vehicles; and
- third indicating and describing the necessary steps to design and evaluate a CTS namely investigating the demand, building consensus among users and non-users, dimensioning the system, ensuring its integration in the urban environment and in the transport network and ensuring the system safety.

Two recommendations have to be added at the end of this introduction.

The CTS technology, although already mature, tend to evolve rapidly causing a premature ageing to some of the figures provided in these guidelines. It is recommended that, especially in some years, before applying the figures here reported they are checked with the system manufactures who will be more than happy to keep them up to date.

Transports are the second most discussed topic after football in Europe; that does not make any person a transport planner although most people may believe so. These guidelines may become a boomerang in the wrong hands. It is strongly recommended, and not only because the main authors are transport planners, that especially the CTS detailed design is made by a trained transport planner who may coordinate a multidisciplinary team.

2 CTS MAIN FEATURES AND SUCCESS FACTORS

Depending on how it is designed a CTS can virtually accomplish any transport task: it can provide a park shuttle service for an historic city centre or a business park; it can be a feeder for the main public transport network or the only available transport service in a quarter or a village; it can serve students and personnel in a campus; and it can even be a city wide transport system. For each of these services CyberMove experimented, tested or simulated different design solutions and can now provide, depending on them, figures on performances and costs.

As a general rule the services can be sub-divided according to the distance: they can be short distance transport services (around 1 km), or long distance ones (5 km and more). The main difference between them is that the long distance system needs to have dedicated high speed infrastructures while the short distance does not necessarily require them. Nine of the ten CyberMove sites were short distance thus the results are here presented for these systems; nevertheless the Copenhagen experience allowed to understand the key differences in terms of performances and costs between short and long distance systems and where these differences exist they are pointed out.

The CTS main features and success factors emerged from CyberMove studies are presented here organised in four sub-sections; each of them replies, as much as possible quantitatively, to the related questions a city may ask about CTSs.

2.1 Transport service characteristics

What kind of service does a CTS accomplish better?

CTSs can be most successfully employed for two short distance transport services:

- as feeders for the main (high frequency and high speed) public transport network;
- as park shuttles linking car-parks to one or many destinations.

These two services have two things in common: they are low to medium demand and are typically supplied today by low frequency bus services.

The typical feeder service is that of a peripheral or semi-peripheral city area which is touched by one or more main public transport lines but the distance between the metro stations and the area extents is around and over 1 km discouraging most people in the area to go on foot to a metro station. Typically the public transport service that links the area with the metro stations makes a long tortuous route into the area covering it almost entirely with one single low frequency line which therefore supplies long and variable waiting times and low commercial speeds. Ameliorating the service with a “frequency” service would be very expensive and the buses would travel empty most of the time; a CTS, running on demand and free ranging on the network can provide better and certain waiting times and better commercial speeds.

Park shuttles, especially if serving a wide ground level car-park or if linking the car-park to several different destinations, can be effectively substituted by CTSs which can run services better responding to the demand needs.

If CTSs are employed to provide the same quality of service of low frequency bus systems they are more expensive and do not provide any specific transport benefit (excluding the environmental benefit due to the CTS vehicles being electric); however, if the quality of service has to be improved, to do it increasing the frequency of a conventional bus service is much more expensive (in ten years) then building a CTS, therefore CTSs are well suitable for low to medium demand areas and short distances trips where a good quality of service has to be provided.

It must be stressed that increasing the quality of the public transport service, which is one of the reasons to adopt CTSs, is not sufficient to increase considerably the PT modal share thus integrated policies are recommended to push more people to use it. Combining CTS installation with some "push" measures, such as parking or road pricing or rationing, may help to make the push measures better accepted by the users and to decrease the modal share of private vehicles.

Another point to stress is that CTSs do provide better transport services, if they are designed so, than low frequency buses but interfacing a CTS with a low frequency bus line would waste the CTS benefits in terms of its attractiveness on the users.

The service best accomplished by long distance CTSs is the city wide service. CTSs can provide a more convenient transport service than metros and, sometimes, even than cars, but they need dedicated and fully segregated high speed infrastructures.

What commercial speed (travel time) can a CTS ensure?

The commercial speed is one of the indicators better measuring, together with the waiting time, the transport performances. It measures the travel time but does not depend on the travelled distance.

The commercial speed for short distance CTSs strongly depends on whether the route is shared or segregated. In the first case it ranges between 5 and 13 km/h while in the second it ranges between 15 and 20 km/h. The typical speed of surface public transport in big congested cities is around 13 km/h that is the average of slower speeds of the peak hours and faster in the off-peak. As such an average speed of 13 km/h and more can make the system more attractive than surface public transport but not of metro or private vehicles. The attractiveness of a CTS with that speed range may increase if the CTS is used as a feeder service for other transport modes (high frequency and high capacity public transport and cars) over short distances (as it was in most CyberMove sites).

The route of the long distance CTS must be segregated and the commercial speed can increase up to 44 km/h which is more than the commercial speed of cars.

The same vehicle can have a double average speed if the route is segregated, with respect to a shared route, for two reasons: the vehicles stop only when passengers boarding or alighting require so, and not because of external influences, and the maximum speed can be much higher than that imposed for safety reason when the route is not segregated. Of course segregation as a "community severance" impact which is typical of surface metro, railways and motorways.

How long the waiting time of a CTS is?

The average waiting time significantly changes with the network extension, the demand and the number of the vehicles employed and ranges between 0.5 and 5 minutes.

Given the demand and the network the waiting time is influenced by the number of vehicles, by their capacity and by their commercial speed. As such, for what said about commercial speed, it is influenced by segregation as well.

The main success factor to highlight about the waiting time is that, although it can be better or worse than that of a conventional PT system depending on how the two are designed, a CTS becomes interesting for a site only in case it is designed to have a lower waiting time than a conventional transport system. As already pointed out describing the "kind of service better accomplished by a CTS", the main part of the cost per kilometre in running a bus service is the driver cost that grows proportionally with the kilometres the buses make each day (and therefore with the frequency) while in a CTS the infrastructure cost is more significant and therefore the cost per vehicle·kilometre decreases increasing the kilometres the CTS vehicles make each day. As a consequence if a transport system is designed to provide long waiting times it is worthwhile to do it by bus while to ensure shorter waiting times CTS becomes financially competitive against the bus.

The other feature of a CTS about waiting time is that since the system is (or may be) on-demand the waiting time is less variable than that of a “frequency” service which can typically range from 0 (in case the passenger reaches the stop the same moment the bus does) to the frequency (in case the bus has just left and the service is so reliable that the next one follows at exactly the frequency interval) and is in average half of the frequency.

Last factor to point out is the correlation between average waiting time and occupancy: lowering the average waiting time the occupancy decreases. As a matter of fact if a service is better responding to the user requests less people travel together in the same vehicle. Lowering occupancy has normally three effects: more vehicles for the same demand; more space used and more energy spent; but a CTS by using smaller and more energy efficient vehicles is able to provide better use of space and better energy consumption per passenger·kilometre than busses even providing a transport service with lower waiting time and therefore lower occupancy.

How much demand does a CTS attract?

A service with lower and more reliable waiting times and shorter travel times does attract more demand.

Furthermore if CTSs provide a better transport service in low demand areas which are the “Achilles heel” of any public transport network and, if used there, they can induce more people to shift from private to public transport on the other parts of the journey as well.

Nevertheless a CTS will not solve the mobility problems alone, other measures to push people to use public transport have to be adopted; the CTS can be the public transport improvement that is always required when adopting such measures.

Last success factor related to demand to point out is the need for a detailed transport study in the CTS design phase to correctly dimension the system, quantify the demand, evaluate the interactions with the transport networks of the city and identify the “accompanying” measures necessary to make the CTS a success.

What capacity does a CTS have?

CTS can theoretically reach any capacity by using the platooning technique which allows the vehicles to form a “train” and therefore lowering the average headway distance to keep for safety reasons.

In short distance services such techniques are usually not necessary for two reasons: the speeds are low, consequently the headway distances which grow with the square of the speed are low, and the origin and destinations are not too distant one another therefore one bigger vehicle can host more people travelling at the same time with different O-Ds, the system capacity can therefore be increased by increasing the size of the vehicles rather than by increasing so much their number to cause congestions.

In long distance services the platooning is a must as well as off-line stops. Nevertheless by using such a technique each network link can reach the 20 000 passengers per hour capacity (considering three and a half platoons of 10 vehicles with 10 passengers per minute travelling at 80 km/h) which is typical of a metro line. A centralised control must be kept to avoid congestion at the nodes and stops.

2.2 Energy consumption and externalities

How much energy per passenger kilometre does a CTS consume?

The average consumption per passenger·kilometre is strongly influenced by many factors; three are the most important: maximum speed, average speed, occupancy.

The consumptions calculated or measured for the CyberMove sites range between 0.05 and 0.5 kWh/p·km. Such figures, although very distant from each other, are both much smaller than that of a normal 100 passenger bus which consumes 0.4 litres of diesel per kilometre that, considering a 30% average occupancy, would result in a consumption of 0.89 kWh/p·km.

Of course the ways to lower the consumption are: by keeping the speed low, which goes as well in favour of safety, but which hamper the performances or by increasing the occupancy, which can be made by increasing the waiting time and therefore by reducing the transport performances. Nevertheless by considering the big picture it is clear that with the same consumption of a bus the CTS can provide a better service and therefore subtract users to the private modes which are all much more consuming and polluting.

Does a CTS emit? And how much does it emit per passenger·kilometre?

Yes a CTS does emit. It does not emit in loco because the motors of the vehicles are electric (at least of the CTS studied in the CyberMove framework) but it emits where the electric energy is produced. Such “delocalisation” of the emissions is already a great benefit because the main concentration of population is in cities and therefore the pollutions are more noxious when produced in cities, but the main benefit is the low emission rate, to produce the same amount of energy, of thermal plants with respect to a motor-vehicle-combustion-engine.

Table 2.1, which is obtained by the data taken from Litman (Litman 1999) using 1.3 people per car and 6 people in a bus with 20 places and multiplying the energy consumption per passenger·kilometre obtained for the CTS (minimum and maximum of the range) by “The emission rate from electricity generation in Europe” estimated by the MEET project (MEET 1999 Figure B5 page 231), shows a comparison of emissions between modes. The CTS emissions, even in the high part of the range, are much lower than those of a bus. With the exception of Volatile Organic Compounds which are comparable between bus and maximum CTS all the other emissions are less than a tenth. The most interesting data come out from the comparison between cars and CTSs: NOx are divided by 4, VOC by 6 and CO buy a factor 600.

Table 2.1 Comparison of emissions per passenger kilometre

Emissions g/pkm	VOC	CO	NOx	PM
Car	2,42	18,13	1,47	0,08
Bus (20 places)	0,37	5,00	2,23	0,57
CTS_Min	0,04	0,00	0,05	0,01
CTS_Max	0,43	0,03	0,45	0,06

Is a CTS safe?

Road safety is traditionally evaluated counting incidents, injured and dead people. Fortunately incidents are rare events compared with the number of vehicles travelling and with the number of kilometres they do. No accident ever occurred to a CTS, not a person was injured neither there were any casualties; nevertheless the number of kilometres travelled all together by all CTS vehicles in the world does not allow any significant statistics on the matter. Therefore as it is now, applying traditional road safety analysis, it is not possible to say whether CTSs are safer or less safe than a conventional transport system.

Since the beginning of CyberMove it was known that in the Project framework it would have been impossible to run enough vehicles for enough kilometres to obtain significant statistics on the matter therefore a completely different approach was applied. In CyberMove framework a certification methodology was developed. Based on the risk analysis, the methodology analyses the CTS design in each site and "evaluates" the risks connected with its implementation, traditional road safety risks as well as system failure risks, and proposes, in a feedback process, amendment to the design to reduce the risks. Although conceived for a certification process the methodology evaluates the safety of the designed CTS.

In this way CTSs are the only "road" transport systems which are designed to ensure safety as for the rail system. Although quantification is always difficult, depending on the country rail accidents have a social cost of around a tenth of that of car accidents and a hundredth of that of motorbikes (Friends of the earth 1999) and it is not too ambitious to expect for CTSs the same "safety" of a rail system.

2.3 Costs, profitability and socio-economic viability

How much is the total investment to start up a CTS?

Total investments vary according to the network extension, the number of vehicles used and their size; they ranged in the CyberMove experience from the 0.22 million € (M€) for a line of 3.8 km to nearly 3 billion € for a 640 km new network covering the entire Greater Copenhagen area.

Excluding the two extremes and dividing the investment costs by the network length (bidirectional) it emerged that the start-up costs vary from 0.5 M€/km to 4 M€/km depending on a number of factors most important of which are the demand the system has to serve and the level of service it has to provide. Such figures are for systems which use the existing infrastructures and therefore typically short distance CTSs.

When these costs are compared to the costs of a tramway at street level, which is around 11M€/km, they seems quite reasonable but on the other hand the investment costs to install a bus line are on the low side of the CTS installation costs: around 0.5M€/km.

For long distance services, in which a new segregated network has to be built, the CTS start-up costs grow to 9.3 M€/km but they are still far from that of a metro which is around 50M€/km.

How much does it cost each year to operate a CTS network?

The yearly operation costs for a CTS system vary as well as the installation costs according to the same parameters. Making the same division of costs per network kilometre the costs would still vary in wide range, between 2 and 0.05 M€/year per network kilometre (bidirectional).

More interesting is the operational cost per vehicle·kilometre (excluding vehicle and infrastructure depreciation) which varies between 0.5 €/veh·km and 3.17 €/veh·km.

It is interesting to notice how the high costs of the only long distance service when divided by the high number of vehicles circulating are reduced to 0.7 €/veh·km.

Although the comparison is not straight forward the average operational cost of a bus service (including this time the vehicle depreciation but not the asphalt disruption) is between 2.8 and 3.5 €/veh·km which proves how the CTS becomes competitive against the buses when a high number of vehicle·kilometres are supplied and therefore when the transport service has to be good.

Is a CTS financially profitable?

The Financial NPVs calculated are almost everywhere negative. This confirms that the public transport services are not profitable in Europe.

Nevertheless there were few sites (two) that, although non-profitable, were able to re-pay the initial investment over 10 years, even more sites (four) that were able to contribute in re-paying the initial investment and two more that were able to cover at least the operational costs.

These results are extremely good because CTS, instead of being subsidised as most of the urban public transport services in Europe, can just be “helped” by ad hoc mobility policies that would push people to use them and, in this case, they would become, if not profitable, financially neutral.

Is a CTS socio-economically viable?

The Socio-economic NPV is the indicator that defines whether it is convenient or not for the community to install the system. With the exception of one site, which was conceived to be just an experiment and therefore scored a very negative socio-economic NPV; all the CyberMove sites have either positive or neutral Socio-economic NPVs.

This proves that CTSs are usually socio-economically viable and that the community would benefit (or not disbenefit) in their installation.

The quantification of the benefit is very much related to how much the community values environmental and safety effects of mobility but applying the average European rates and adopting ad-hoc “accompanying” policies the socio-economic NPV in ten years can have a magnitude of ten times the initial investment to start up the system.

2.4 User reactions

How easy to use the users think the CTS is?

Ease of use is the highest scoring indicator among those selected to measure the user reactions. It clearly appears that all people that used any of the demonstrated CTSs think they are easier to use than conventional transport systems.

It is true that users have to get used to the system or being provided with good quality information but once they are used to the system or if information is provided they are more than satisfied with CTS easiness.

How performing is the CTS according to user perceptions?

Perceived performances are controversial; they are either perceived very well or not well at all.

Such controversial reaction is probably due to the fact that some of the people interviewed after a test ride perceived the vehicle top speed to be low (compared to that of a private vehicle) and transferred such sensation to judge the performances of the system while others interviewed after presenting them with the actual waiting and travel times the system would have supplied after its full-scale implementation judged the performances comparing such times with their daily trips.

It is true that CTS vehicles adapt their top speed to the environment and, for safety reasons, they can have in certain areas (with lot of pedestrians) low speeds as private vehicles should do too; but the commercial speed and the waiting time measured proved that they are better performing than conventional transport systems therefore it may become necessary to address a wrong perception with a campaign explaining to users to measure the performances by travel time rather than by the perceived maximum speed.

How safe the users think the CTS is?

Perceived safety is high. Although differences exist from site to site CTSs are generally perceived to be safer than conventional public transport.

How secure the users think the CTS is?

Security is generally perceived as high as safety although an increased “fear of attack” in one site in which the test vehicles were not equipped with CCTV highlighted the need to address, probably by installing and making well visible a CCTV or a call button in each vehicle, this problem with the users. Such countermeasures demonstrated to be effective since in the other sites, where the in-vehicle surveillance systems were clearly visible, the users felt more secure in the CTS than in conventional transport systems.

3 CTS PRE-DESIGN METHOD

To have a first rough dimensioning of the short distance CTS according to the site characteristics and exigencies and, given the dimensioning, to have and idea of the CTS main features, a pre-design methodology based on six steps is provided. The method was not tested on longer distance service and, therefore, at the moment it is applicable to sites in which the average travelled distance does not exceed the 2 kilometres.

The site characteristics needed to be known a-priori are: CTS network length and foreseen demand. Other than these two there are three CTS characteristics that can be chosen by the designer: vehicles capacity, maximum allowed vehicle speed and maximum allowed waiting time at CTS stops, which indicates the level of service to provide. Having defined the five characteristics as initial data the methodology is articulated in the following six steps. Designers are, obviously, allowed to try more combinations of characteristics and to compare costs and benefits of the different systems resulting.

1. First step is the identification of the number of vehicles circulating on the network: once the ratio demand/network length is known, the ratio between number of vehicles and network length can be calculated.
2. Second step is the identification of the average waiting time provided by the chosen service and the range in which it may vary depending on the chosen CTS characteristics (maximum speed, vehicle capacity and level of service).
3. Third step is the calculation of the total vehicle·kilometres the CTS will run in a day, obtained as a function of the ratio demand/network length and total network length.
4. Fourth step is the calculation of the commercial speed of the vehicles as a function of the ratio demand/network length.
5. Fifth step is the calculation of the occupancy rate of the vehicles, starting from the ratio between the foreseen demand and the number of circulating vehicles obtained in the first step.
6. Sixth step is the calculation of CTS investment and yearly costs on the basis of the system dimensioning made in the previous five steps.

As final result the methodology provides one formula for each step linking the searched variables with the initial data.

3.1 Initial data

A step zero for the identification of the initial data has to be done, in order to make all the five initial characteristics available before the first step of the methodology. If these characteristics are not available as initial data, some hypotheses have to be formulated to obtain reasonable values to adopt during the application of the methodology.

CTS network length is the first characteristic needed to design a CTS, it is strongly influenced by the site configuration but it can be roughly obtained by dividing the site are in squares of 100 meters side length. Of course a better estimation is desirable and can be made as suggested in section 4.3.

The foreseen demand is directly dependent on network length (a long network means big dimensions of the site thus more people who can use the CTS), but it is mainly influenced by two factors: the present mobility situation and the quality of service the CTS will provide. If the number of daily potential CTS users is not known by some previous study, some hypotheses on the basis of these two factors have to be made and the demand foreseen. In most of CyberMove sites an iterative procedure has been adopted iterating the demand forecasting after each system dimensioning (CyberMove 2004a) but for a pre-design just the initial estimation, as described in section 4.1, can be sufficient.

Vehicles capacity is due to the kind of vehicle chosen to cover the network. In this methodology three different vehicle capacities have been presented: four-place, ten-place and twenty-place vehicles. The choice of the vehicle capacity is directly linked with network features and with the demand CTS has to satisfy. For example in Antibes, where the network is 3 kilometres long in the ex-post study and the initial demand is made of about 700 potential users, the vehicles chosen to cover the line are twenty places, whereas in Bayonne ex-post study four-place vehicles have been chosen to cover the 6 kilometres of the network and to satisfy about 1000 potential users. Not knowing a-priori what vehicle size would best fit the site exigencies to try more than one solution is strongly recommended.

The maximum allowed vehicle speed has to be chosen on the basis of safety considerations: if the CTS is not segregated the maximum allowed speed has to be about 15-20 km/h, whereas with the segregation it can grow up to 25-30 km/h. As a general rule the highest the speed the better the service (with the same number of vehicles). Network length is another factor that should influence the maximum speed choice; typically 15 km/h maximum speed allow a commercial speed in the range between 8 and 12 km/h while with a maximum speed of 30 km/h the commercial speed range is between 11 and 17 km/h; 8 km/h is too low for a 5 kilometres run (that would last nearly 40 minutes), whereas if the run decreases to 1 kilometre 8 km/h is a good maximum speed. At the same time the mode of transport against which CTS has to “fight” once implemented directly influences the required quality of service and consequently the maximum speed. For example in Antibes the quality of service in ex-ante study (CyberMove 2004a) with three twenty places vehicles circulating on a 2 kilometres network at a maximum 30 km/h speed is different from that obtained in the ex-post study (CyberMove 2004b) with three twenty places vehicles circulating on the longer (3 kilometres) network at a maximum 15 km/h speed (average of the maximum of 20 in a part of the track and 10 in the other), as it can be seen by looking at the average waiting time (75 seconds in the ex-ante against 290 seconds in the ex-post). To consider the different possible CTS implementations, four possible maximum vehicle speeds has been taken into account: 15 km/h, 20 km/h, 25 km/h and 30 km/h.

The maximum allowed waiting time is the fifth characteristic to be chosen to apply the methodology. A time window is defined as the maximum time users would wait at CTS stops after pushing the call button. In a CTS pre-design a different value of the time window causes different results in terms of number of vehicles, demand satisfied by the system and financial and socio-economic impacts. To consider the different level of service available for CTS users, three time windows have been considered: 250 s, 625 s and 1000 s.

Considering three possible vehicle capacities, four possible maximum vehicle speeds and three different levels of service, the methodology provides $4 \cdot 3 \cdot 3 = 36$ different formulas per each step, linking the searched variable with the initial datum.

3.2 Number of circulating vehicles

The first feature to be identified is the number of vehicles needed to satisfy the foreseen demand.

Initial data needed for this step are the foreseen demand and the network length; the ratio between the number of vehicles circulating on the network and network length is function of the ratio between demand and network length.

The formulas to calculate this ratio are reported in Table 3.2.1 for 4-place vehicles, in Table 3.2.2 for 10-place vehicles and in Table 3.2.3 for 20-place vehicles, where x is the demand/network length and y is number of vehicles/network length. Once maximum allowed speed, vehicle capacity and level of service have been chosen, the ratio number of vehicles/network length is available by inserting the ratio demand/network length in the formula correspondent to the chosen configuration.

Table 3.2.1 Number of vehicles/network length for 4 place vehicles

4 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 2.7\cdot10^{-3}\,x + 1.644$	$y = 2.5\cdot10^{-3}\,x + 1.040$	$y = 2.2\cdot10^{-3}\,x + 0.957$
20 km/h	$y = 2.4\cdot10^{-3}\,x + 1.187$	$y = 2.2\cdot10^{-3}\,x + 0.814$	$y = 2.2\cdot10^{-3}\,x + 0.557$
25 km/h	$y = 2.4\cdot10^{-3}\,x + 1.083$	$y = 2.3\cdot10^{-3}\,x + 0.641$	$y = 1.9\cdot10^{-3}\,x + 0.616$
30 km/h	$y = 2.3\cdot10^{-3}\,x + 1.345$	$y = 2.1\cdot10^{-3}\,x + 0.855$	$y = 2.0\cdot10^{-3}\,x + 0.620$

Table 3.2.2 Number of vehicles/network length for 10 place vehicles

10 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 1.1\cdot10^{-3}\,x + 1.732$	$y = 1.2\cdot10^{-3}\,x + 0.647$	$y = 1.2\cdot10^{-3}\,x + 0.466$
20 km/h	$y = 1.0\cdot10^{-3}\,x + 1.417$	$y = 1.2\cdot10^{-3}\,x + 0.488$	$y = 1.1\cdot10^{-3}\,x + 0.350$
25 km/h	$y = 1.1\cdot10^{-3}\,x + 1.080$	$y = 1.1\cdot10^{-3}\,x + 0.563$	$y = 1.0\cdot10^{-3}\,x + 0.517$
30 km/h	$y = 1.4\cdot10^{-3}\,x + 0.996$	$y = 1.3\cdot10^{-3}\,x + 0.534$	$y = 1.0\cdot10^{-3}\,x + 0.525$

Table 3.2.3 Number of vehicles/network length for 20 place vehicles

20 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 7.0\cdot10^{-4}\,x + 2.021$	$y = 9.0\cdot10^{-4}\,x + 0.662$	$y = 9.0\cdot10^{-4}\,x + 0.453$
20 km/h	$y = 8.0\cdot10^{-4}\,x + 1.476$	$y = 9.0\cdot10^{-4}\,x + 0.562$	$y = 9.0\cdot10^{-4}\,x + 0.311$
25 km/h	$y = 1.2\cdot10^{-3}\,x + 1.135$	$y = 1.0\cdot10^{-3}\,x + 0.680$	$y = 9.0\cdot10^{-4}\,x + 0.503$
30 km/h	$y = 8.0\cdot10^{-4}\,x + 1.378$	$y = 7.0\cdot10^{-4}\,x + 0.733$	$y = 7.0\cdot10^{-4}\,x + 0.422$

Once y quantity is known, by multiplying it for network length and rounding the result the number of needed vehicles is obtained.

Figure 3.2.1 (depicting first row of Table 3.2.3) represents, for a CTS with 15 km/h maximum speed and 20-place vehicles, the relationships between the ratio number of vehicles/network length and the ratio demand/network length for the three levels of service (Max WT in the chart).

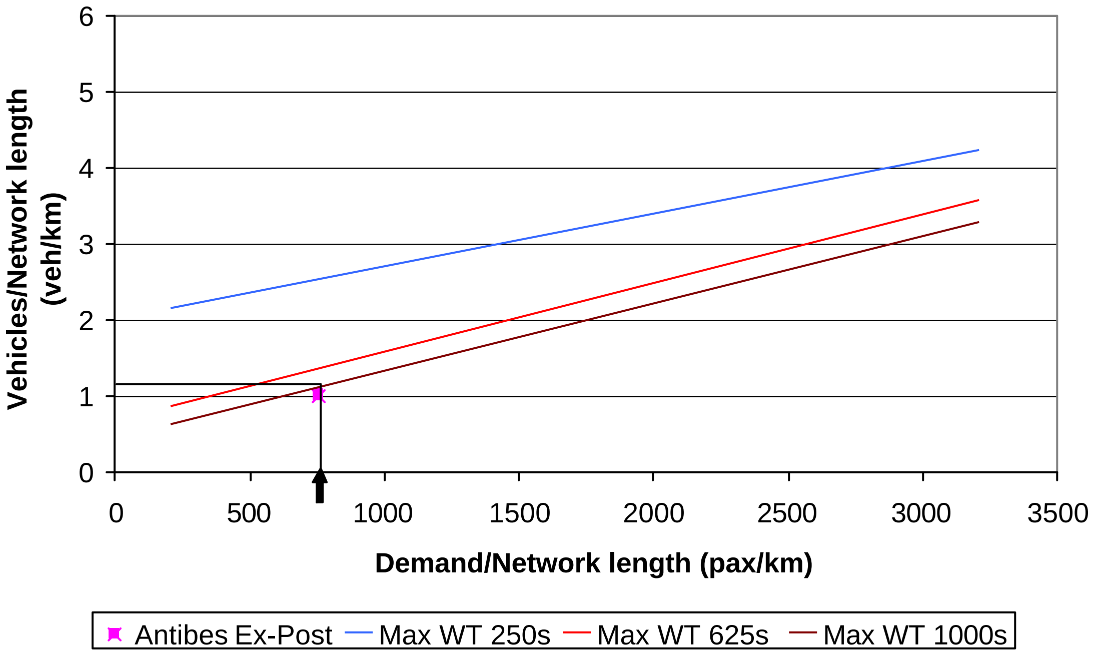

Figure 3.2.1 Number of vehicles circulating with 10 place vehicles and 15 km/h maximum speed

The single point in Figure 3.2.1 is Antibes ex-post result. The arrow shows the point correspondent to the ratio demand/network length of Antibes, which is 2270/3 = 756.67 pax/km. Dimensioning the system for a 1000 s maximum waiting time (if the required maximum waiting time is 625 s or 250 s the line starting from the arrow would arrive to the correspondent other line on the chart), the ratio vehicles/network length is 1.13, meaning 3.4 vehicles would be needed to provide that level of service. Of course it is not possible to have half vehicle therefore the choice is between 3 vehicles (with slightly lower quality service) or 4 vehicles (with slightly better quality). Antibes chose in the ex-post to run the service with 3 vehicles providing a maximum waiting time higher than 1000 s. As reported in D4.3&D2.3b, the possibility of using 4 vehicles on Antibes network leads to lower waiting times and a consequent higher level of service, even if system costs would grow.

The choice of the exact number of vehicles directly influences the other steps of the methodology, thus it has to be done on the basis of considerations about the quality of service required to the system.

Figure 3.2.2 shows the ratio number of vehicles/network length for a CTS with 20 km/h maximum speed and 4 place vehicles circulating on the network as a function of the demand/network length for the three levels of service.

The single point is that of Bayonne ex-post for which a level of service is 400 s maximum waiting time (as reported in D4.3&D2.3b) was chosen obtaining a fleet of 10 vehicles which, divided by the network length of 6.1 kilometres, gave the 1.64 number of vehicles/network length ratio reported in Figure 3.2.2. As it can be seen on the chart, the point is little under the line of 250 s maximum waiting time and over the 625 s line, as expected being the level of service chose in Bayonne 400 s maximum waiting time.

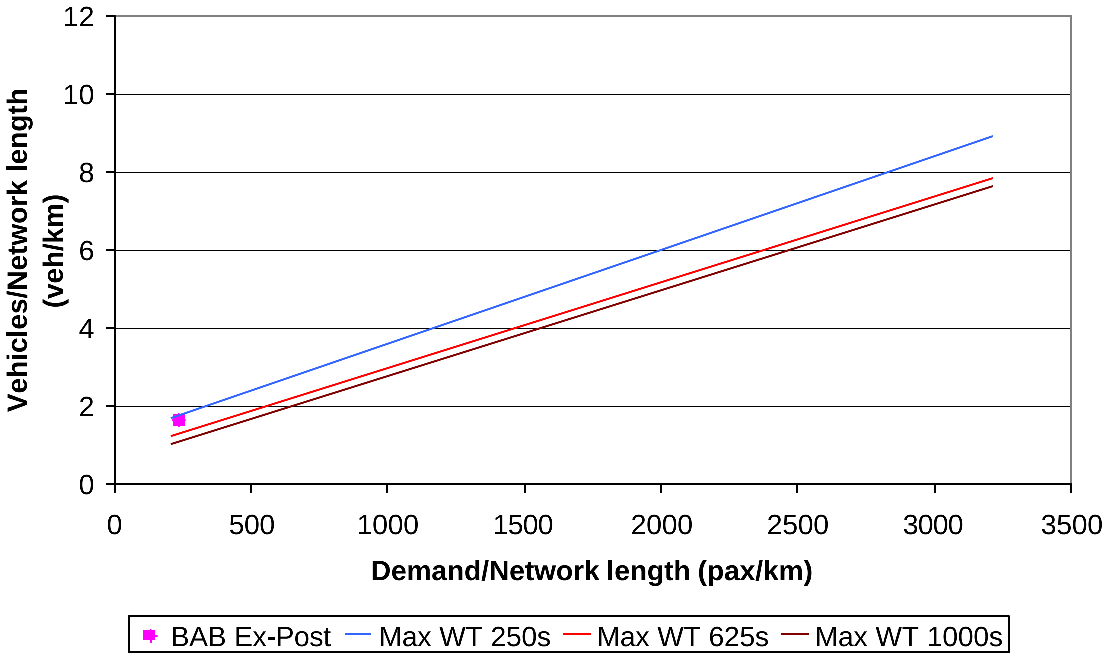

Figure 3.2.2 Number of vehicles circulating with 4 place vehicles and 20 km/h maximum speed

3.3 Average waiting time

The second feature to be identified is the average waiting time at CTS stop. It is independent from both the foreseen demand and the network length; once the number of vehicles is chosen according to the methodology step 1 the average waiting time depends only on the chosen maximum waiting time.

In Table 3.3.1 maximum and minimum values of average waiting time are reported for 4-place vehicles, in Table 3.3.2 for 10-place vehicles and in Table 3.3.3 for 20-place vehicles.

Table 3.3.1 Maximum and minimum average waiting times for 4 place vehicles

4 place vehicles						
	Time windows					
	250 s		625 s		1000 s	
Maximum speed	Minimum Average WT	Maximum Average WT	Minimum Average WT	Maximum Average WT	Minimum Average WT	Maximum Average WT
15 km/h	45	90	95	205	155	380
20 km/h	45	80	95	200	140	380
25 km/h	45	80	95	195	140	375
30 km/h	35	80	90	195	120	375

Table 3.3.2 Maximum and minimum average waiting times for 10 place vehicles

10 place vehicles						
	Time windows					
	250 s		625 s		1000 s	
Maximum speed	Minimum Average WT	Maximum Average WT	Minimum Average WT	Maximum Average WT	Minimum Average WT	Maximum Average WT
15 km/h	55	95	100	210	165	325
20 km/h	55	90	95	205	160	325
25 km/h	55	90	90	200	150	320
30 km/h	50	90	90	190	145	320

Table 3.3.3 Maximum and minimum average waiting times for 20 place vehicles

20 place vehicles						
	Time windows					
	250 s		625 s		1000 s	
Maximum speed	Minimum Average WT	Maximum Average WT	Minimum Average WT	Maximum Average WT	Minimum Average WT	Maximum Average WT
15 km/h	55	100	120	210	155	310
20 km/h	55	100	110	210	155	310
25 km/h	55	100	110	210	155	300
30 km/h	55	95	105	195	145	300

Once chosen the maximum speed, the vehicle capacity and the required level of service, the range in which the average system waiting time is known.

In Antibes ex-post study average waiting time is 290 s: the CTS fleet is made of three 20-place vehicles, the maximum allowed speed is 15 km/h and the level of service is such that the maximum waiting time is slightly over 1000 s. Looking at the first row of Table 3.3.3, the maximum value of the average waiting time for 1000 s time window and 15 km/h maximum speed is 310 s and the minimum is 155 s, thus the value of 290 s is correctly inside this range and near the maximum value because of the level of service little lower than that provided for 1000 s time window.

Bayonne system in the ex-post study is made of a fleet of ten 4-place vehicles with a maximum speed of 20 km/h and a time window of 400 s: the average waiting time obtained is 104 s. Looking at the second row of Table 3.3.1 the range of average waiting time for 250 s time window is 45-80 s and for 625 s time window it is 95-200 s. The average value of 104 s is inside 625 s time window range, near its lower limit and slightly higher than the maximum for a 250 s time window service as expected.

3.4 Total vehicle·kilometre run daily

The third feature to be identified is the total number of vehicle·kilometre run daily by the CTS vehicles.

Initial data needed for this step are the foreseen demand, the network length and the calculated number of vehicles (result of step 1); the ratio between total number of vehicle·kilometre run daily and network length is function of the ratio between demand and network length.

The formulas to calculate this ratio are reported in Table 3.4.1 for 4-place vehicles, in Table 3.4.2 for 10-place vehicles and in Table 3.4.3 for 20-places vehicles, where x is the demand/network length and y is the vehicle run/network length. Once maximum allowed speed, vehicle capacity and level of service have been chosen, by inserting the ratio demand/network length in the formula correspondent to the chosen configuration the ratio vehicle run/network length is available.

Table 3.4.1 Vehicle run/network length for 4 place vehicles

4 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 2.8\cdot10^{-1}\ x + 101.7$	$y = 2.6\cdot10^{-1}\ x + 69.5$	$y = 2.5\cdot10^{-1}\ x + 99.4$
20 km/h	$y = 2.8\cdot10^{-1}\ x + 101.6$	$y = 2.7\cdot10^{-1}\ x + 73.8$	$y = 2.6\cdot10^{-1}\ x + 62.2$
25 km/h	$y = 2.9\cdot10^{-1}\ x + 100.9$	$y = 2.8\cdot10^{-1}\ x + 63.0$	$y = 2.6\cdot10^{-1}\ x + 65.5$
30 km/h	$y = 3.1\cdot10^{-1}\ x + 103.3$	$y = 2.9\cdot10^{-1}\ x + 81.5$	$y = 2.8\cdot10^{-1}\ x + 65.7$

Table 3.4.2 Vehicle run/network length for 10 place vehicles

10 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 1.6\cdot10^{-1}\ x + 139.6$	$y = 1.6\cdot10^{-1}\ x + 75.4$	$y = 1.6\cdot10^{-1}\ x + 54.3$
20 km/h	$y = 1.7\cdot10^{-1}\ x + 139.2$	$y = 1.7\cdot10^{-1}\ x + 71.2$	$y = 1.6\cdot10^{-1}\ x + 52.6$
25 km/h	$y = 1.8\cdot10^{-1}\ x + 131.8$	$y = 1.8\cdot10^{-1}\ x + 70.3$	$y = 1.6\cdot10^{-1}\ x + 62.5$
30 km/h	$y = 2.1\cdot10^{-1}\ x + 119.9$	$y = 1.9\cdot10^{-1}\ x + 71.4$	$y = 1.7\cdot10^{-1}\ x + 63.1$

Table 3.4.3 Vehicle run/network length for 20 place vehicles

20 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 1.2\cdot10^{-1}\ x + 165.2$	$y = 1.1\cdot10^{-1}\ x + 78.9$	$y = 1.1\cdot10^{-1}\ x + 52.6$
20 km/h	$y = 1.3\cdot10^{-1}\ x + 158.9$	$y = 1.2\cdot10^{-1}\ x + 82.0$	$y = 1.2\cdot10^{-1}\ x + 50.2$
25 km/h	$y = 1.6\cdot10^{-1}\ x + 141.6$	$y = 1.3\cdot10^{-1}\ x + 81.8$	$y = 1.2\cdot10^{-1}\ x + 68.1$
30 km/h	$y = 1.5\cdot10^{-1}\ x + 160.2$	$y = 1.2\cdot10^{-1}\ x + 95.7$	$y = 1.2\cdot10^{-1}\ x + 64.3$

Once y quantity is known, by multiplying it for network length the total number of vehicle·kilometre run daily by the CTS is obtained.

Figure 3.4.1 shows the curves representing the first row of Table 3.4.3, that is to say the total number of vehicle·kilometre run daily for a system with 15 km/h maximum speed and 20 place vehicles for each of the three levels of service.

The point in Figure 3.4.1 is Antibes ex-post result. The arrow shows the ratio demand/network length in Antibes, which is 2270/3 = 756.67 pax/km: dimensioning the system with 1000 s maximum waiting time (if the required maximum waiting time were 625 s or 250 s the line starting from the arrow would arrive to one of the other two lines on the chart), the ratio vehicle run/network length is 135.8 veh·km/km, meaning 407 veh·km, higher than that calculated for Antibes in the ex-post (106 veh·km/km meaning 318 veh·km). It means that the service provided in Antibes runs slightly less vehicle·kilometre than a service with a maximum waiting time of 1000 s as expected.

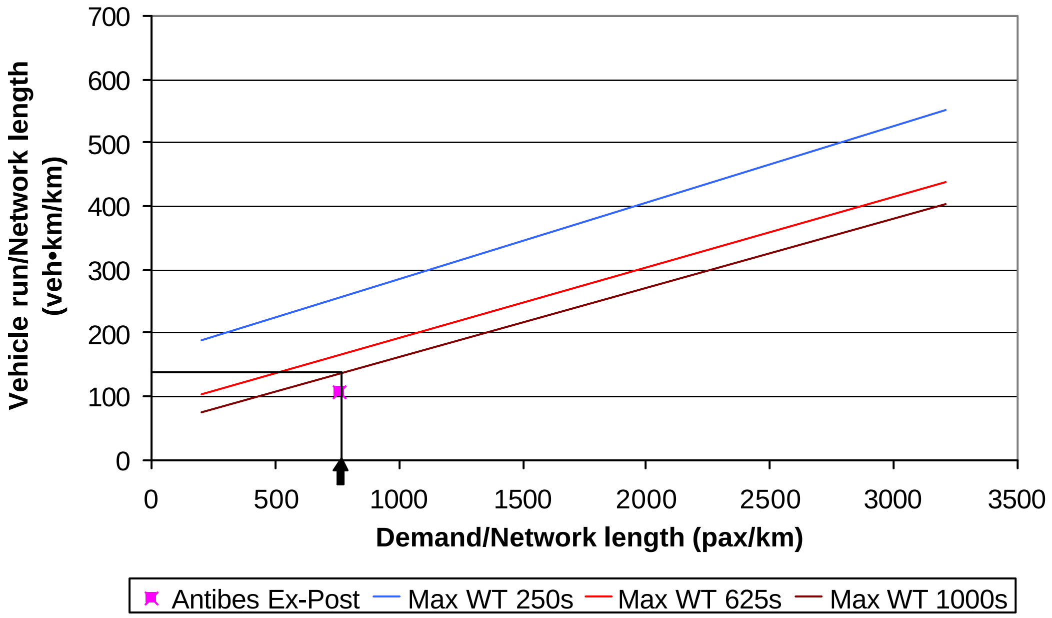

Figure 3.4.1 Total vehicle run with 10 place vehicles and 15 km/h maximum speed

Figure 3.4.2 shows total vehicle run/network length for a CTS with 20 km/h maximum speed and 4-place vehicles circulating on the network as a function of demand/network length for the three levels of service (second row of Table 3.4.1).

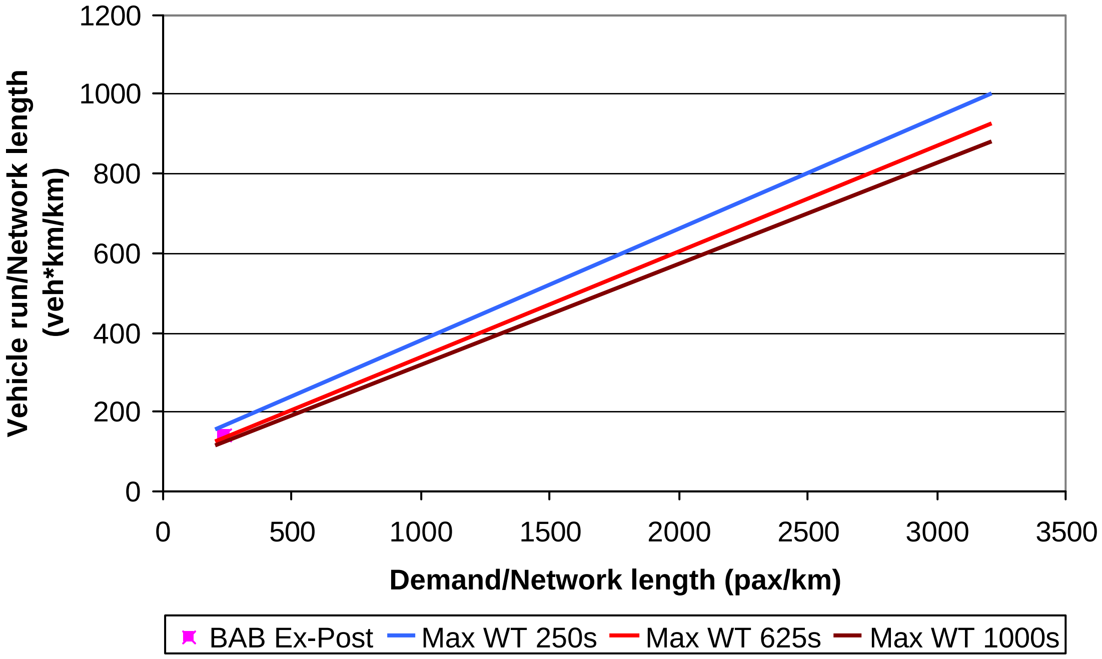

Figure 3.4.2 Total vehicle run with 4 place vehicles and 20 km/h maximum speed

The single point is Bayonne ex-post result. The Bayonne level of service is 400 s maximum waiting time (as reported in D4.3&D2.3b) and the ratio obtained there is 141.2 veh·km/km. Network length is 6.1 kilometres, meaning that the total vehicle·kilometre run in a day is 861.6 veh·km. As it can be seen in Figure 3.4.2, the point is slightly under the line of 250 s maximum waiting time and over that of 625 s, as expected.

3.5 Commercial speed

The fourth feature to be identified is vehicle commercial speed.

Initial data needed for this step are the foreseen demand and the network length; the commercial speed of the vehicles is function of the ratio between these two quantities.

The formulas to calculate it are reported in Table 3.5.1 for 4-place vehicles, in Table 3.5.2 for 10-place vehicles and in Table 3.5.3 for 20-place vehicles, where x is the demand/network length and y is the vehicle commercial speed. Once maximum allowed speed, vehicle capacity and level of service have been chosen, the vehicle commercial speed is calculated by inserting the ratio demand/network length in the formula correspondent to the chosen configuration.

Table 3.5.1 Commercial speed for 4 place vehicles

4 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 12.682\ x^{-0.0173}$	$y = 12.148\ x^{-0.0128}$	$y = 12.023\ x^{-0.0120}$
20 km/h	$y = 15.079\ x^{-0.0205}$	$y = 14.574\ x^{-0.0172}$	$y = 14.356\ x^{-0.0158}$
25 km/h	$y = 17.497\ x^{-0.0223}$	$y = 16.727\ x^{-0.0177}$	$y = 16.544\ x^{-0.0170}$
30 km/h	$y = 18.418\ x^{-0.0217}$	$y = 18.155\ x^{-0.0211}$	$y = 17.950\ x^{-0.0203}$

Table 3.5.2 Commercial speed for 10 place vehicles

10 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 15.783\ x^{-0.0557}$	$y = 14.189\ x^{-0.0460}$	$y = 13.154\ x^{-0.0376}$
20 km/h	$y = 19.000\ x^{-0.0611}$	$y = 16.840\ x^{-0.0500}$	$y = 15.506\ x^{-0.0410}$
25 km/h	$y = 22.020\ x^{-0.0641}$	$y = 19.323\ x^{-0.0518}$	$y = 19.158\ x^{-0.0536}$
30 km/h	$y = 22.830\ x^{-0.0610}$	$y = 21.671\ x^{-0.0599}$	$y = 21.645\ x^{-0.0629}$

Table 3.5.3 Commercial speed for 20 place vehicles

20 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 18.968\ x^{-0.0855}$	$y = 18.069\ x^{-0.0895}$	$y = 16.476\ x^{-0.0813}$
20 km/h	$y = 23.348\ x^{-0.0952}$	$y = 22.219\ x^{-0.0987}$	$y = 20.072\ x^{-0.0904}$
25 km/h	$y = 25.741\ x^{-0.0903}$	$y = 26.486\ x^{-0.1066}$	$y = 26.931\ x^{-0.1159}$
30 km/h	$y = 28.160\ x^{-0.0948}$	$y = 30.185\ x^{-0.1169}$	$y = 29.347\ x^{-0.1199}$

Figure 3.5.1 shows the curves representing the first row of Table 3.4.3, that is to say the commercial speed for a system with 15 km/h maximum speed and 20-place vehicles for each of the three levels of service.

The point in Figure 3.5.1 is Antibes ex-post result. The arrow shows the demand/network length in Antibes, which is 2270/3 = 756.67 pax/km: dimensioning the system with 1000 s maximum waiting time, the commercial speed would result 9.6 km/h, little lower than that calculated for Antibes in the ex-post 9.8 km/h. As it can be seen by looking at Figure 3.5.1, commercial speed curves are very flat (for example with 1000 s waiting time for 500 pax/km commercial speed is about 10 km/h and for 3000 pax/km it is little under 9 km/h), thus the differences between maximum waiting times and demand levels do not cause big variations in the commercial speed. Antibes commercial speed is just 2% more than that calculated for a 1000s waiting time service although in Figure 3.5.1 such difference may appear bigger.

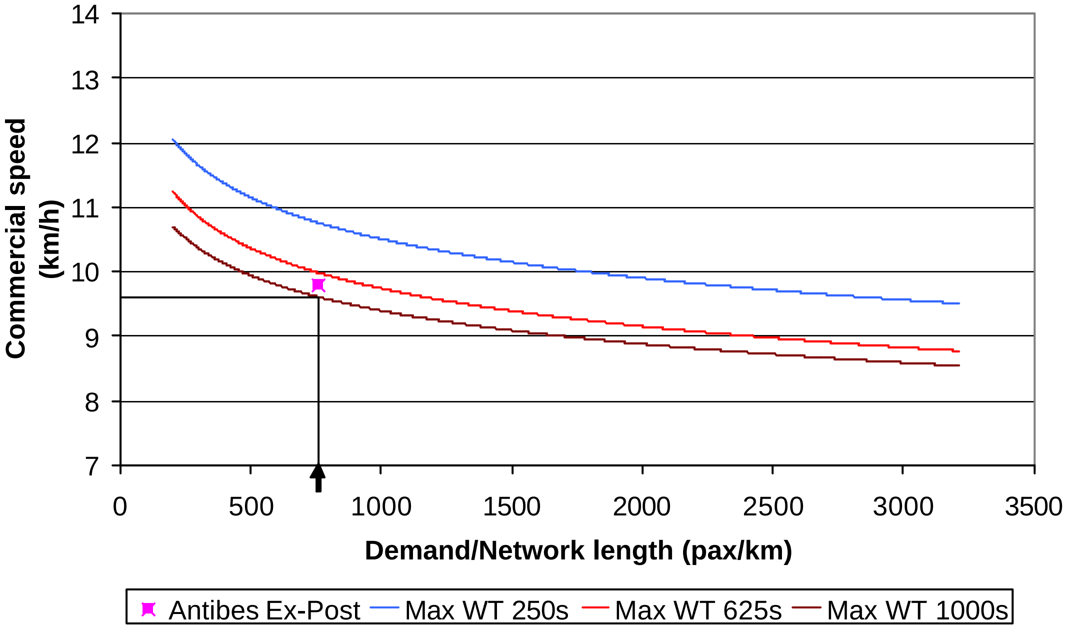

Figure 3.5.1 Commercial speed with 10 place vehicles and 15 km/h maximum speed

Figure 3.5.2 shows commercial speed for a CTS with 20 km/h maximum speed and 4-place vehicles as a function of the ratio between demand and network length for the three levels of service (second row of Table 3.5.1).

The point is Bayonne ex-post result. Where 400 s maximum waiting time was chosen as level of service (as reported in D4.3&D2.3b – CyberMove 2004b) and the commercial speed obtained is 13.8 km/h. The point is little over the 250 s maximum waiting time line. As for Antibes situation, commercial speed curves are very flat and the difference between the expected value of 13.5 km/h and the 13.8 calculated value is small enough to be accepted.

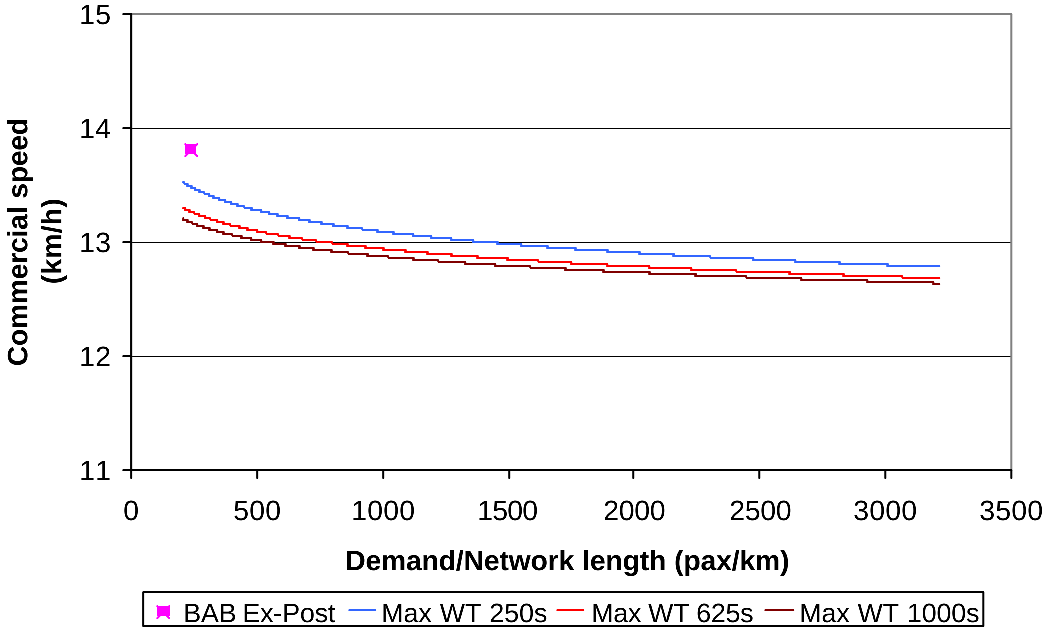

Figure 3.5.2 Commercial speed with 4 place vehicles and 20 km/h maximum speed

3.6 Occupancy rate

The fifth feature to be identified is vehicle occupancy rate.

Initial data needed for this step are the foreseen demand and the number of vehicles calculated after the first step; the occupancy rate is function of the ratio between demand and number of vehicles.

The formulas to calculate this quantity are reported in Table 3.6.1 for 4-place vehicles, in Table 3.6.2 for 10-place vehicles and in Table 3.4.3 for 20-place vehicles, where x is the demand/number of vehicles and y is the occupancy rate. Once maximum allowed speed, vehicle capacity and level of service have been chosen, the vehicle occupancy rate is obtained by inserting the ratio demand/number of vehicles in the formula correspondent to the chosen configuration.

Table 3.6.1 Occupancy rate for 4 place vehicles

4 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 9.26 \cdot 10^{-2}\ x + 14.89$	$y = 6.82 \cdot 10^{-2}\ x + 24.76$	$y = 7.05 \cdot 10^{-2}\ x + 25.66$
20 km/h	$y = 7.55 \cdot 10^{-2}\ x + 15.55$	$y = 6.61 \cdot 10^{-2}\ x + 21.69$	$y = 4.80 \cdot 10^{-2}\ x + 31.52$
25 km/h	$y = 7.35 \cdot 10^{-2}\ x + 14.81$	$y = 6.87 \cdot 10^{-2}\ x + 19.74$	$y = 6.37 \cdot 10^{-2}\ x + 22.19$
30 km/h	$y = 7.07 \cdot 10^{-2}\ x + 14.31$	$y = 6.52 \cdot 10^{-2}\ x + 18.05$	$y = 6.73 \cdot 10^{-2}\ x + 18.95$

Table 3.6.2 Occupancy rate for 10 place vehicles

10 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 3.89 \cdot 10^{-2}\ x + 4.76$	$y = 3.94 \cdot 10^{-2}\ x + 5.88$	$y = 3.40 \cdot 10^{-2}\ x + 11.30$
20 km/h	$y = 3.36 \cdot 10^{-2}\ x + 4.58$	$y = 3.55 \cdot 10^{-2}\ x + 5.26$	$y = 2.89 \cdot 10^{-2}\ x + 11.87$
25 km/h	$y = 2.94 \cdot 10^{-2}\ x + 5.37$	$y = 2.21 \cdot 10^{-2}\ x + 12.79$	$y = 2.15 \cdot 10^{-2}\ x + 17.47$
30 km/h	$y = 3.25 \cdot 10^{-2}\ x + 5.13$	$y = 3.44 \cdot 10^{-2}\ x + 7.38$	$y = 3.13 \cdot 10^{-2}\ x + 9.25$

Table 3.6.3 Occupancy rate for 20 place vehicles

20 place vehicles			
	Time windows		
Maximum speed	250 s	625 s	1000 s
15 km/h	$y = 2.17 \cdot 10^{-2}\ x + 2.03$	$y = 2.40 \cdot 10^{-2}\ x + 2.25$	$y = 2.30 \cdot 10^{-2}\ x + 4.50$
20 km/h	$y = 2.08 \cdot 10^{-2}\ x + 1.22$	$y = 2.22 \cdot 10^{-2}\ x + 1.11$	$y = 2.36 \cdot 10^{-2}\ x + 1.16$
25 km/h	$y = 2.14 \cdot 10^{-2}\ x + 1.63$	$y = 1.87 \cdot 10^{-2}\ x + 4.63$	$y = 1.90 \cdot 10^{-2}\ x + 6.03$
30 km/h	$y = 1.80 \cdot 10^{-2}\ x + 1.80$	$y = 1.72 \cdot 10^{-2}\ x + 3.18$	$y = 2.03 \cdot 10^{-2}\ x + 1.90$

Figure 3.6.1 shows the curves representing the first row of Table 3.6.3, that is to say the occupancy rate for a system with 15 km/h maximum speed and 20-place vehicles for each of the three levels of service.

The point in Figure 3.6.1 is Antibes ex-post result. The arrow shows the ratio demand/number of vehicles in Antibes, which is 2270/3 = 756.67 pax/veh. Dimensioning the system with 1000 s maximum waiting time, the occupancy rate is 22%, lower than that calculated for Antibes in the ex-post 28%. This difference is due to the fact that in the Antibes ex-post study 3 vehicles have been chosen to cover the network, thus under-estimating the value of 3.4 vehicles calculated in the first step of the methodology: in this way the same number of users travels on a lower number of vehicles and consequently vehicles are more “full of people”. If the number of vehicles was 4, they would run emptier decreasing the occupancy rate.

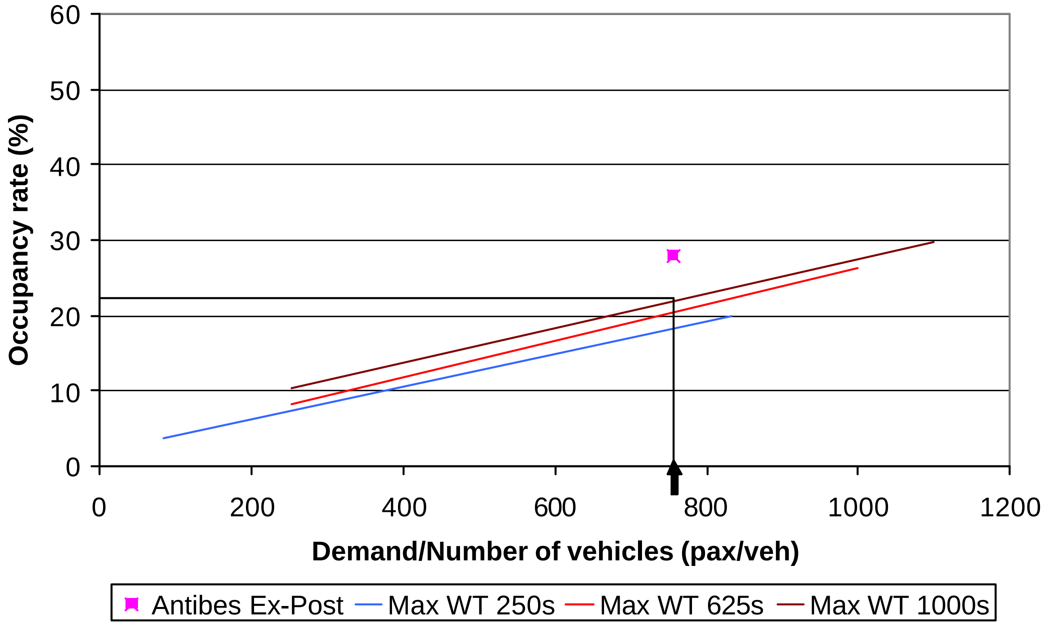

Figure 3.6.1 Occupancy rate with 10 place vehicles and 15 km/h maximum speed

Figure 3.6.2 shows occupancy rate for a CTS with 20 km/h maximum speed and 4-place vehicles as a function of the demand for the three levels of service (second row of Table 3.6.1).

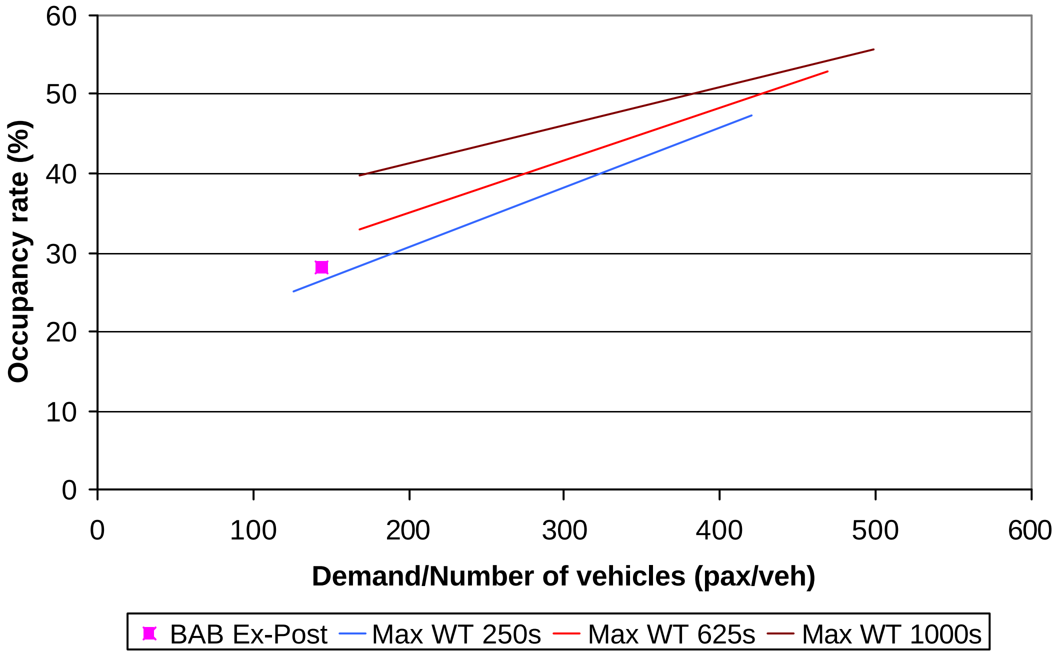

Figure 3.6.2 Occupancy rate with 4 place vehicles and 20 km/h maximum speed

The point is Bayonne ex-post study result. The level of service chosen is 400 s maximum waiting time (as reported in D4.3&D2.3b) and the occupancy rate obtained is 28%. As it can be seen in Figure 3.6.2, the point is little over the 250 s maximum waiting time line and under 625 s one, as expected.

3.7 Pre-design costs

Design costs are the sixth feature provided by the methodology.

In order to have a first rough idea of both start-up and yearly costs due respectively to the installation and to the maintenance of a system with the features calculated in the previous steps, indicative values of these costs are provided in this section.

The start-up costs have been provided subdividing the costs according to the different cost factors: building the stops, building the road, building the depot (with the recharging station and what is necessary for the maintenance), setting up the control station, providing and installing the control and communication systems and purchasing/building the vehicles. In analogy the maintenance and running costs have been made.

CTS stops must be simple and well integrated in the surrounding environment with information provided about the waiting and travel time. A simple configuration of the stop with a shelter and a touch-screen for information and to call the vehicle has been hypothesised. The cost of each stop has been set to 6 000 € two for the screen and four for the shelter and the structure. The estimated yearly maintenance cost has been set between the 6% and the 10% of the construction cost.

The cost for the installation of the control station (one for the two line) has then been set to 1 040 €/m^2. Usually it can be assumed to be a single 10 square-meter room, thus its costs is 10 400 €. The annual rental for a so dimensioned control station has been estimated to be 3000 € including all services (cleaning, electricity, air conditioning…), meaning 300 €/ m^2. A personnel of two people was also considered at the cost of 50 000 €/year (for both).

Depots, maintenance areas and recharging stations have been considered in proportion to the kind and the number of vehicles and the cost per vehicle had been gathered by the SkyLoop experience. To consider building, furniture, scaffolding and tools an additional cost of 30 500 €/vehicle has been set for 4 place vehicles, 70 500 €/vehicle for 10 place vehicles and 82 000 €/vehicle for 20 place vehicles. A maintenance cost of 1 700 €/year·vehicle has been used to include insurance, air conditioning cleaning service, electricity, heating, water use and waste collection for 4 place vehicles, 4000 €/year·vehicle for 10 place vehicles and 4 600 €/year·vehicle for 20 place vehicles.

The cost of the street is not included where the CTS runs on existing streets. Where is necessary to asphalt the street the cost is 60 000 €/km.

The control system and the wireless communication system costs are in proportion to network length: 52 600 €/km are needed to their installation. The maintenance cost of the infrastructure is assumed to be between 6% and 10% of the investment.

4 place vehicles cost has been set to 60 000 € each and their maintenance and operating costs has been divided in three parts: the fixed costs (including insurance and cleaning) 370 €/year·veh; the mileage costs (mechanic and electric maintenance and battery and tyres substitution) 0.156 €/km; and the energy cost, due to the consumed energy, assumed 0.06 €/kWh according to EDF prices. 10 place and 20 place vehicles start-up cost is 233 500 € each and their maintenance and operating costs the same as for 4 place vehicles, with the exception of fixed operating and maintenance costs 490 €/year·veh.

All these costs are reported in Table 3.7.1 (start-up costs) and in Table 3.7.2 (operating and maintenance costs).

Table 3.7.1 Start-up costs

			Costs
Stops			6 000 €/stop
Control station			1 040 €/ m^2
Street			60 000 €/km
Control and wireless communication systems			52 600 €/km
	4-place vehicle costs	10-place vehicle costs	20-place vehicle costs
Vehicles	60 000 €/vehicle	233 500 €/vehicle	233 500 €/vehicle
Depots and recharging stations	30 500 €/vehicle	70 500 €/vehicle	82 000 €/vehicle

Table 3.7.2 Operating and maintenance costs

			Costs
Stops			360 ÷ 600 €/stop
Control station			300 €/ m^2
Control and wireless communication systems			3 156 ÷ 5 260 €/km
	4-place vehicle costs	10-place vehicle costs	20-place vehicle costs
Vehicles	370 €/vehicle	1200 €/vehicle	1200 €/vehicle
Vehicle mileage	0.156 €/km	0.156 €/km	0.156 €/km
Vehicle energy	0.06 €/kWh	0.06 €/kWh	0.06 €/kWh
Depots and recharging stations	1 700 €/vehicle	4 000 €/vehicle	4 600 €/vehicle

In order to have a complete overview of the financial impacts of CTS installation, where the CTS substitutes other transport services the revenues due to the reduction of the costs of those services has to be considered. A cost of 2.68 €/veh·km can be assumed where LPG buses are operating and 3.58 €/veh·km for electric buses, in order to calculate those revenues once known the daily veh·km ran by the existing service.

4 CTS DESIGN METHOD

4.1 Demand and user needs analysis

Demand analysis is a traditional activity preliminary to any transport study. CTSs, although innovative transport systems, do not differ from others in the way their demand can be studied. Several methods exist to study the demand and this section does not think to be exhaustive on a topic which has been covered by many text books for transport-planning-students in all countries. In this section three situations met during CyberMove studies are described along with the solution adopted. The suggestions for further reading report the CyberMove deliverables in which such studies have been reported in details while no demand-analysis text-book is specifically recommended because any of them can be fine bearing in mind that demand studies should be made by specialists to guarantee correct results.

The three situations encountered in CyberMove demand studies are:

- the zone where the CTS will be built does not exist yet and therefore no demand data were collected and there was no way to collect them;
- the zone exists, there are other transport systems at work and some historic data are available but there is no money available to collect more focused data;
- the zone exists, historic data are available and there is some available budget for an in-depth demand analysis.

The third situation is obviously the most favourable to make a demand study; for the first two a preliminary study can be made but to pass to a pre-implementation design some money for a detailed demand analysis “of the third kind” has to be found.

Nancy was the “under construction” CyberMove site (CyberMove 2004b). An almost definitive plan of the buildings to be built existed but since nobody yet lives there it was neither possible to observe their behaviour nor it was possible to interview them to ask them to state their preferences. To have a first rough quantification of the potential demand the number of trips generated and attracted each day by each building were guessed, knowing size and future use, from those of similar buildings in the same region. According to the average behaviour of Nancy’s citizens a subdivision in internal (to the newly built zone) and external trips was made and for the external trips the average modal split of the city was applied. Then since the CTS is planned to be the only public transport available in the area a logit model (calibrated with literature data) was applied to subdivide between two modes, pedestrian and CTS, all the internal trips and the public-transport-share-of-external-trips. Applying the logit the modal split changes depending on the quality of the service.

In Antibes and Bayonne ex-ante studies (CyberMove 2004a) data about traffic and public transport service load were available. It was not possible to run enough interviews to calibrate a logit model therefore, after using the data available today to reconstruct the actual O-D matrix of the transport systems the CTSs will substitute, the growth of demand due to the improved quality of service was calculated by means of a logit model calibrated with literature data.

Finally in the Technion campus study (CyberMove 2004a) a questionnaire for revealed and stated preferences analysis was developed and issued to a sample representing the campus population respecting both the present modal split (subdivided in parking permit holders, car users non holding a permit and public transport users) and the campus population proportions (academics, technicians and students). The results were used to calibrate a logit model and the calibrated model allowed to determine what would be the modal share of the CTS.

This latter kind of demand analysis can as well be used to determine the user needs and to start building consensus for the project (see section 4.2).

User needs analysis (UNA) can be addressed to a general public, as it was that made in CyberMove (CyberMove 2002c), and used to define general vehicle and infrastructure characteristics such as the most appreciated vehicle design, the necessary vehicle optionals, the shelter stop design and features.

On the other hand when the UNA is made in-loco, better if contemporary to the demand analysis, more site and system related questions can be asked (e.g. preferred location for stops or even the preferred route). Such participation of the future users in the system design have two main benefits: users know better than most of the planners the zone and, if opportunely guided, they can positively contribute to make a more functional system design; second benefit is that the involvement of users in the design make easier to build consensus among them (see section 4.2).

Suggestions for further readings about demand analysis

CyberMove consortium (2002c) User needs analysis, Deliverable D1.2 of CyberMove project

CyberMove consortium (2004a) Ex-ante Evaluation, Deliverable D2.3a&6.2b of CyberMove project

CyberMove consortium (2004b) Ex-post Evaluation, Deliverable D2.3b&4.3 of CyberMove project

4.2 Building consensus

A CTS installation can be the big opportunity for a local administration to invert the European tendency to travel more and more by car even inside the cities. Such tendency can only be inverted by adopting measures to discourage people to use their cars either by making it more expensive (road and parking pricing) or by rationing the access to certain areas or streets. These measures are normally unpopular because they are perceived as a limitation to movement but if in place of the reduced car availability an improved transport service is provided these measures may be better accepted. CTS can be the public transport improvement, but still consensus has to be built among the people that may be affected by such initiatives.

Maestro guidelines (Maestro 2000) defined the consensus issue as follows.

> *Ensure that the institutions and stakeholders that will be involved in and affected by the project have been identified and consulted. All parties should agree that enough information has been collected for a decision to proceed. They should also consider the project worthwhile and support the objectives that have been identified. At this stage you also need to take account of those individuals or groups who are affected by the proposed project but who are not actively involved in it. At the very least you should ensure that (potential) conflict is minimised if it is not possible to ensure (full) consensus.*

How do you build consensus for the project among the users?

Consensus building starts an interaction with the actors, which continues during the entire project life.

Ways to build the actor consensus include making the actors aware of what is happening, having experts available to provide explanations and involving the actors in the decision making process of the project.

A continuing dialogue is essential. Available tools for such a structured dialogue include conferences, newsletters, information sessions, interactive designing, information points and Web sites.

The best way to ensure consensus among the actors in a project is to involve them from its very beginning.

Actors to be involved are:

- end-user groupings (public transport users, car drivers, pedestrians, cyclists),
- operator groupings (public transport operators, traffic/transport departments),
- authority groupings (local, regional, national, European) and
- destination groupings (shopkeepers, residents, other destinations, e.g. medical facilities, leisure facilities).

However, it must be recognised that the approach towards consensus building varies across Europe, and reflects the cultural and societal values in the area(s) within which the project is proposed. Within some Member States, it is the norm that consensus will be achieved, and all participants work towards that goal. Once consensus is reached, the support of the various participants can be relied on downstream in the project.

By contrast, in other Member States the mechanisms for consensus building are not well developed. There may not be strong obligations on the promoters of the project, or there may be a tradition of a more directive or confrontational approach. In these situations, it is recommended that the actions of outreach, dialogue and inclusion be used to understand the diversity of views, and to create the basis for a future consensus. Project promoters should review relevant case studies from Europe and North America to identify good outreach and dialogue methods.

A good example of consensus building has been made in CyberMove framework in the city of Antibes. A demonstration of the system (CyberMove 2004c) has been organised of a couple of weeks and people were invited to ride the system and interviewed afterwards. All people were provided with explanations and were asked whether they would have used the system in different scenarios including those in which a new policy increasing parking fees would have been adopted. Users responded enthusiastically to all the questions and the highest parking fees scenarios resulted to be the most appreciated.

Suggestions for further readings about consensus building

Anderson, I. E., et al. (eds.). (1995). Feasibility Study on New Awareness Initiatives: Studying the Possibilities to Implement Consensus Conferences and Scenario Workshops. Study for Value II Programme of the European Commission. Copenhagen, Danish Board of Technology.

CyberMove consortium (2004c) Demonstration report, Deliverable D5.4 of CyberMove project

Joss, S., and Durant, J. (1995). Public Participation in Science: The Role of Consensus Conferences in Europe. London, Science Museum.

MAESTRO consortium (2000). Guidelines for transport in the 21st century. EC DG VII January 2000

4.3 CTS network and system dimensioning

A distinction must be made between dimensioning a long distance CTS network or a short distance one.

The first needs separate infrastructures that must be built on purpose. Although many constraints may exit (such as the ground characteristics if it is underground or the available space if it is overhead above the ground) the new infrastructure can follow a design to maximise its utility. The most recent way to design metro lines (which can be used as a model for long distance CTSs) is to follow radial and circumferential paths with respect to the city, starting from the radial lines which cross the most densely populated areas and linking them with several rings with different radiuses.

A short distance CTS is a different matter. If it is built to supply a feeder service it must capillary cover the zone maintaining a trade off between cost and quality of service, both of which grow with the length of the network. A number of suggestions can prove important:

- to use as much as possible already existing infrastructures because building new ones would lead to higher costs and to space availability problems;
- to choose as much as possible “segregable” links, in other words links which can be surrounded by barriers without causing a community severance; such choice can help to minimise start-up and operational costs without decreasing the quality of service;
- to locate the CTS stops as much as possible in places easily reachable on foot;
- to have, at least at the stops, passing bays in which non-stopping vehicles following can overtake;
- to minimise the number of conflict points with the surrounding traffic by choosing on purpose the links to destine to the CTS but also being ready to slightly modify the car circulation.

The distance between the stop and the door-steps has to be in a hundred meters range because over this distance, especially if the overall distance is around one kilometre it becomes much easier to go directly on foot.

Once a network is designed and a demand study made to design a CTS is necessary to:

- choose the vehicle capacity;
- choose the energy system (battery or fed through the ground);
- choose number and position of depots and recharging stations (if necessary);
- select the most appropriate number of vehicles.

Although the pre-design methodology described in section 2 of this document gives the possibility to roughly quantify these parameters to make the pre-implementation design the application of special software is needed.

In the framework of CyberCars (CyberCars 2003) and CyberMove (CyberMove 2004a and 2004b) several software and methods have been developed and applied almost all of them use simulation as the basis to choose the best possible configuration of parameters which represent the final design. Each software and method developed uses its own simulation method and it is not possible to select the best but it is possible to say that conventional transport planning models, unless modified on purpose, do not reproduce correctly the behaviour of on demand systems such as CTS and therefore an ad-hoc developed software or method is recommended.

Suggestions for further readings about network and CTS dimensioning

CyberCars consortium (2003) New technologies for infrastructures, Deliverable D3 of CyberCars project

CyberMove consortium (2004a) Ex-ante Evaluation, Deliverable D2.3a&6.2b of CyberMove project

CyberMove consortium (2004b) Ex-post Evaluation, Deliverable D2.3b&4.3 of CyberMove project

4.4 CTS integration with the city environment

Urban growth

Which is the intention of the town of tomorrow?

If its original structure remains, the use of the vacuum (public domain) in opposition to the full (built field) very largely evolved.

It exploded, from an urban composition often folded up on itself, to extend, in detriment to its immediate environment.

The zoning reinforces the idea of dispersion by making the various zones composing the built territory mono-functional.

And the zoning is greedy as regards trips: times of way do not change but the distances to be travelled increase (and with them harmful effects and costs).

The city was thus seriously devitalized by the increase in mobility and the peri-urbanisation (wished or undergone). It must from now on be centred, gather around values such as economic vitality, environmental quality and social solidarity. The urban concentration preserves, indeed, certain virtues which it is possible to rehabilitate beyond the only built inheritance.

Then on one hand the vestiges of the history are restored with nostalgia and on the other the available territory is despoiled. Can this cohabitation last speaking about sustainable development?

CTSs are brand new transport systems and in designing them interactions with cyclist, pedestrians, cars and all the surrounding environment has to be taken into account therefore an integrated approach to the urban planning is strongly recommended when deciding how to “lay-down” a CTS network.

CTSs have proven to be now technologically ready but the reaction of the users during their trips as well as the appreciation of CTS by the non-users will strongly depend on the quality of their integration in the urban environment.

The urban policy

Through its 10 pilot sites and studies the CyberMove project clearly shows the close links between the planning of the city and that of transport. CTS implementation cannot be justified if the “needs” to be addressed are not clearly identified. CTSs are “transport tools” at the service of the city planning. It is only through the complementarities of the transport service supplied, the urban integration and the setting of “accompanying” measures addressing the use of private vehicles that this new way to “move” will be likely to resist to the pressure of private mobility.

To “contain” car use should not result in a slow down of the mobility then, let us transform the constraints into opportunities: let us collect the cars in periphery of the urban centres, offer a powerful alternative to mobility and especially, profit to offer to the citizens new public gardens, new places of social animation. Let us start to rebuild the image of the public domain, to find the essence of vicinity and urban proximity, the means of the street.

The local authorities of Antibes, strong with the CyberMove study, decided to undertake the experimentation real size of an electric shuttle entirely automated, on a section of approximately 500 meters.

To find the needed space, it has been necessary to remove parking bays from road maintenance spaces and to defer an axis of one-way traffic on another.

One of the objectives was to analyze if it were possible to integrate this type of futuristic transport without architectural barriers (or almost) in the city and finally, that the user uses it readily, in all confidence.

From the urbanistic point of view, it was shown that this type of soft mobility (mixed, in Antibes, with the two-wheeled vehicles, rollers, scooters, etc) gains space on the car domain. In other words, it is possible to restore the public domain with profit for the pedestrians and social animation, while ensuring urban mobility.

It, moreover, was proposed a decorated luminous installation of trees and bushes, offering at a glance a great spatiality and a certain approval to a pavement quite narrow until there...

Lessons learnt from CyberMove

The experiment in Antibes was very conclusive as regards urban integration. Indeed, beyond the convenience which one can propose to the users as soon as one uses the free spaces left by the removed parking bays, it was proven that it is not inevitably necessary to create a specific site, skirted by not-aesthetic barriers, to integrate a CTS line: a simple integration accompanied by floral barriers can be sufficient.

The urban culture of the users takes part in integration. If one chooses to release a street without modifying its aspect, the user will naturally tend to behave as he usually does in an environment which he frequently practises.

Moreover, the urban policies are generally directed towards the soft modes. The integration of a CTS line combined with a cycle track is spare and rational in terms of public spaces.

It thus constitutes a true urban valorisation opportunity, while attenuating the sources of pollutant emissions.

Beyond the experimentation in Antibes, the prospects are cheering. To set a line of one kilometre and half length means, from now on, about one hectare at least (according to the selected accompanying measures) gained on the car... without damaging mobility!

The prospects as regards urban mobility are very promising since the executive authority will have decided to engage a policy of strong and coherent urban revalorization in its various components as regards mobility, town planning and social animation.

Where to go? We go towards a new attractive city, more populated but also more convivial, less noisy, less polluted and especially, more mobile. In this sense, the VOLTair's methodology, which has been developed in parallel with the CyberMove study, is likely to motivate and help local stakeholders in their actions and measures for the quality of life improvement .

Suggestions for further readings about urban integration

CyberMove consortium (2003a) Conceptual design, Deliverable D2.2a of CyberMove project

CyberMove consortium (2004c) Demonstration report, Deliverable D5.4 of CyberMove project

CyberMove consortium (2004e) General process of urban transport planning and integration: where and how do cybercars fit?, Deliverable D2.4 of CyberMove project

4.5 CTS integration in the city transport system

The integration of a CTS in the city transport system presents two sets of issues:

- the normal issues related to passenger interchanges
- and the specific CTS issues.

To integrate the different city transport systems is a matter of integrating ticketing and information but most of all it is a matter of facilitating transfer from one transport mean (or even mode) to another. Such “transfer” happens in crucial nodes of the transport networks called “passenger interchanges”. A number of design, construction and management actions can be undertaken to make interchanges functional; the MIMIC project (MIMIC 2000a and 2000b) highlighted all the possible barriers to intermodality and suggested for each of them a "best-practice" to overcome such barrier.

Although all the best-practices highlighted by MIMIC are useful tips in designing interchanges for passenger transport networks only those mostly useful to integrate CTSs with other passenger transport networks are reported here.

Synchronisation

From CyberMove experience the integration of a CTS providing short waiting and travel times with a low frequency bus service hampers the user perception of the good performances of the CTS. It is therefore necessary to interchange the CTS with high frequency transport services to avoid losing the benefit in terms of demand attraction the CTS installation would have.

Nevertheless CTSs can be feeder for interurban, international or even intercontinental services (bus, train, plane or ship) which by definition have a precise but not frequent schedule. In these cases the CTS service has to be synchronised with the timetable of the longer distance mode. Such synchronisation, being the CTS on-demand, can be made with the help of information rather than by setting the departure and arrival time of the feeder service on that of the longer distance mode as it is traditionally made.

The CTS user has to provide its destination to the system when calling for a CTS vehicle; in "synchronisation" cases the user has to be allowed to provide the identification code of the long distance transport he is going to get and the system can therefore better respond to the user exigencies, even communicating that by no means it is possible to reach the other transport on-time if this is the case.

The other synchronisation aspect is when the passenger comes with a long distance low frequency mode and needs a CTS ride to destination; in this case, which applies to park and ride as well, an advanced reservation method has to be foreseen so to synchronise the presence of the reserved CTS vehicle with the arrival of the longer distance transport shortening the waiting time.

In using the CTS as a park shuttle the user could be asked to provide the destination and the number of people riding in the car at the car-park gate and then be guided to a given slot where the CTS vehicle would pick him (them) up.

Integration of information

Information is vital for the CTS functioning but, to the technical functioning of the system, it is just necessary to have the system related information. To make the CTS integrated with the other transport systems information about the other systems, timetables, ticket costs … has to be provided. It would be even better to have a best routing facility that would help the user in choosing his itinerary to destination and even to reserve places on other transports and buy appropriate tickets, if necessary.

Integration of ticketing or on board ticketing

CTSs, especially if used on short distances, are means to shorten the walking distance. If at the end of a CTS ride the user is asked to alight the vehicle walk till a ticket counter or a ticket machine and then walk back to the other transport mode most of the benefit would be lost. The user must be allowed either to purchase an integrated ticket valid for his entire journey including the CTS (which is always desirable but not always possible) or to buy a ticket for its next journey on the CTS vehicles themselves.

Communicating a feeling of security

In one CyberMove site the users felt the absence of the driver as an increased risk of attacks; elsewhere where CCTV cameras were well visible they did not have such fear. From MIMIC experience similar fears exist in interchanges when there are dark passageways or dark corners or even non-transparent elevators (that are commonly built transparent now) and other similar things. In designing the integration between CTSs and other transport systems it is necessary to address such issue opportunely adopting where necessary transparencies in vehicles and structures, lighting the areas, making visible surveillance … .

Avoiding physical barriers and shortening the walking distance

There are two ways of thinking about the walking distance between stops of different transport means in the same interchange: one tends to shorten it as much as possible; the other to make it more pleasant by providing shopping facilities and other amenities. For short distance CTSs the first philosophy has to prevail. They are means to shorten the walking distance therefore it is inconceivable to increase it; shopping facilities may be present at the interchange but it must be the user decision to walk to the shopping area. The CTSs, with their great flexibility, offer the unique opportunity to have several different stopping bays in the interchange each one close to the stop of another mode, especially if the interchange is big and features several modes. The CTS can even be conceived to have different stopping bays for the two directions of a metro line. This solution on one hand decongests the stopping area of the CTS by making several different stops and on the other it lowers to the minimum the walking distance.

The other aspect to address is that physical barriers (e.g. steps) should be avoided. Not only to facilitate the movements of impaired mobility people but to make quicker and easier the transfer from one mode to another. With conventional transport systems such issue is addressed by building escalators, elevators and moving walkways but the CTS offers the great opportunity to fully integrate the different systems and, by making the stopping bay at the desired level, eliminating any physical barrier between modes.

Suggestions for further readings about integration between transport systems

CyberMove consortium (2004a) Ex-ante Evaluation, Deliverable D2.3a&6.2b of CyberMove project

MIMIC consortium (2000a) Recommendations and guidelines for passenger interchange development. Deliverable 4 of MIMIC EC project. 2000

MIMIC consortium (2000b) Nodi di interscambio passeggeri, divulgative publication of the Mobility InterModality and InterChanges EC project. Regione Lazio 2000

4.6 Ensuring CTS safety

CyberMove developed certification procedures for Cybernetic Transport Systems. Since there are no applicable legal frameworks for fully automated, non-physically guided, vehicles such as CTS, to deal with this situation, a framework for a comprehensive safety assessment had to be developed in this research project.

Although liability can be addressed by referring to directives originally drawn up for other purposes or by excepting the pilot project as being an experiment in terms of law, safety is not taken into account in the same way. To work on this, a Risk Reduction Methodology has been proposed in CyberMove (CyberMove 2003c) to suit these needs during the pre-design and design phase of a Cybernetic Transport System.

Assessment of the feasibility studies and field trials of the CyberMove project showed that carrying out this Risk Reduction Methodology lead to designs of safer sites and systems. However, the question "How safe is safe?" had not been answered yet.

In CyberMove deliverable 3.2 (CyberMove 2004d) we proceed from this starting point by presenting a System Safety Analysis to be added as a quantitative method to be used in the development and construction phase of a Cybernetic Transport System.

As a basis for the System Safety Analysis a Failure Modes, Effects and Criticality Analysis (FMECA) has been chosen. In a typical FMECA a group of 4 - 5 people use their knowledge and experience to systematically list all possible failure modes of the system to be analyzed. Then the causes and effects of these failure modes are established and the severity and likelihood of the effects are rated. Whether or not the result is reproducible depends on the knowledge of the participants but also strongly on the strictness with which the procedure is being followed.

Essential in this respect is the system definition that precedes the actual FMECA. A complex system like a Cybernetic Transport System is divided in a number of subsystems that are analyzed separately. It is essential that it is clear to all participants what the boundaries of a system are. When the systems to be analyzed are clearly defined a function analysis should provide all possible functions that the system performs. These functions are the basis of the FMECA, where a failure is defined as a failure to perform a certain system function.

The result of the FMECA analysis is a table with a large number of safety scores and a number of recommendations. The safety level for the system or subsystem is equal to the lowest safety score in the table. That means that if one single failure mode results in a safety score that is lower than the safety requirement, than the complete system does not meet that requirement. The complete system is to be considered as safe as its weakest link.

Together, the Risk Reduction Methodology and the System Safety Analysis form a framework for comprehensive safety assessment of Cybernetic Transport Systems.

Because a System Safety Analysis is based on the output of the design phase and if the design passes the test, it can be used as a blue-print for the development & construction phase. One way of certification is now within reach: a final check at the end of the development & construction phase that everything is constructed conform the blue-print, deserves a stamp of approval.

As long as there are no generally accepted safety standards and no notified bodies to certify, this way of self-certification is the best method to work on safe sites and systems.

Suggestions for further readings about ensuring CTS safety

CyberMove consortium (2003c) Risk reduction methodology, Deliverable D3.1 of CyberMove project

CyberMove consortium (2004d) Safety assessment, Deliverable D3.2 of CyberMove project

4.7 Financial and Socio-Economic evaluations

Financial and socio-economic evaluations are useful tools for two main purposes: to assess whether the designed CTS would ameliorate the present situation and to choose between different project alternatives.

For both the evaluations in the CyberMove framework the Cost-Benefit analysis (CBA) has been used. The financial CBA has been made by accounting for the cash-flows only while in the Socio-

Economic one the socio-economic impacts have been monetised and accounted for as if they were cash flows.

A CBA can provide as a result: the Net Present Value of an investment over a fixed amount of time, given the inflation and interest rates; the Internal Rate of Return (IRR) which somehow is an index to the interest rate the investment would pay on a given time horizon; or the time needed for the investment to be paid back given both interest and inflation rates. The NPV over ten years has been chosen as the CyberMove indicator for profitability (Financial CBA) and socio-economic viability (Socio-Economic CBA).

Detailed instructions on how to perform a CBA can be found on Maestro Guidelines (MAESTRO 2000) and a number of examples can be found on both ex-ante and ex-post CyberMove evaluation deliverables (CyberMove 2004a and 2004b).

Suggestions for further readings about financial and socio-economic evaluation

CyberMove consortium (2004a) Ex-ante Evaluation, Deliverable D2.3a&6.2b of CyberMove project

CyberMove consortium (2004b) Ex-post Evaluation, Deliverable D2.3b&4.3 of CyberMove project

MAESTRO consortium (2000). Guidelines for transport in the 21st century. EC DG VII January 2000

ANNEX 1: CTS PRE-DESIGN METHOD SYNTHESIS

This annex explains how the pre-design method presented in section 3 has been synthesised and how well the average values and regression lines provided approximate the results.

The method has been synthesised by running 2880 simulations on the Nancy site. That site was chosen because among the CyberMove sites Nancy was the only one in which the CTS was conceived to provide short distance (total length 2.488 m) service over a small network.

The simulations were made by means of CTSDesign, a software package developed by DITS in the frameworks of CyberCars projects (CyberCars 2002), based on an Advance Request Dial-A-Ride with Time Windows algorithm. Given the demand and the network of the CTS and the aimed level of service, CTSDesign simulates all the possible options of CTS dimensioning (number and capacity of vehicle, energy system, position and number of depots and recharging stations) providing the right number of vehicles to employ to serve all the demand.

The method synthesised has been validated on the CyberMove ex-post studies, Antibes and Bayonne. The two validation sites were chosen because they have been investigated twice each and with different simulation methods, insuring a higher reliability of the results. Even if in both these sites the CTS network is just one line the results are very much in line with these expected applying the pre-design method as shown in section 3 of the main text.

The 2880 simulation runs have been made by: 16 different steps of demand (from 500 to 8 000 daily passengers increasing 500 passengers each step), 5 lists of calls; 4 maximum allowed speeds (15 km/h, 20 km/h, 25 km/h and 30 km/h); 3 vehicle-capacities (4-place, 10-place and 20-place); and 3 levels of service (250 s, 625 s and 1000 s maximum waiting time).

On the basis of the simulation results regressions have been made and both (simulation results and regression lines) have been reported in charts organised according to the clustering in different levels of service, vehicle capacity and maximum vehicle speed. For each methodology step 12 charts, each one featuring the three levels of service, have been made. The charts report: the points obtained by simulation, the regression line, the equation of the regression line and the R^2 coefficients (providing an indication about how good the regression line interpolates the simulation points).

A1.1 Number of vehicles

Figure A1.1 represents the relationships between the ratio number of vehicles/network length and the ratio demand/network length for the three levels of service for a CTS with 15 km/h maximum speed and 4-place vehicles.

R^2 coefficients reported in Figure A1.1 are all over 0.92, meaning that all the three equations approximated satisfactorily the trends of the points obtained by simulation. The best result was provided for 1000 s maximum waiting time, with a value of about 0.96 as correlation coefficient.

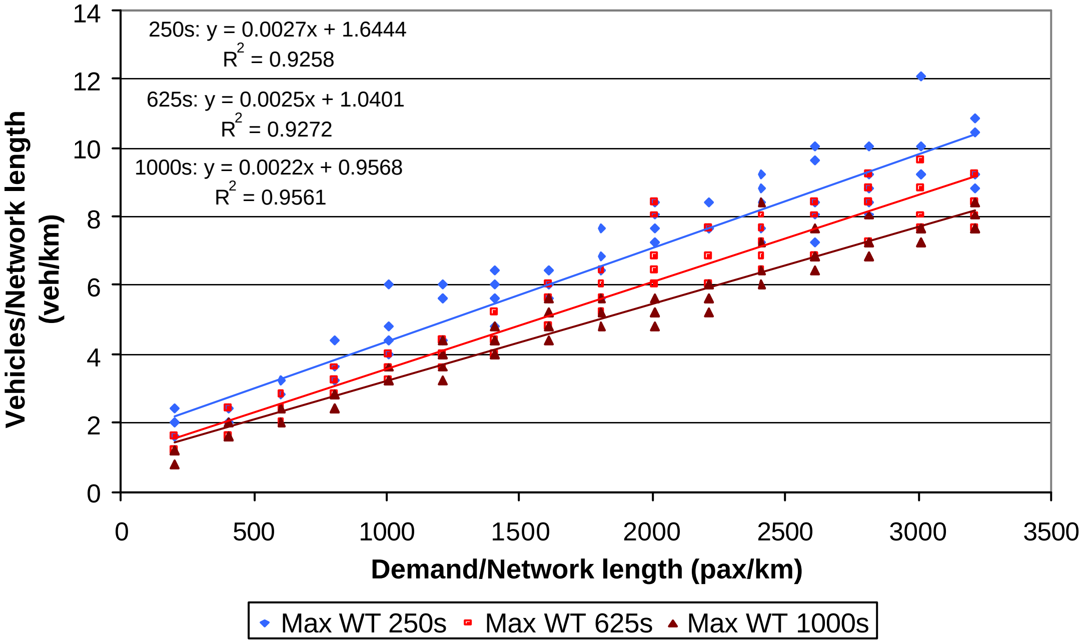

Figure A1.1 Number of vehicles circulating with 4-place vehicles and 15 km/h maximum speed

In Figure A1.2 the relationships between the ratio number of vehicles/network length and the ratio demand/network length for a CTS with 20 km/h maximum speed and 4-place vehicles are presented for the three levels of service.

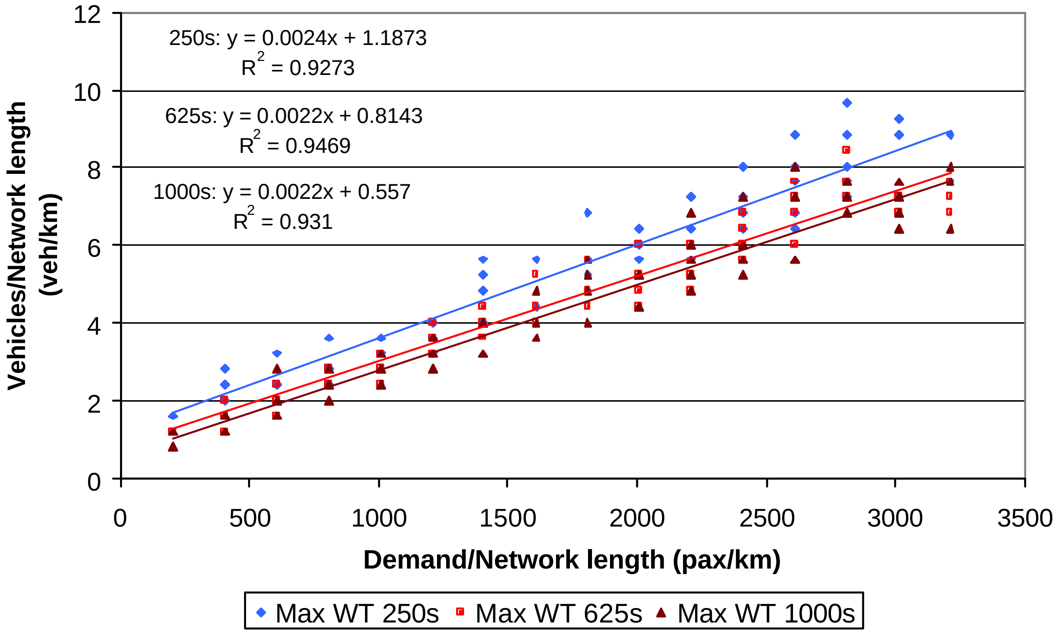

Figure A1.2 Number of vehicles circulating with 4-place vehicles and 20 km/h maximum speed

As for 15 km/h maximum speed, the R^2 coefficients were all over 0.92, thus well approximating simulation result trends. The best result was provided with 625 s waiting time, where R^2 is near 0.95.

For 25 km/h and 30 km/h maximum speed and 4-place vehicles, reported in Figure A1.3 and A1.4, the coefficients R^2 were also all over 0.92. As for 15 km/h maximum speed, the best correlations are observed for 1000 s maximum waiting time, where R^2 is over 0.97 for both 25 km/h and 30 km/h maximum speed.

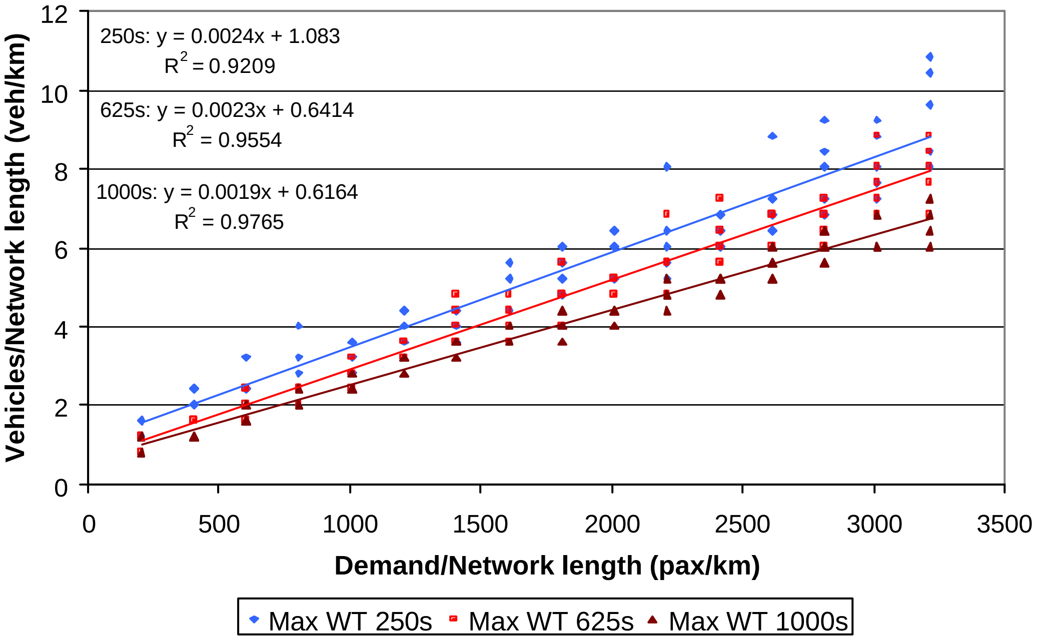

Figure A1.3 Number of vehicles circulating with 4-place vehicles and 25 km/h maximum speed

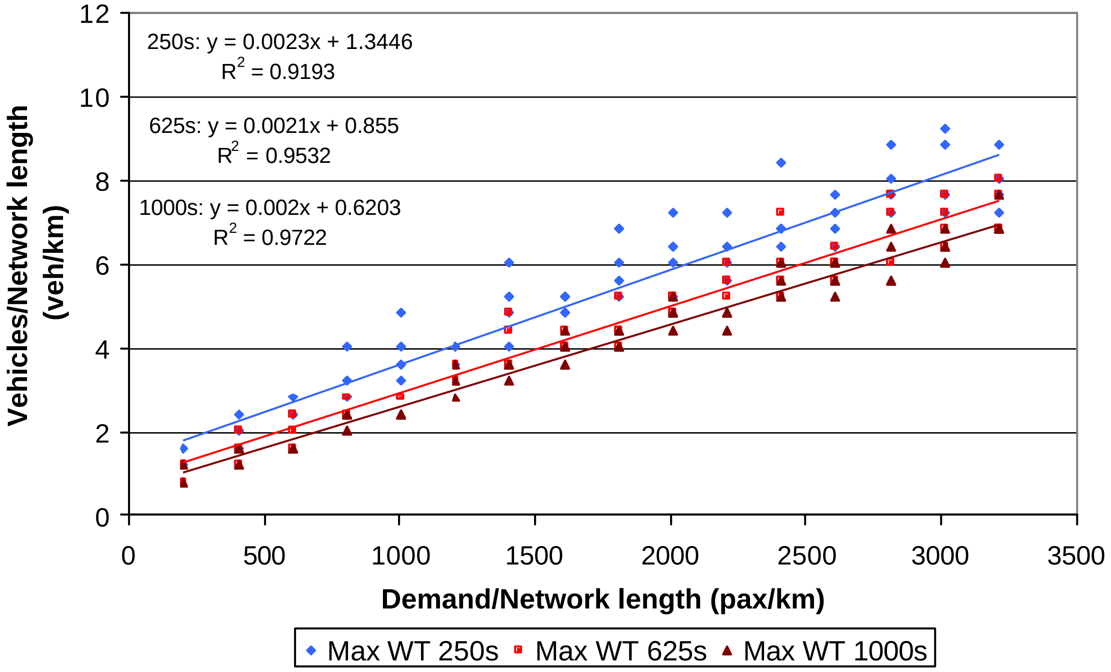

Figure A1.4 Number of vehicles circulating with 4-place vehicles and 30 km/h maximum speed

Figure A1.5, Figure A1.6, Figure A1.7 and Figure A1.8 report the relationships between the ratio number of vehicles/network length and the ratio demand/network length for a CTS with 10-place vehicles. They respectively report the results obtained for 15 km/h, 20 km/h, 25 km/h and 30 km/h maximum speed each one for the three levels of service.

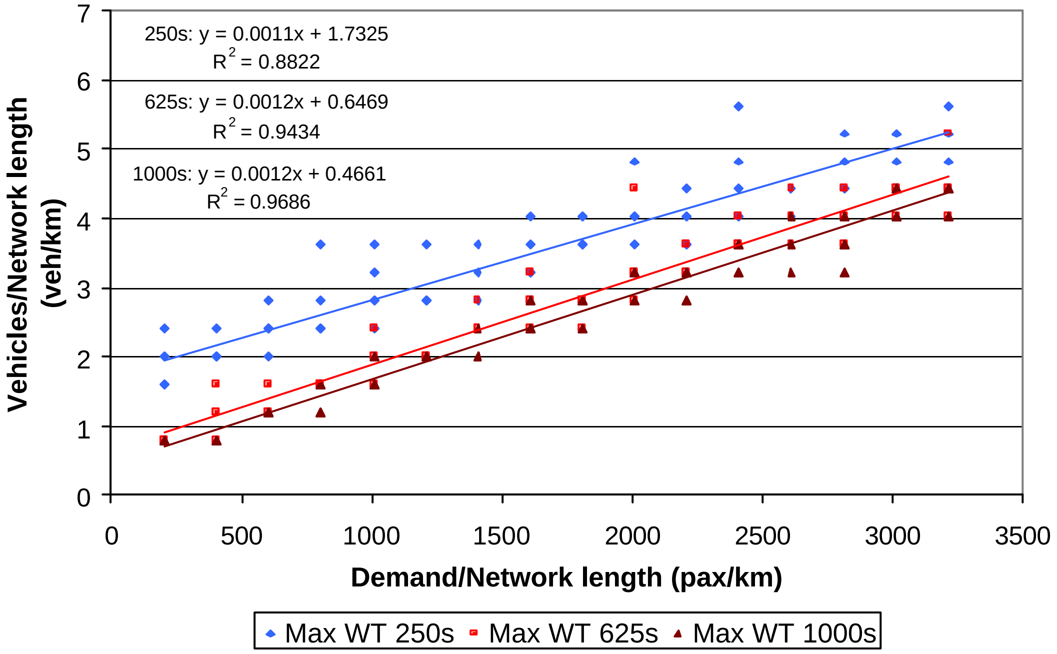

Figure A1.5 Number of vehicles circulating with 10-place vehicles and 15 km/h maximum speed

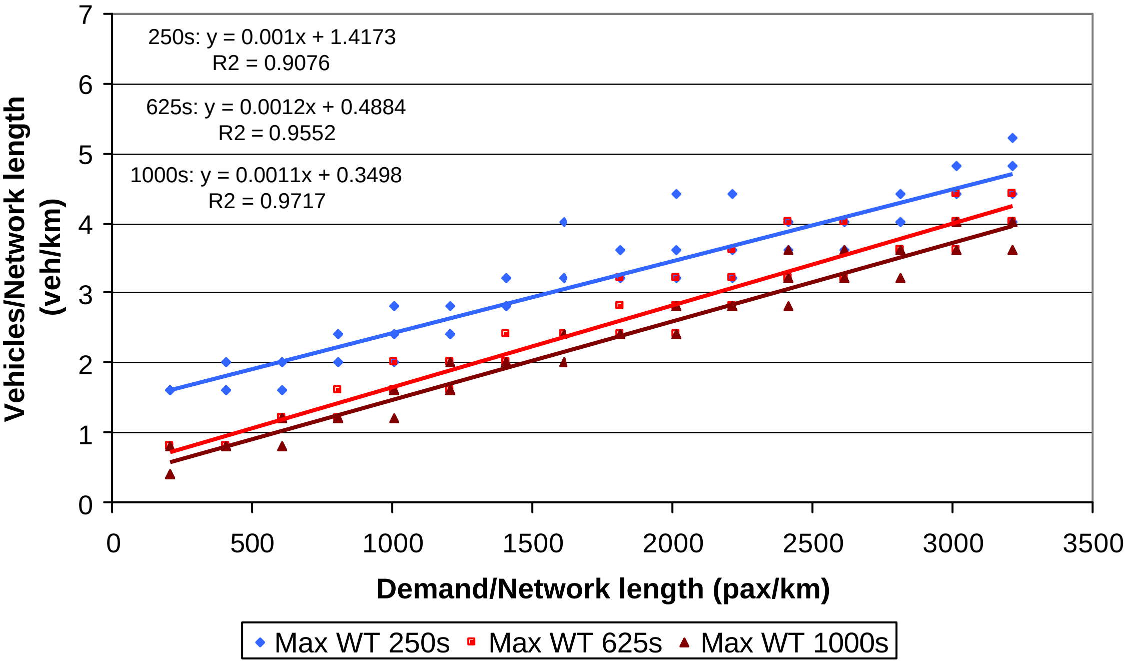

Figure A1.6 Number of vehicles circulating with 10-place vehicles and 20 km/h maximum speed

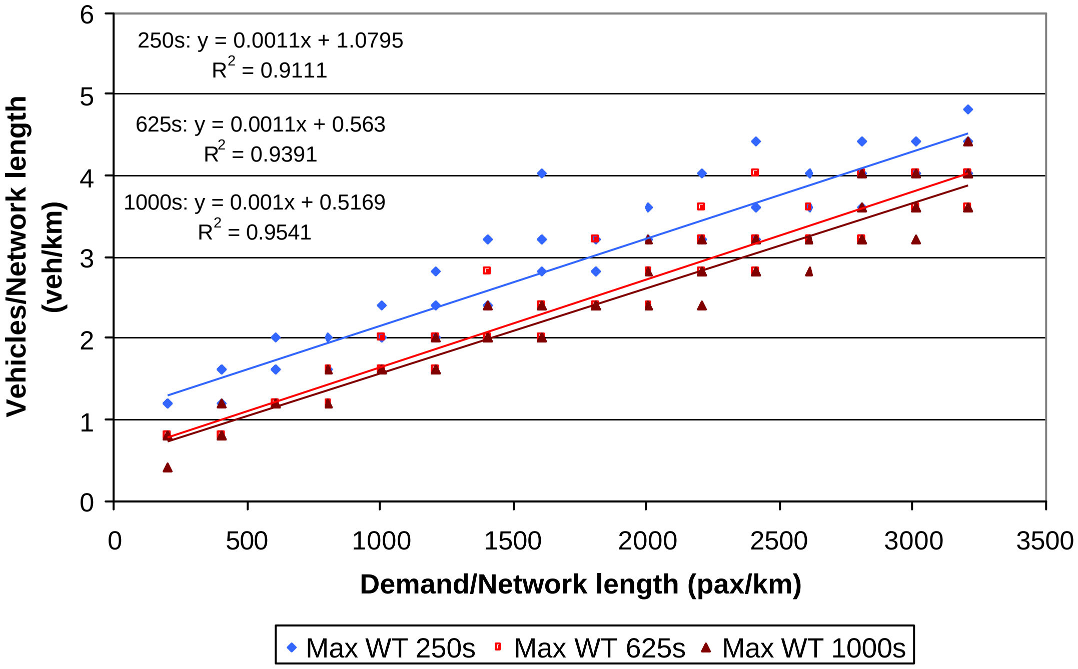

Figure A1.7 Number of vehicles circulating with 10-place vehicles and 25 km/h maximum speed

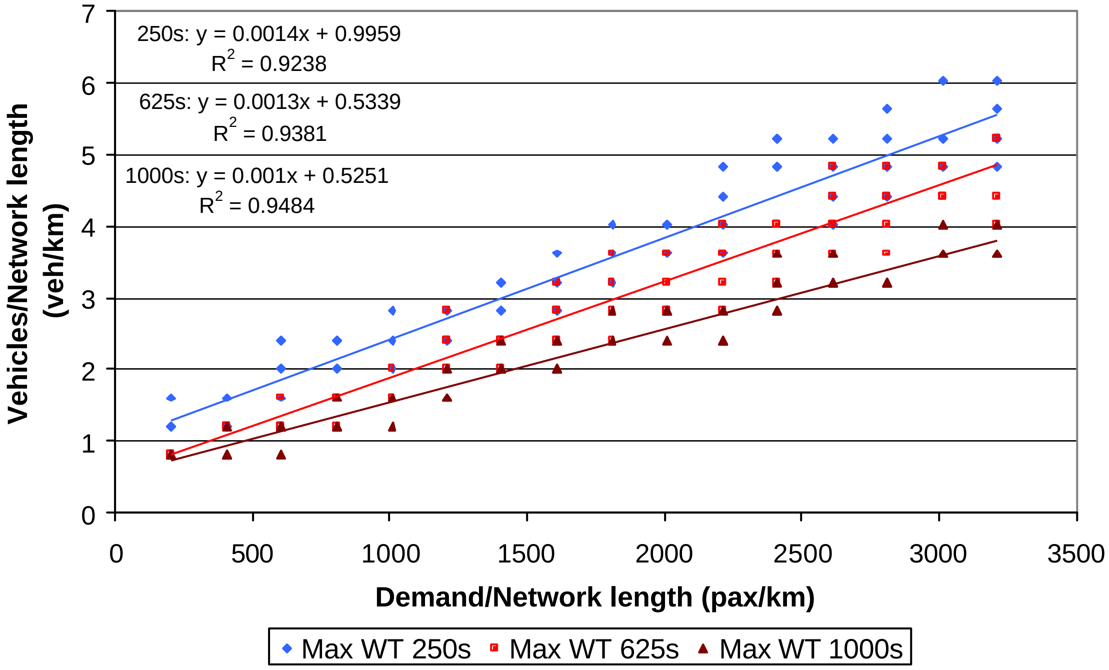

Figure A1.8 Number of vehicles circulating with 10-place vehicles and 30 km/h maximum speed

For all the possible maximum speeds the best results in terms of correlation were provided for 1000 s maximum waiting time: R^2 was always over 0.94 and for 20 km/h maximum speed it passed 0.97.

For 625 s time window results were also good, with R^2 between about 0.94 and 0.95, whereas for 250 s the correlation coefficient was little lower, even if it was always over 0.90, with the only exception of 15 km/h maximum speed, where R^2 was 0.88. The lower values of R^2 for 250 s was due to the fact that using 10-place vehicles the possibility to travel empty or with few people on board is higher than using 4-place vehicles, because of their different capacities, and this possibility grows as the time window decreases, thus the results about the same demand were sometimes different from one simulation to another thus making R^2 lower in those cases.

Figure A1.9, Figure A1.10, Figure A1.11 and Figure A1.12 represent, for a CTS with 20-place vehicles, the relationships between the ratio number of vehicles/network length and the ratio demand/network length for 15 km/h, 20 km/h, 25 km/h and 30 km/h maximum speed respectively each one for the three levels of service.

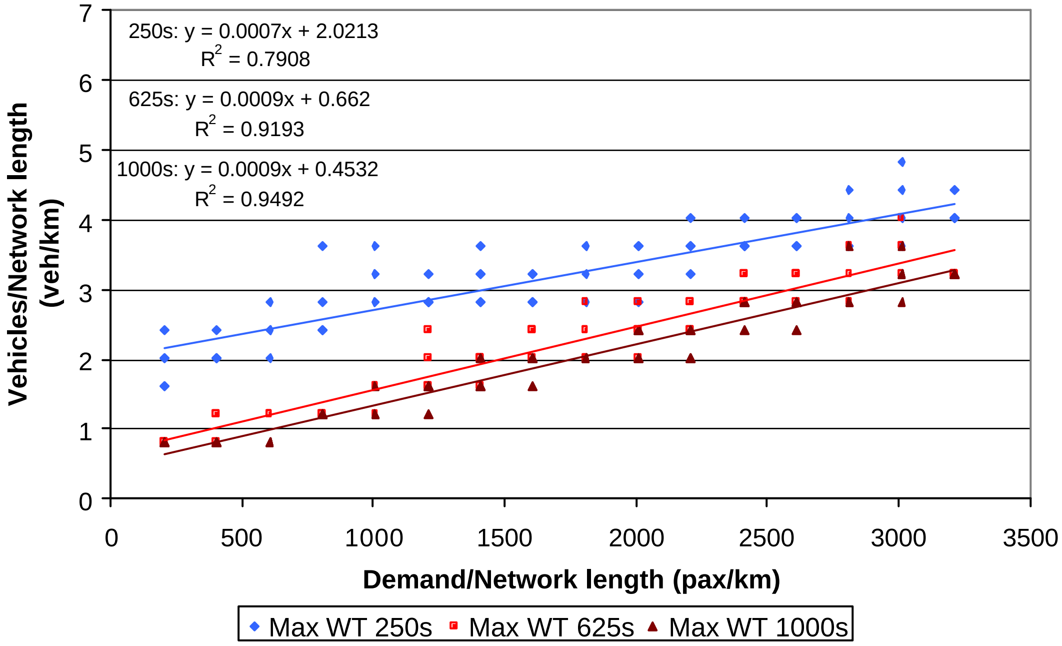

Figure A1.9 Number of vehicles circulating with 20-place vehicles and 15 km/h maximum speed

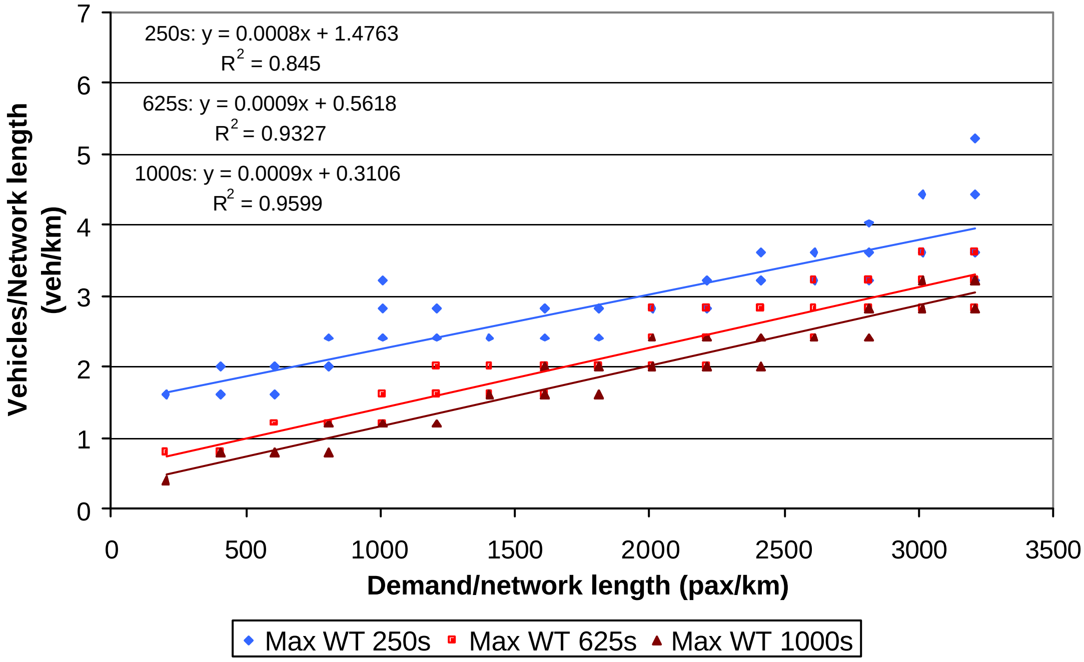

Figure A1.10 Number of vehicles circulating with 20-place vehicles and 20 km/h maximum speed

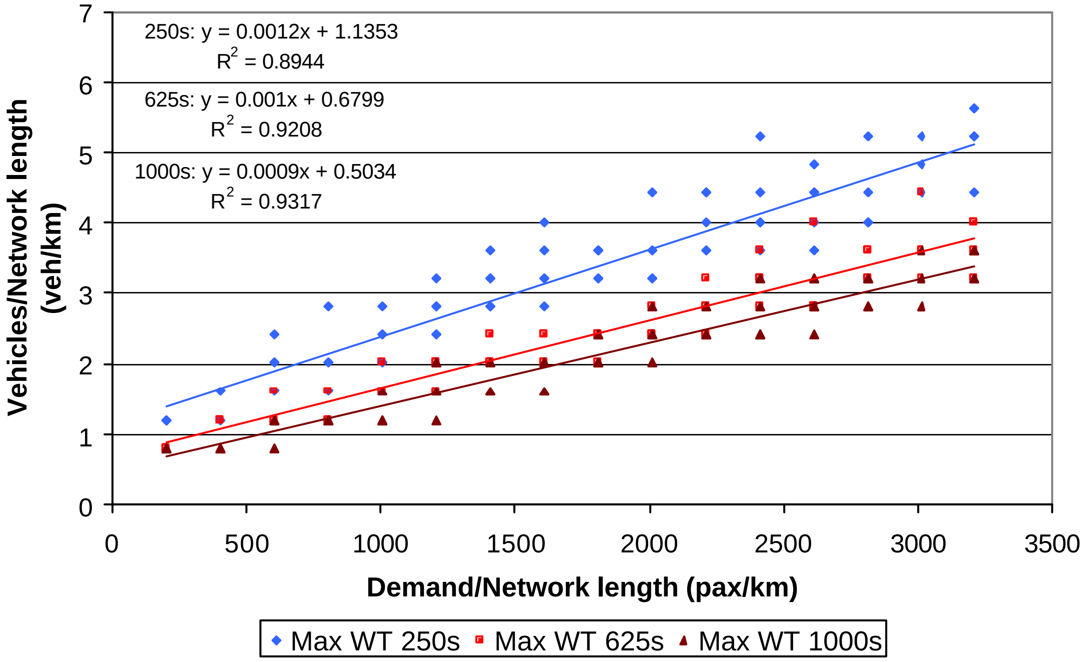

Figure A1.11 Number of vehicles circulating with 20-place vehicles and 25 km/h maximum speed

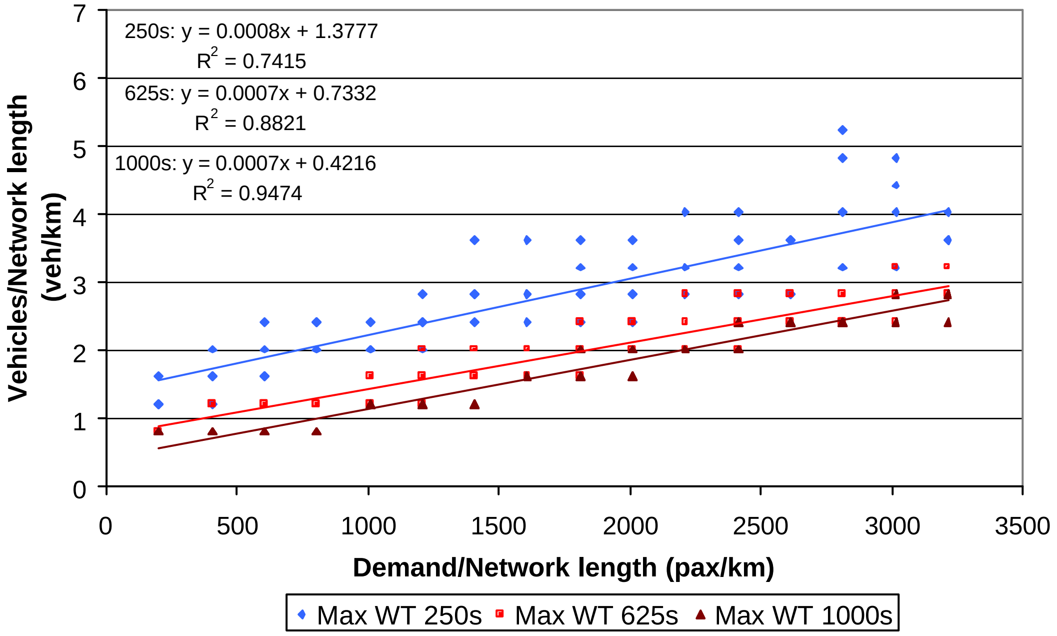

Figure A1.12 Number of vehicles circulating with 20-place vehicles and 30 km/h maximum speed

As for 10-place vehicles, for all the possible maximum speeds the best results in terms of approximation were provided for 1000 s maximum waiting time: R^2 was always over 0.93 and for 20 km/h maximum speed it was 0.96.

For 625 s time window correlation was little lower, with R^2 ranging between 0.88 and 0.93, and for 250 s the same trend observed for 10-place vehicles can be observed: R^2 varied from 0.74 (when maximum speed is 30 km/h) to 0.89. These low values are due to the high capacity of the used vehicles, which can travel emptier than 4-place and 10-place vehicles once the level of required service grows.

A1.2 Average waiting time

The average waiting time is independent on both the foreseen demand and the network length; once the number of vehicles is chosen according to the step 1 of the methodology the average waiting time depends only to the chosen level of service (maximum waiting time). Of course several factors may have influence on it but they are not deterministically predictable therefore in section 3 of the main text rather than giving equations for the regressions, as for any of the other steps, ranges were provided.

To have a representation of how the average waiting time ranges have been obtained per each configuration of the system, in this section the simulation results are reported in charts (one per each kind of vehicle and per each maximum speed) where the x axis is the ratio between the foreseen demand and the number of vehicles and the y axis is the average waiting time.

Figure A1.13, Figure A1.14, Figure A1.15 and Figure A1.16 show the average waiting times calculated for 4-place vehicles for 15 km/h, 20 km/h, 25 km/h and 30 km/h maximum speed respectively.

For 250 s maximum waiting time level of service, the maximum value of average waiting time never exceeded 100 s and the minimum value was around 50 s. The maximum average waiting time was measured for 15 km/h maximum speed and was about 90 s, whereas the minimum value of about 35 s was measured for 30 km/h.

For 625 s and 1000 s it can be seen that the two ranges had a common part, usually between 150 s and 200 s. 625 s maximum waiting time range was from about 100 s and about 200 s, whereas for 1000 s the minimum average waiting time was about 150 s and the maximum was little under 400 s.

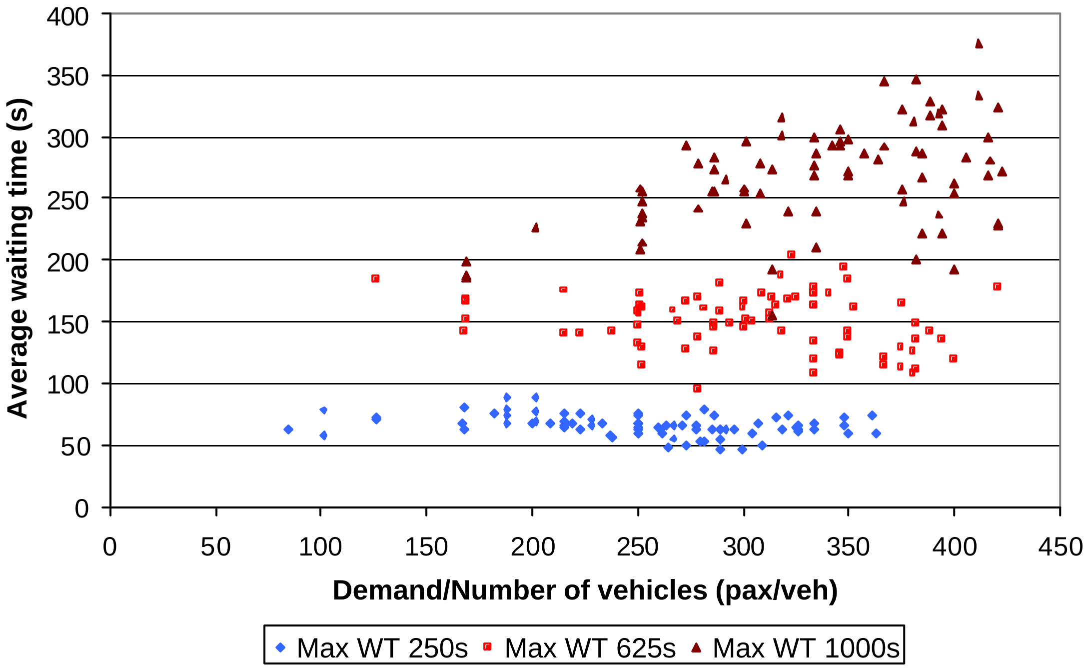

Figure A1.13 Average waiting time with 4-place vehicles and 15 km/h maximum speed

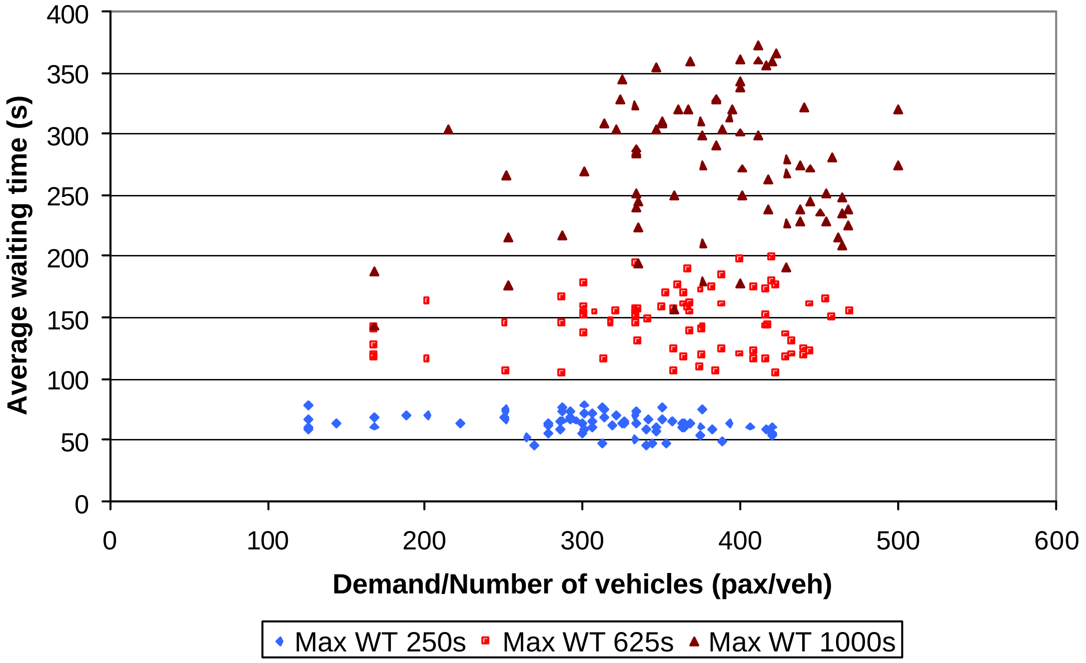

Figure A1.14 Average waiting time with 4-place vehicles and 20 km/h maximum speed

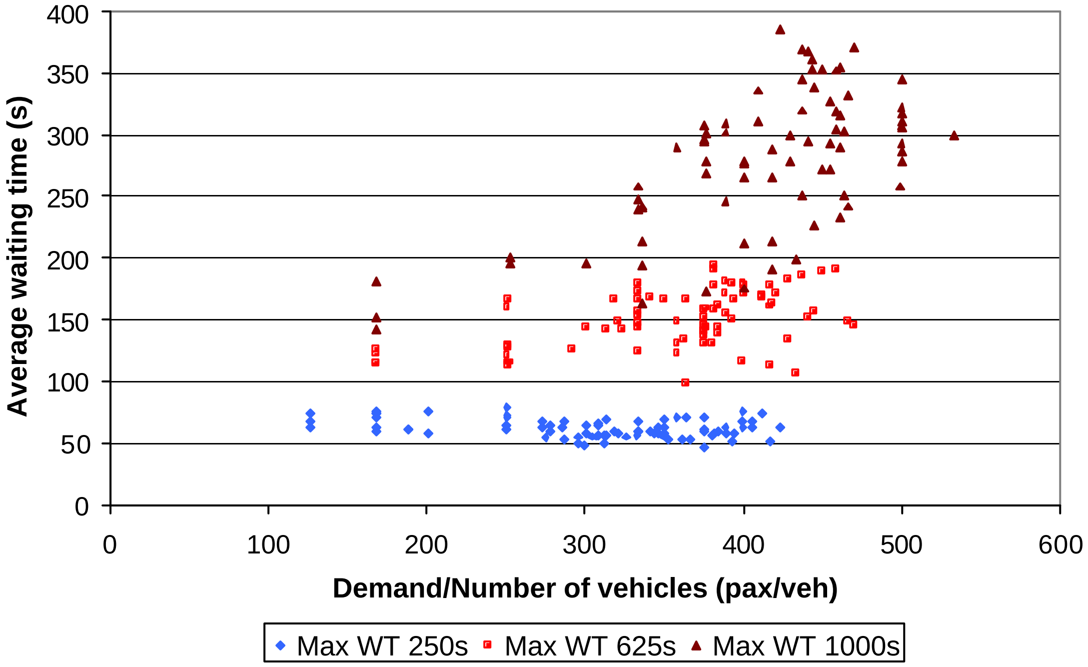

Figure A1.15 Average waiting time with 4-place vehicles and 25 km/h maximum speed

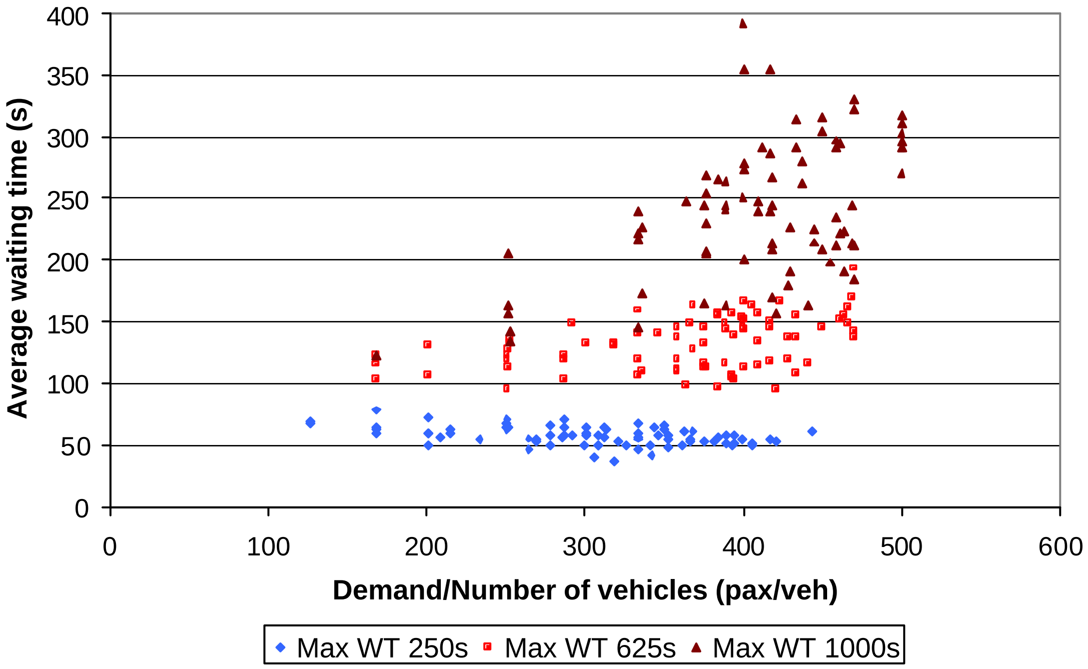

Figure A1.16 Average waiting time with 4-place vehicles and 30 km/h maximum speed

As for 4-place vehicles, for 10-place vehicles the range correspondent to 250 s maximum waiting time was between 50 s and about 100 s, as it has been reported in Figure A1.17, Figure A1.18, Figure A1.19 and Figure A1.20.

For 625 s the range was measured between about 100 s and 200 s, whereas for 1000 s the range was always from 150 s and values near 350 s. As for 4-place vehicles the common area was between 150 s and 200 s, the only difference was about the maximum average waiting time for 1000 s, which only for 30 km/h was over 350 s and thus was under 400 s for each maximum speed.

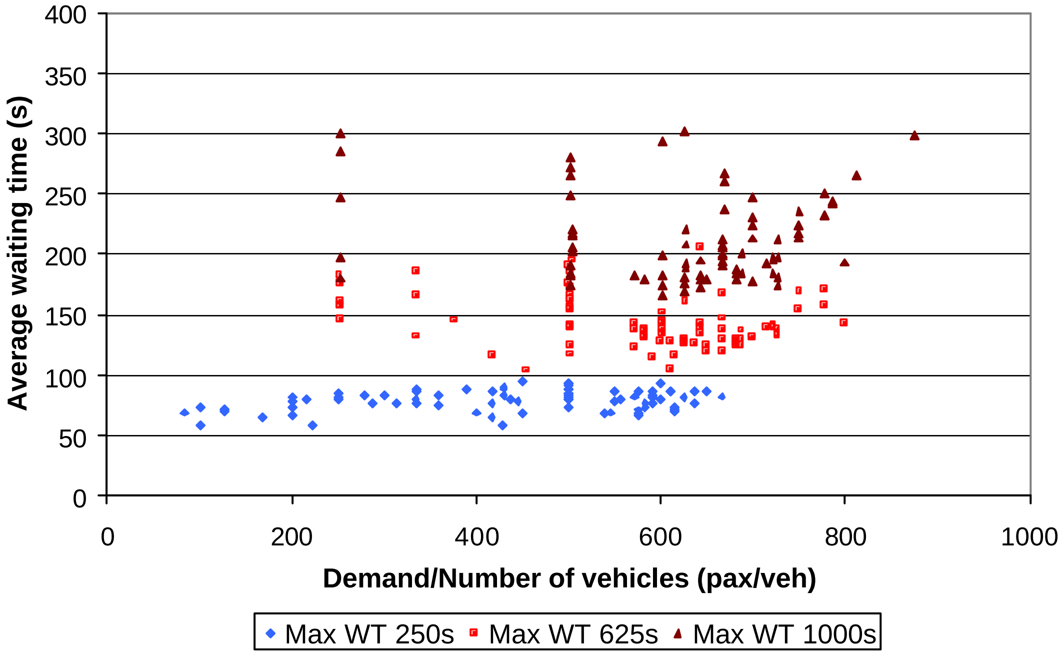

Figure A1.17 Average waiting time with 10-place vehicles and 15 km/h maximum speed

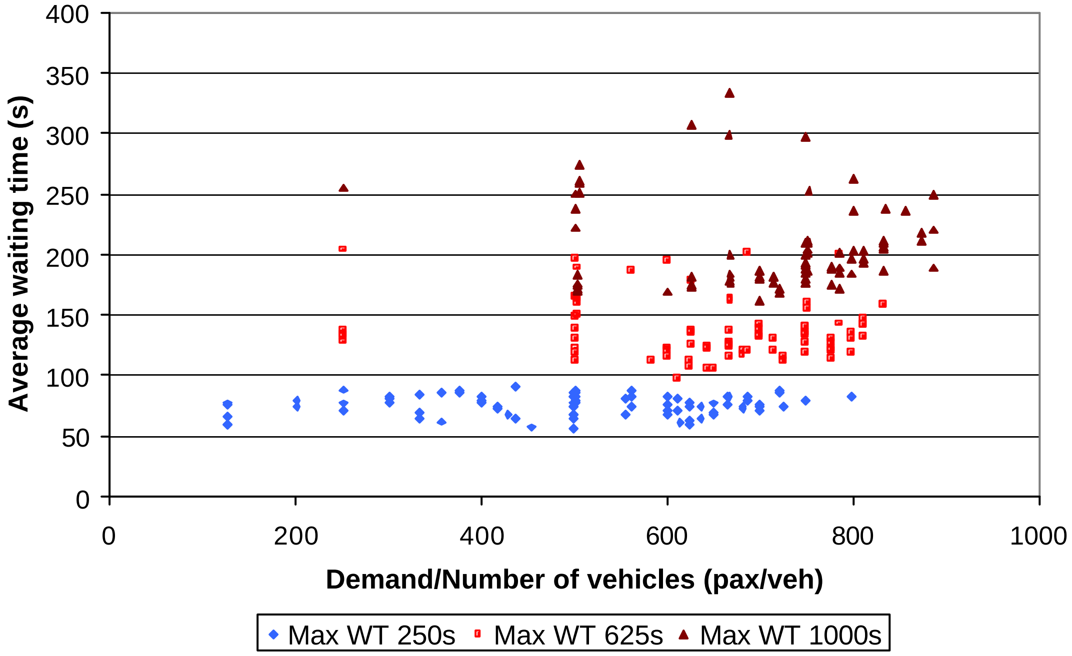

Figure A1.18 Average waiting time with 10-place vehicles and 20 km/h maximum speed

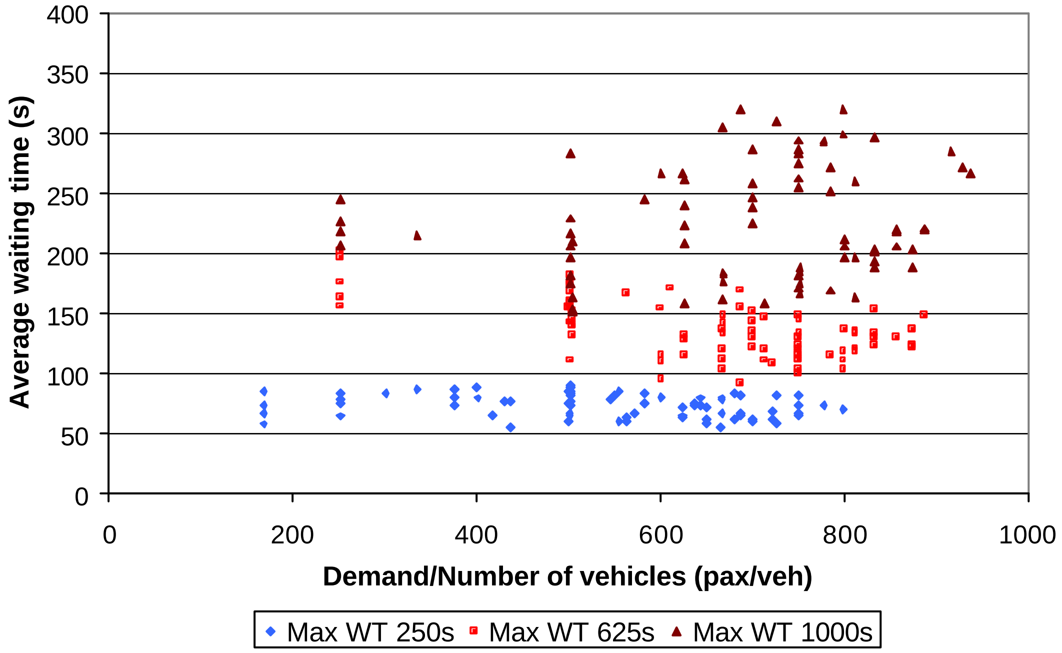

Figure A1.19 Average waiting time with 10-place vehicles and 25 km/h maximum speed

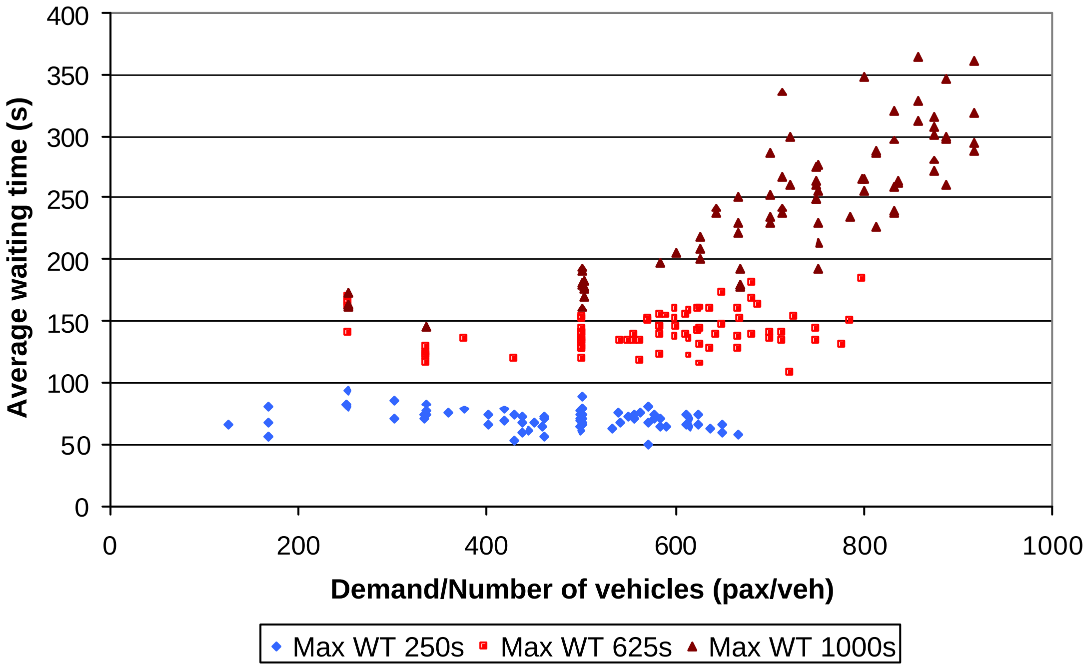

Figure A1.20 Average waiting time with 10-place vehicles and 30 km/h maximum speed

Figure A1.21, Figure A1.22, Figure A1.23 and Figure A1.24 show the results obtained for 20-place vehicles.

The range for 250 s was between little over 50 s and 100 s, whereas for 625 s the minimum average waiting time was little over 100 s and the maximum about 200 s. For both these levels of service the minimum value of average waiting time was little higher than those measured for 4-place and 10-place vehicles both for 250 s and 625 s, whereas the maximum value was similar.

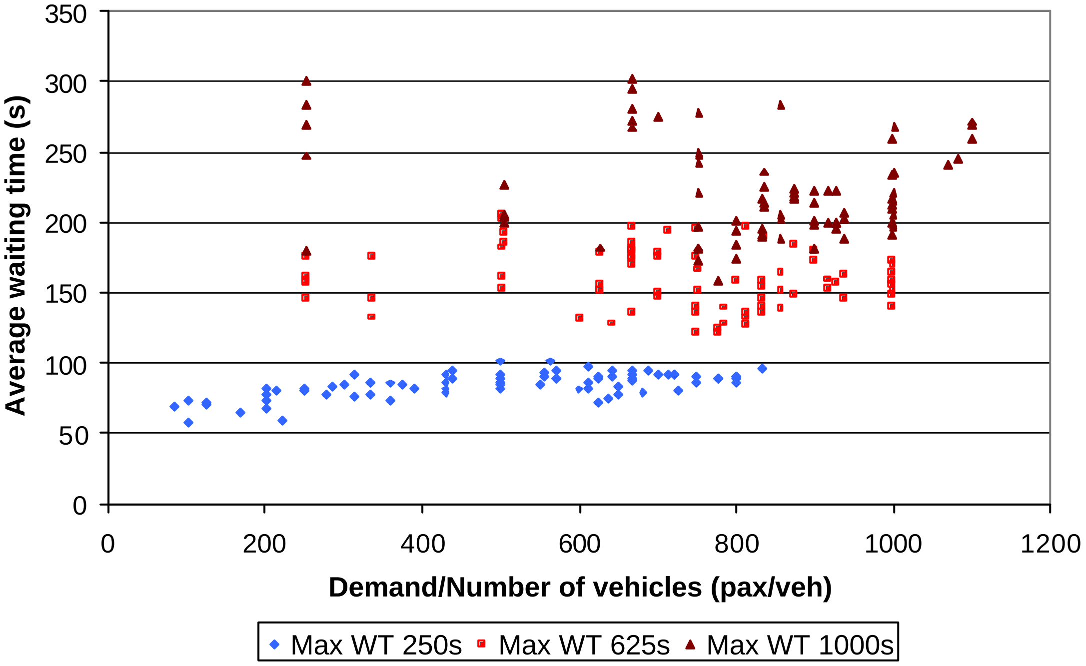

Figure A1.21 Average waiting time with 20-place vehicles and 15 km/h maximum speed

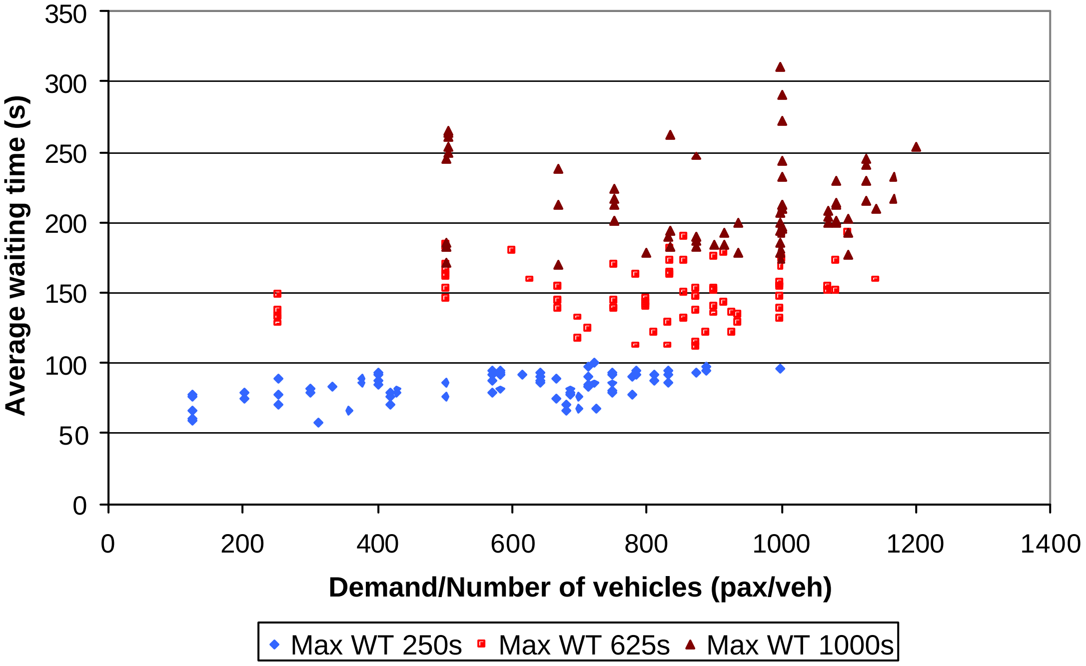

Figure A1.22 Average waiting time with 20-place vehicles and 20 km/h maximum speed

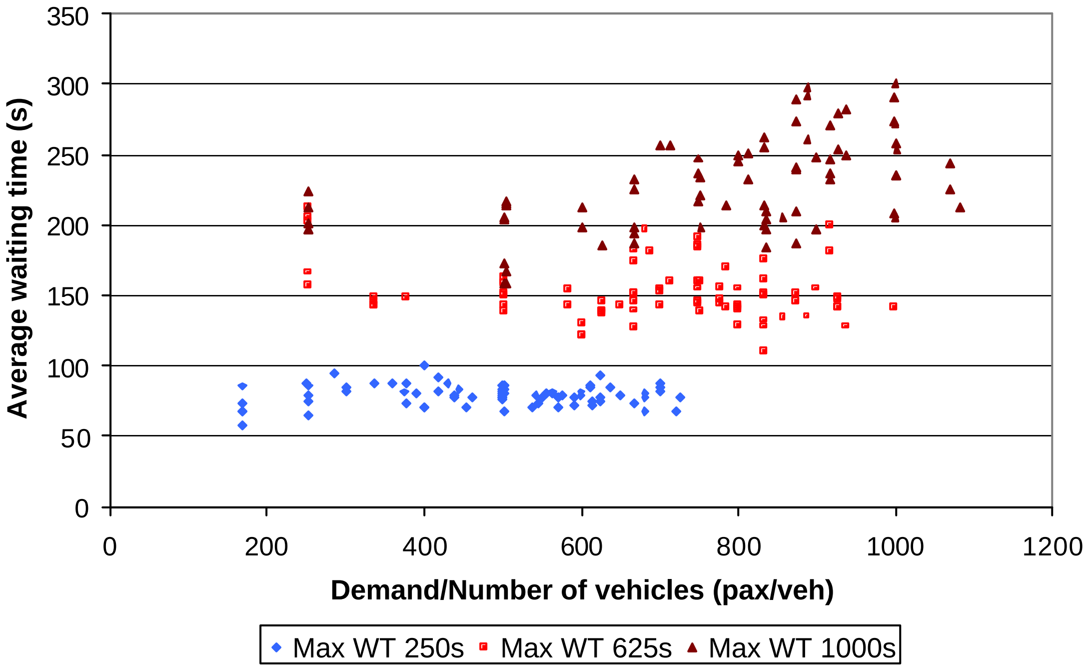

Figure A1.23 Average waiting time with 20-place vehicles and 25 km/h maximum speed

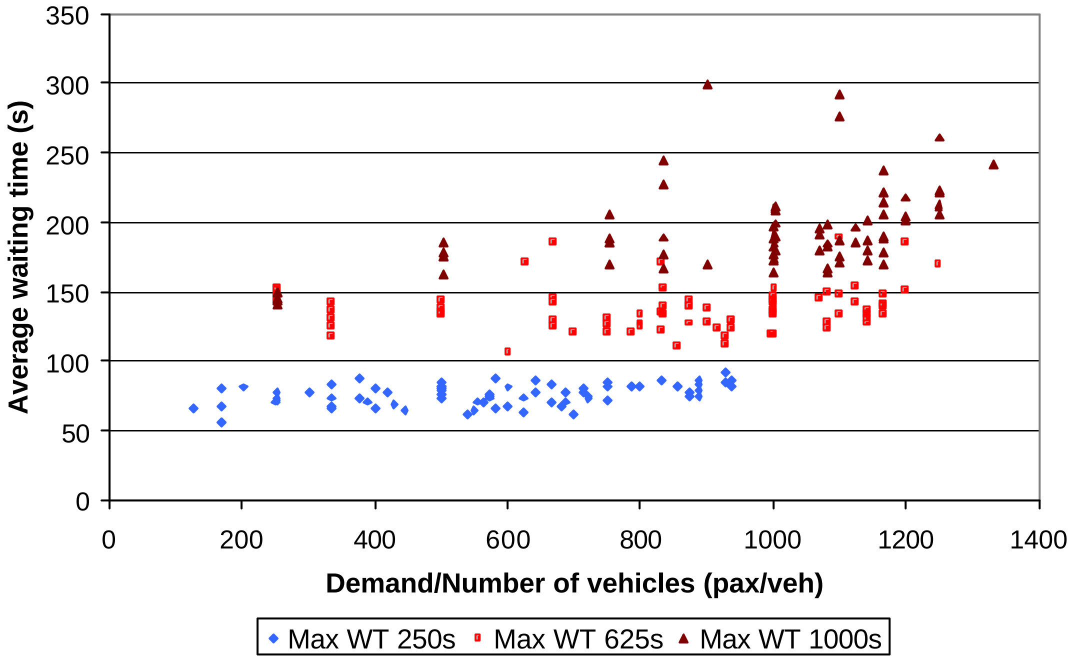

Figure A1.24 Average waiting time with 20-place vehicles and 30 km/h maximum speed

For 1000 s the minimum average waiting time was always near 150 s and the maximum value was about 300 s: the common area for 625 s and 1000 s was about the same measured for 4-place and 10-place vehicles, whereas the upper limit of 1000 s service was lower than the previous cases.

A1.3 Total vehicle run

Figure A1.25, Figure A1.26, Figure A1.27 and Figure A1.28 show the relationships between the ratio vehicle run/network length and the ratio demand/network length for a CTS with 4-place vehicles and, respectively, 15 km/h, 20 km/h, 25 km/h and 30 km/h maximum speed. Each chart reports one line for each of the three levels of service.

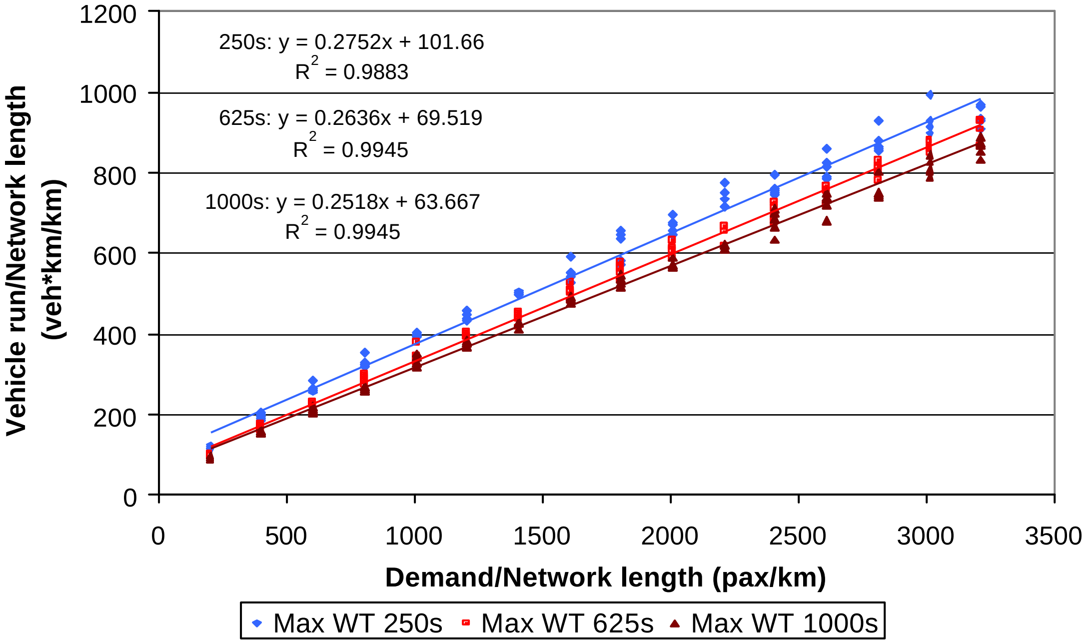

Figure A1.25 Total vehicle run with 4-place vehicles and 15 km/h maximum speed

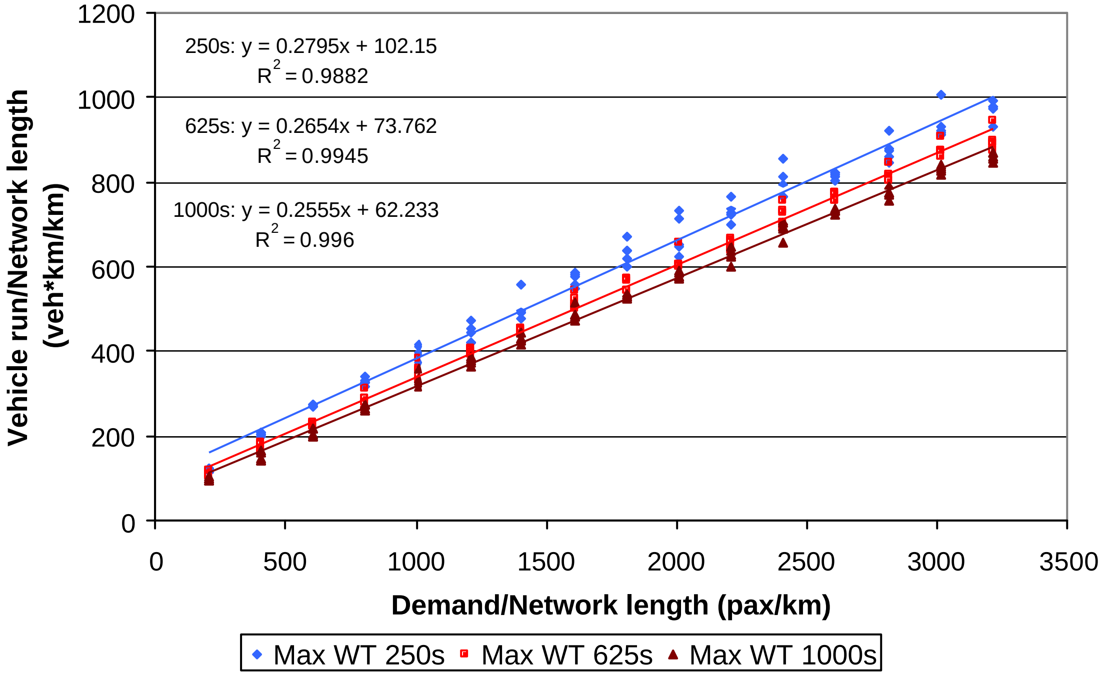

Figure A1.26 Total vehicle run with 4-place vehicles and 20 km/h maximum speed

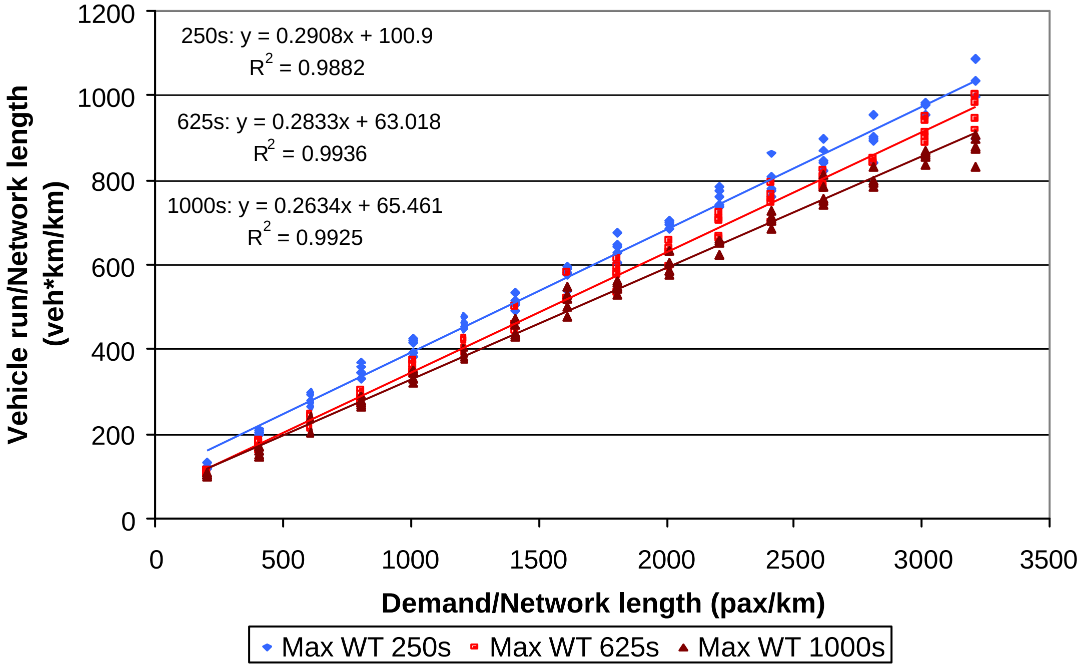

Figure A1.27 Total vehicle run with 4-place vehicles and 25 km/h maximum speed

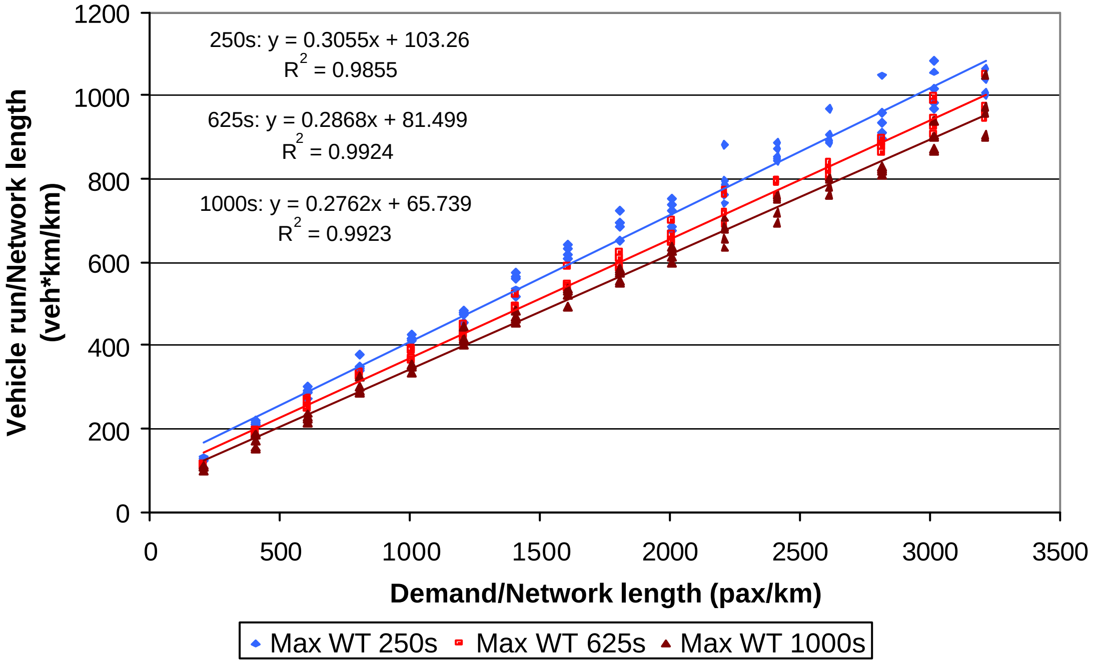

Figure A1.28 Total vehicle run with 4-place vehicles and 30 km/h maximum speed

The correlation is excellent for each level of service and for each maximum speed: R^2 varies from over 0.98 to over 0.99 (with 20 km/h maximum speed and 1000 s time window R^2 is about 1), meaning that all the equations approximate simulations' trends very well.

Figure A1.29, Figure A1.30, Figure A1.31 and Figure A1.32 show the relationships between the ratio vehicle run/network length and the ratio demand/network length for a CTS with 10-place vehicles and, respectively, 15 km/h, 20 km/h, 25 km/h and 30 km/h maximum speed. Each of the charts has three lines one per each of the three levels of service.

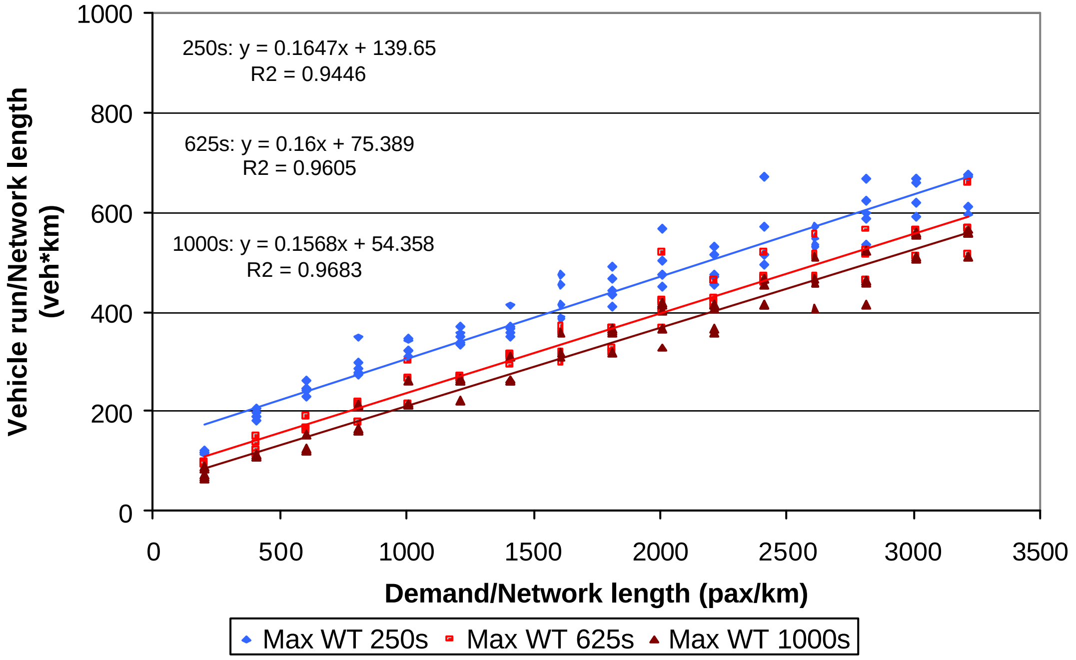

Figure A1.29 Total vehicle run with 10-place vehicles and 15 km/h maximum speed

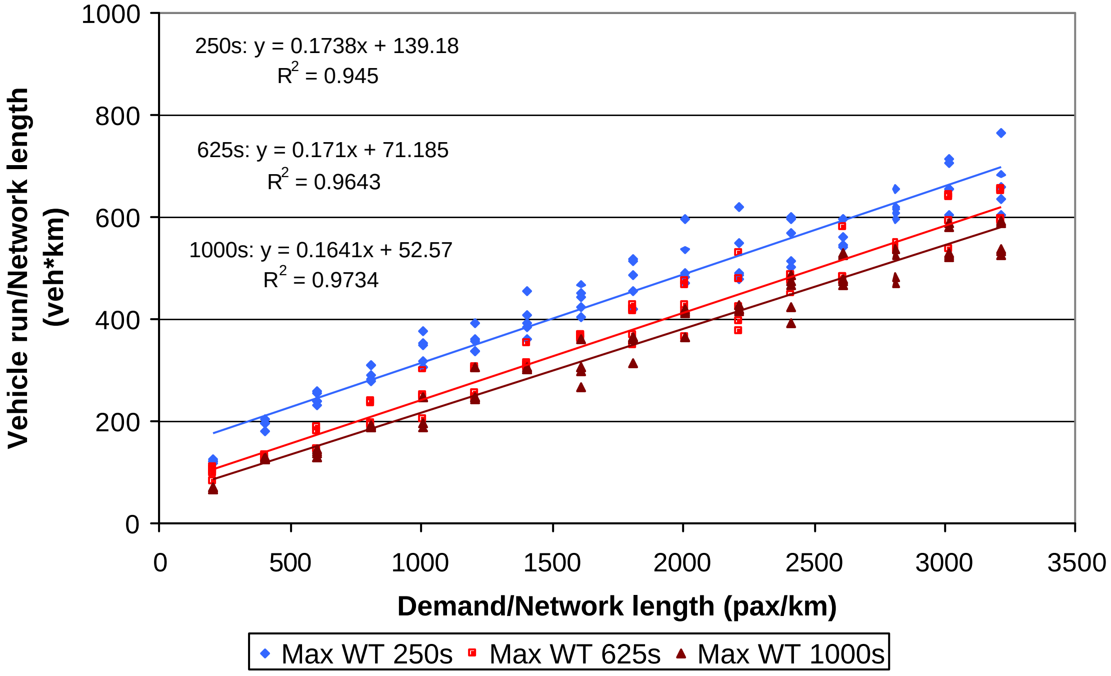

Figure A1.30 Total vehicle run with 10-place vehicles and 20 km/h maximum speed

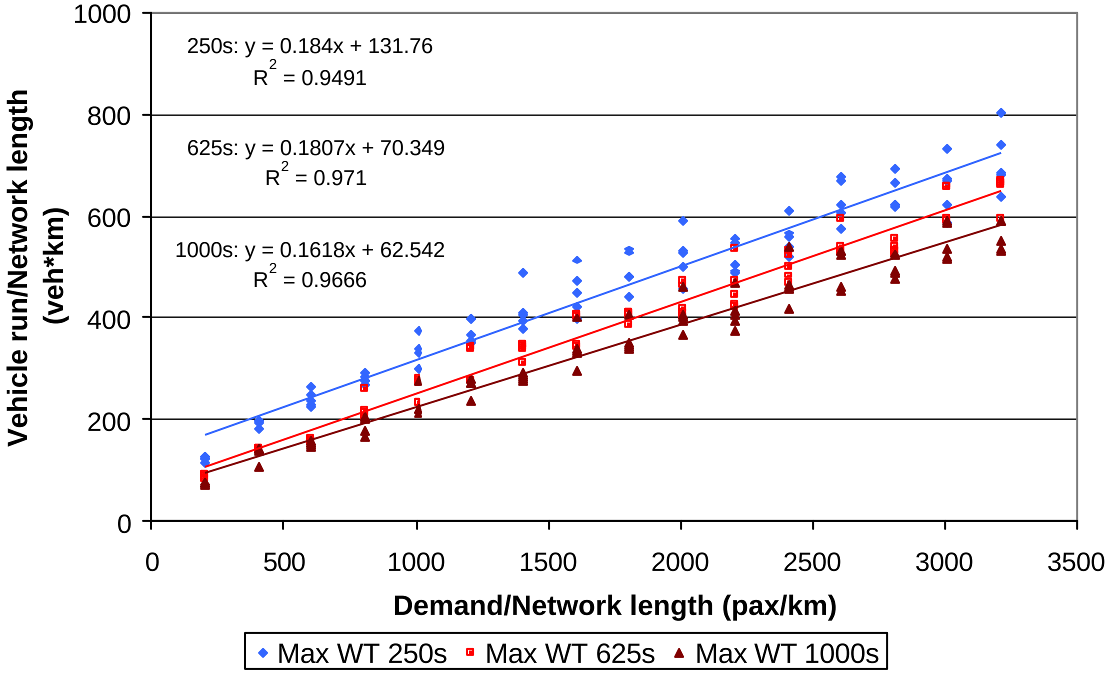

Figure A1.31 Total vehicle run with 10-place vehicles and 25 km/h maximum speed

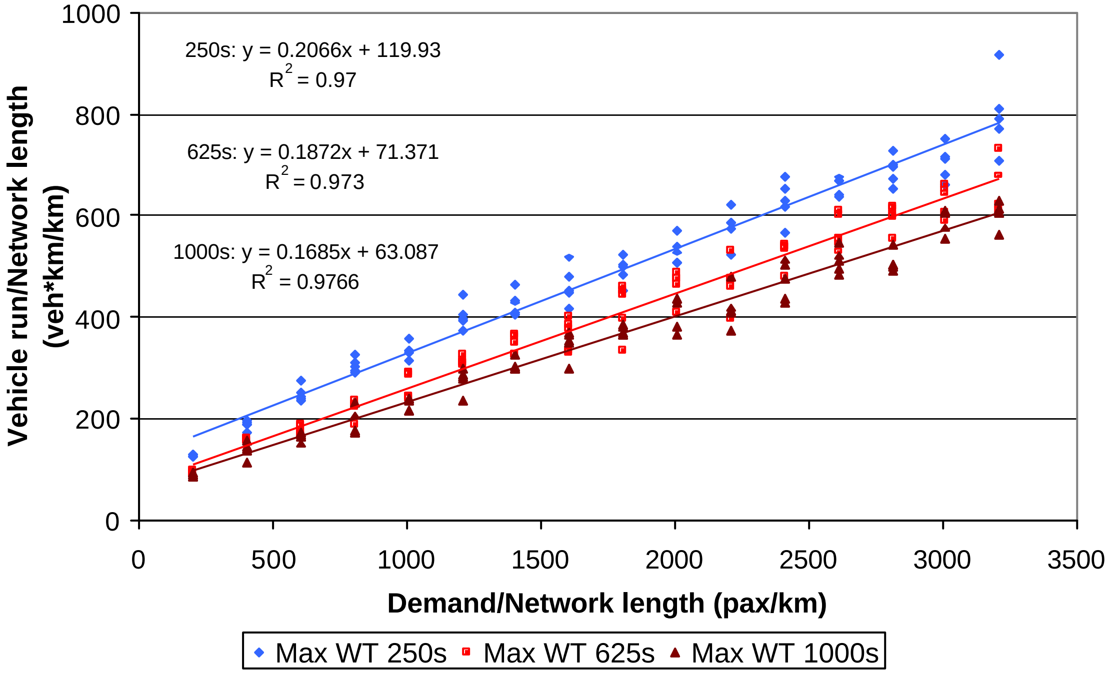

Figure A1.32 Total vehicle run with 10-place vehicles and 30 km/h maximum speed

The approximation provided by the adopted formulas was generally very good, even if little lower than that of the 4-place vehicles. R^2 varies from 0.94 to about 0.98, meaning that for 10-place vehicles too vehicle run was well correlated to the demand. Considering the levels of service, the best results were provided for 1000 s time window, where R^2 was always about 0.97. The other two levels of service

(250 s and 625 s) provided however very good results and the difference with the 1000 s one is very little.

Differently from 4-place and 10-place vehicles, the results obtained for the 20-place vehicles are more influenced by the chosen level of service, as it can be seen by looking at Figure A1.33, Figure A1.34, Figure A1.35 and Figure A1.36.

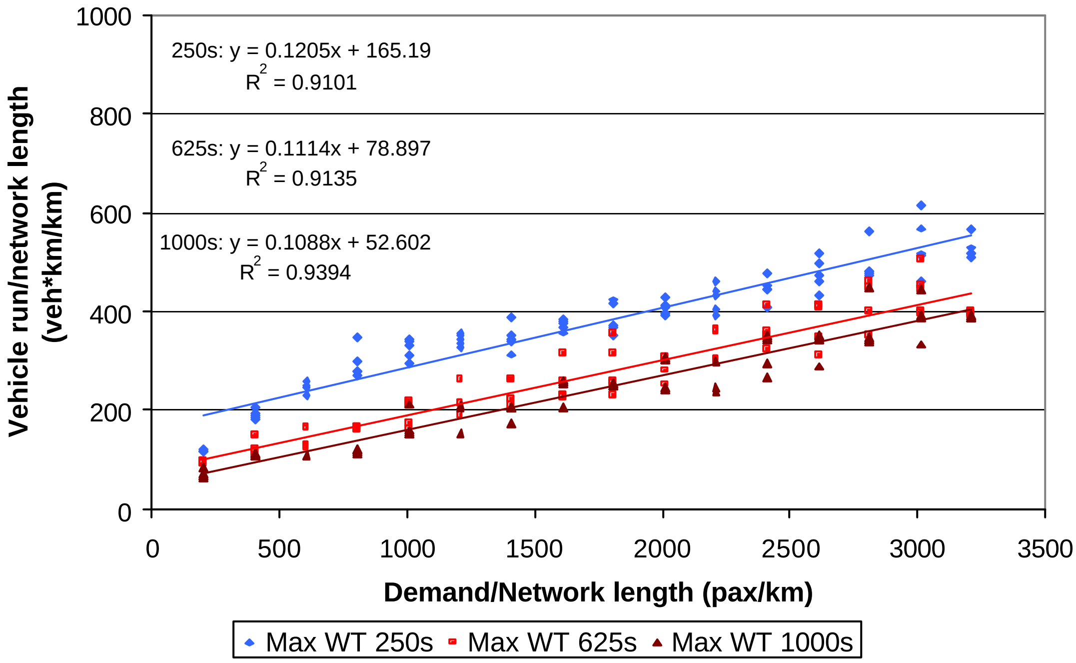

Figure A1.33 Total vehicle run with 20-place vehicles and 15 km/h maximum speed

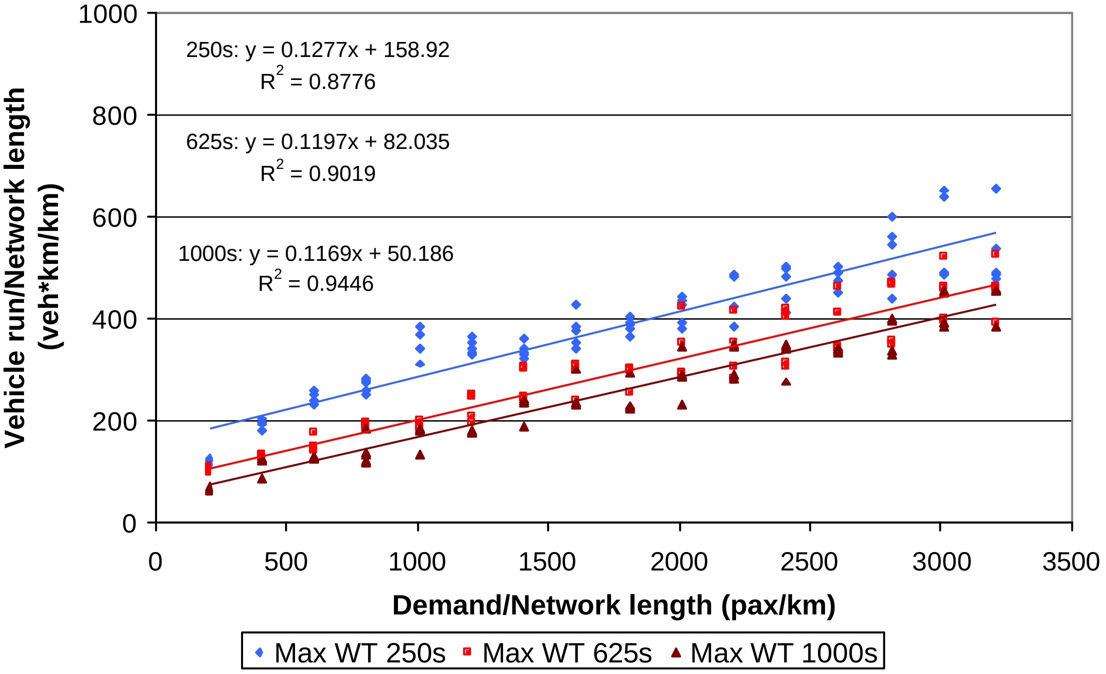

Figure A1.34 Total vehicle run with 20-place vehicles and 20 km/h maximum speed

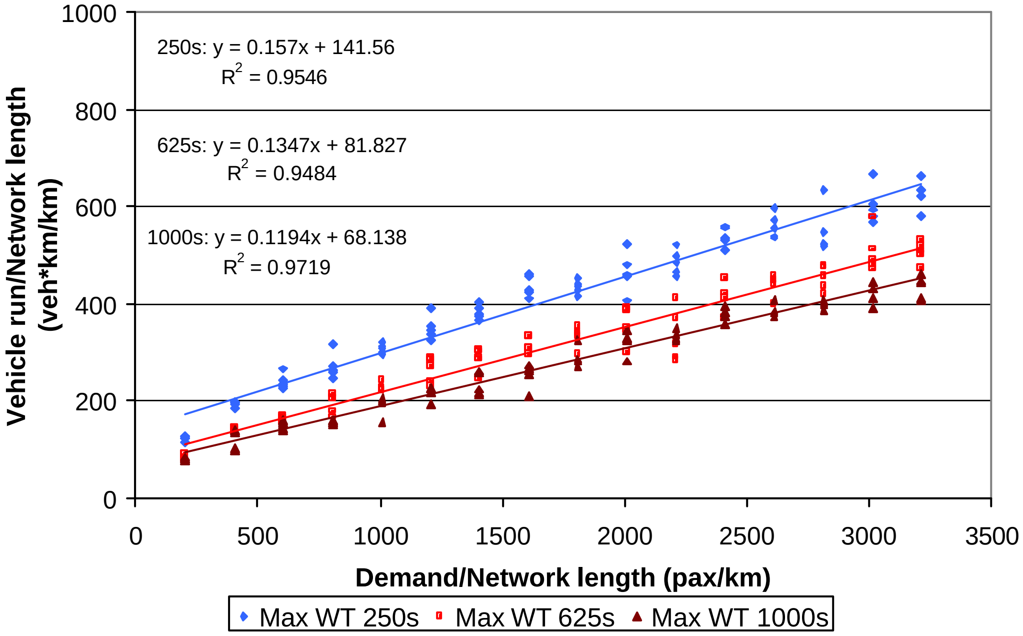

Figure A1.35 Total vehicle run with 20-place vehicles and 25 km/h maximum speed

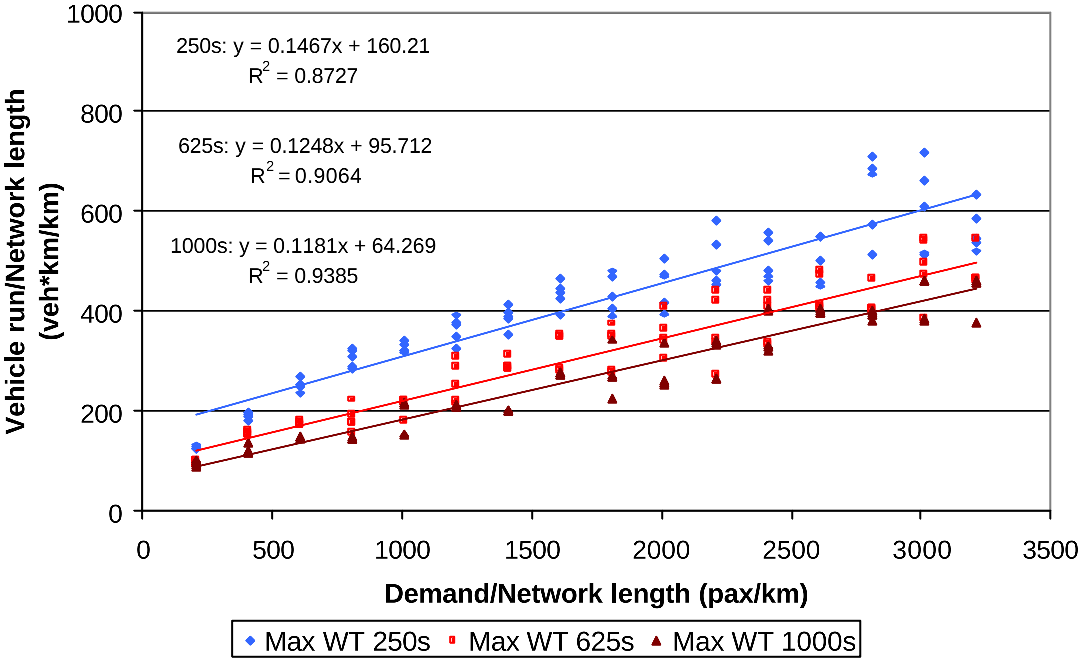

Figure A1.36 Total vehicle run with 20-place vehicles and 30 km/h maximum speed

For 250 s maximum waiting time R^2 varies from 0.87 to 0.95, meaning that the high capacity of these vehicles directly influenced the number of vehicles circulating and consequently their total run.

For 625 s results were little better, with R^2 varying from 0.90 to 0.95; the best results were provided with 1000 s, where R^2 varied from 0.94 to 0.97, similar to the results obtained for 10-place vehicles.

A1.4 Commercial speed

Figure A1.37, Figure A1.38, Figure A1.39 and Figure A1.40 represent, for a CTS with 4-place vehicles, the relationships between the commercial speed and the ratio demand/network length for 15 km/h, 20 km/h, 25 km/h and 30 km/h maximum speed respectively, each one for the three levels of service.

The approximation provided by the formulas (exponential and not linear as for number of vehicles and total vehicle run) obtained was generally quite good: R^2 varied between 0.87 to 0.93 and the changes in level of service did not provide substantial differences. For 250 s maximum waiting time R^2 varied from 0.88 to 0.91, for 625 s from 0.87 to 0.93 and for 1000 s from 0.87 and 0.92.

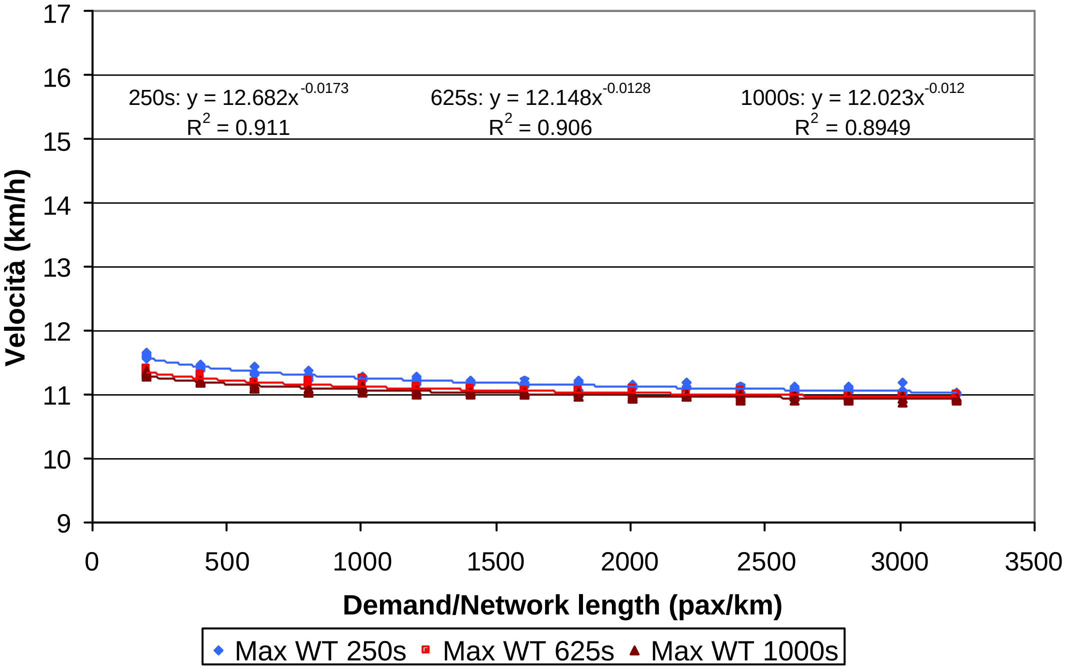

Figure A1.37 Commercial speed with 4-place vehicles and 15 km/h maximum speed

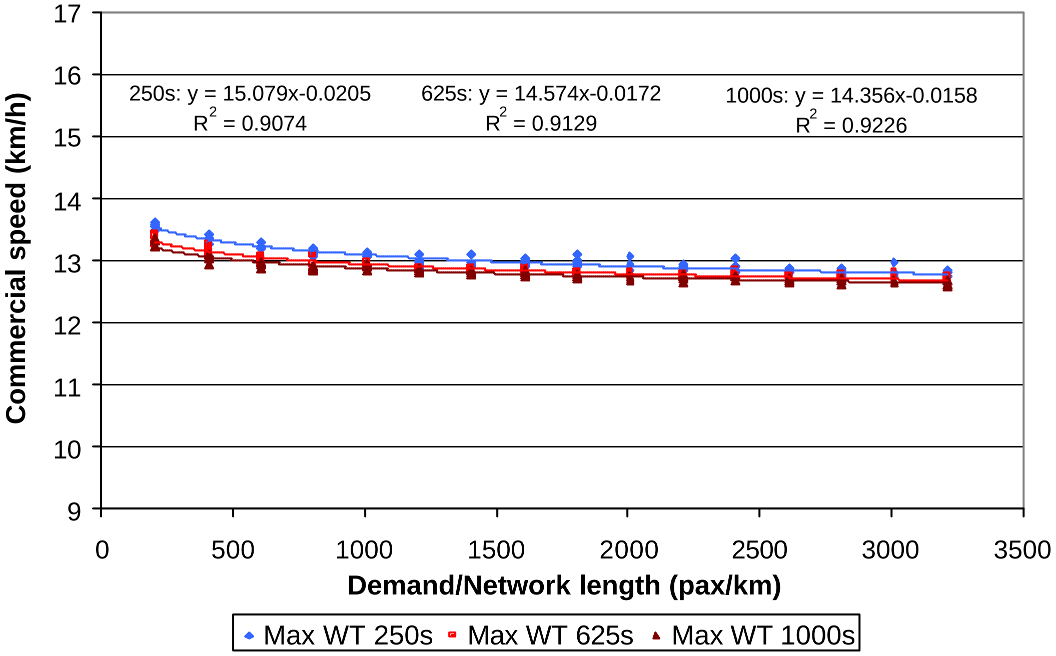

Figure A1.38 Commercial speed with 4-place vehicles and 20 km/h maximum speed

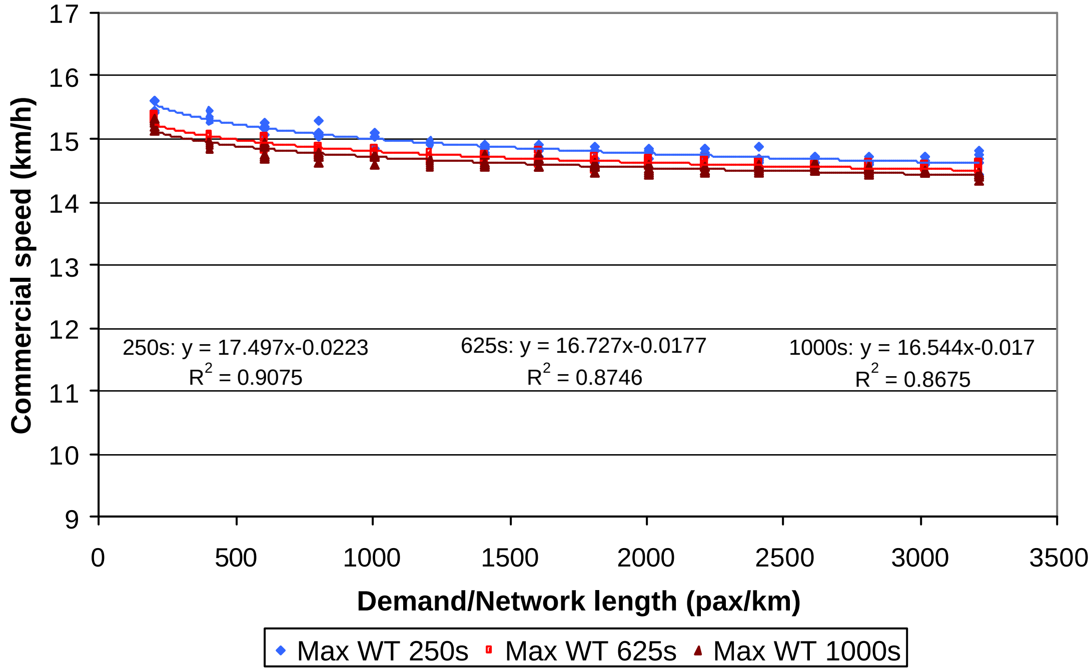

Figure A1.39 Commercial speed with 4-place vehicles and 25 km/h maximum speed

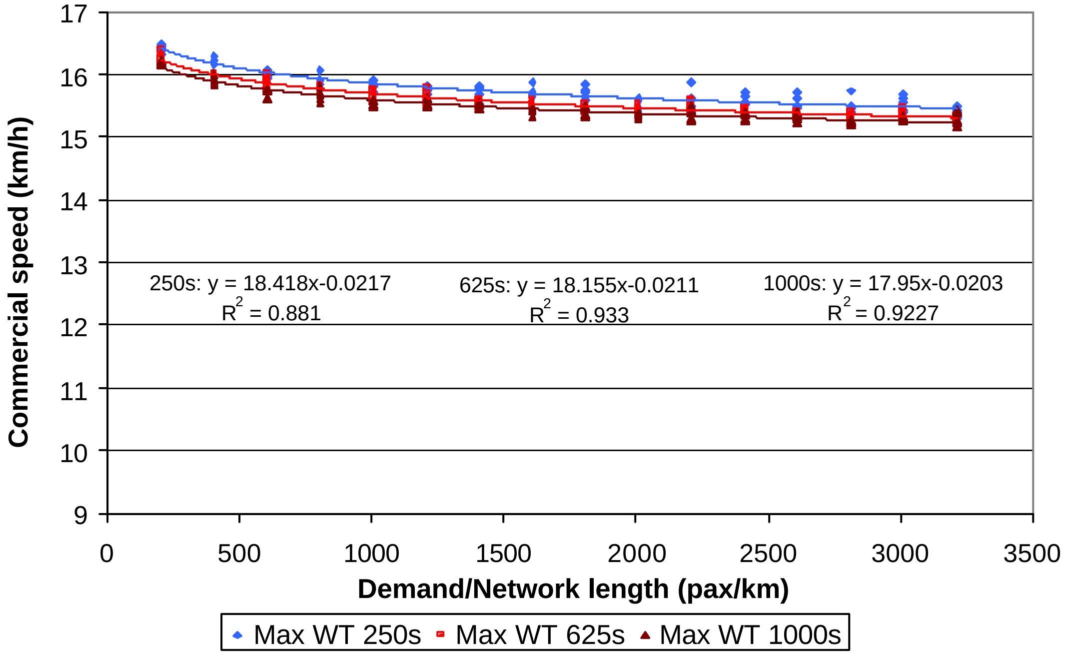

Figure A1.40 Commercial speed with 4-place vehicles and 30 km/h maximum speed

Differently from 4-place vehicles, for 10-place vehicles both level of service and maximum speed influenced the correlation coefficient of the formulas provided, as it can be seen by looking at Figure A1.41, Figure A1.42, Figure A1.43 and Figure A1.44.

The best results were provided for 250 s maximum waiting time: R^2 varied from 0.92 to 0.94, meaning that the high level of service required “obliged” the vehicles to have similar commercial speeds for each list of calls. For 625 s R^2 varied from 0.86 to 0.94 and for 1000 s from 0.84 to 0.94. Furthermore, considering the R^2 trends for each maximum speed, 30 km/h was that with the higher "performances": R^2 is 0.94 for each level of service.

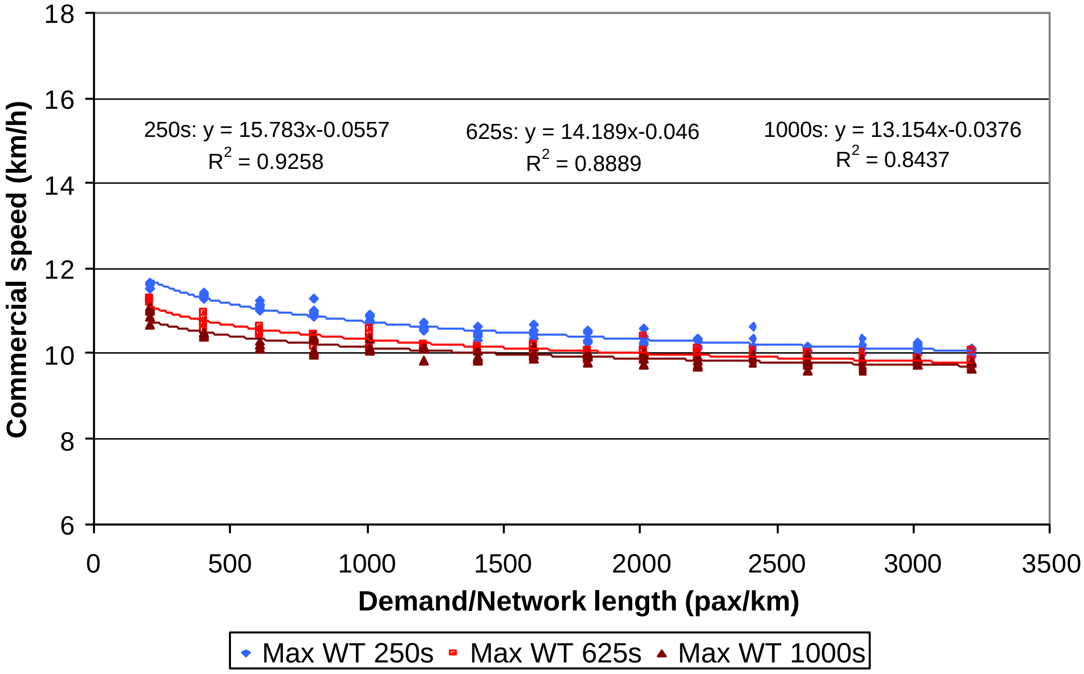

Figure A1.41 Commercial speed with 10-place vehicles and 15 km/h maximum speed

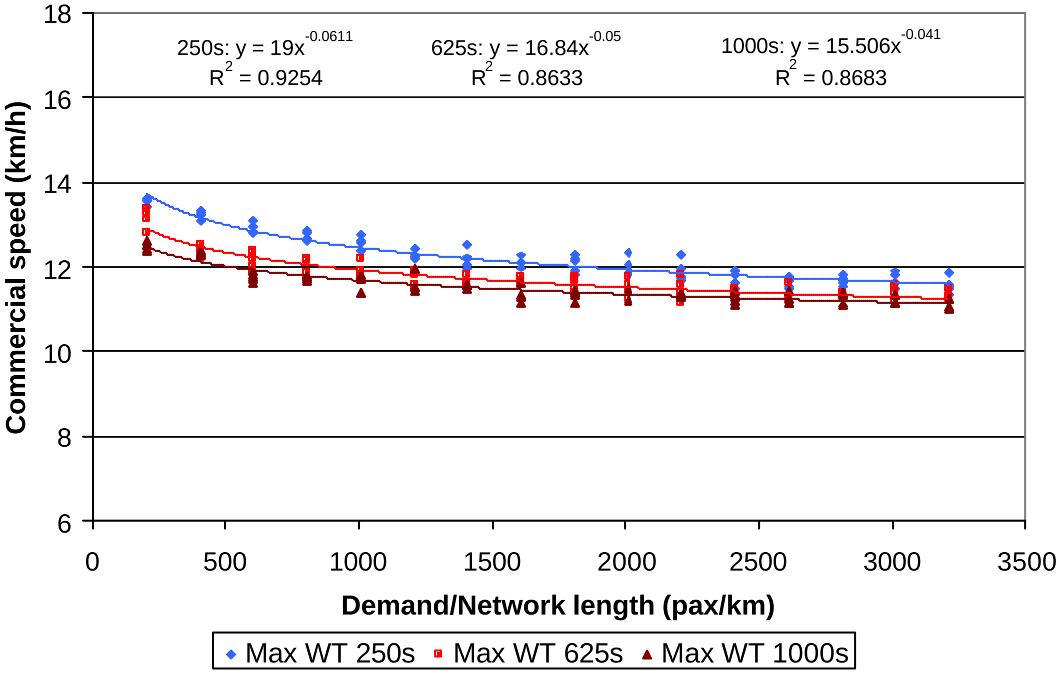

Figure A1.42 Commercial speed with 10-place vehicles and 20 km/h maximum speed

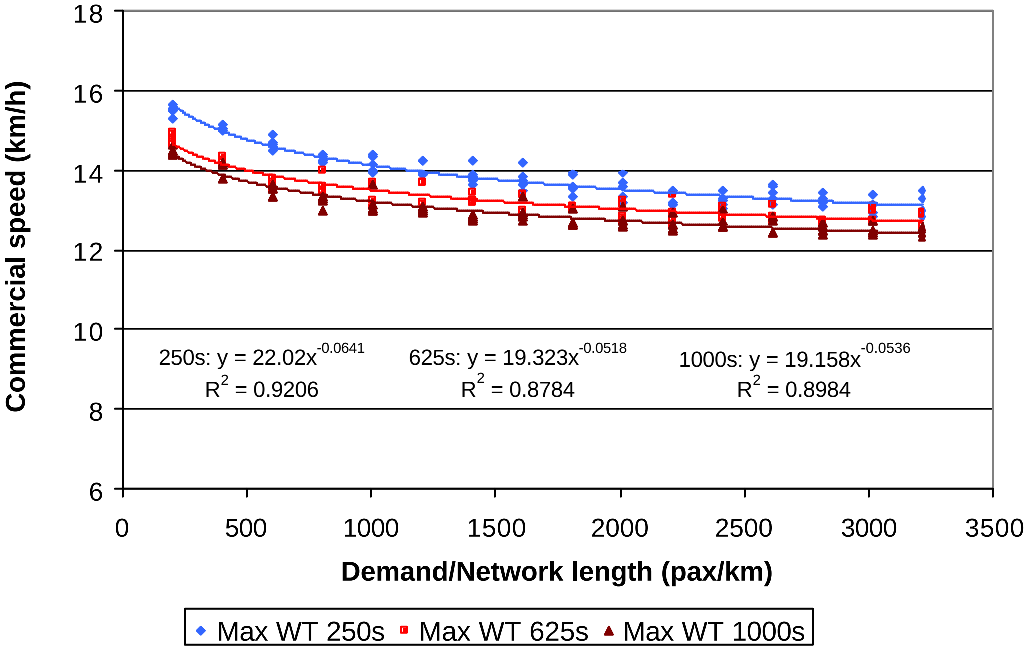

Figure A1.43 Commercial speed with 10-place vehicles and 25 km/h maximum speed

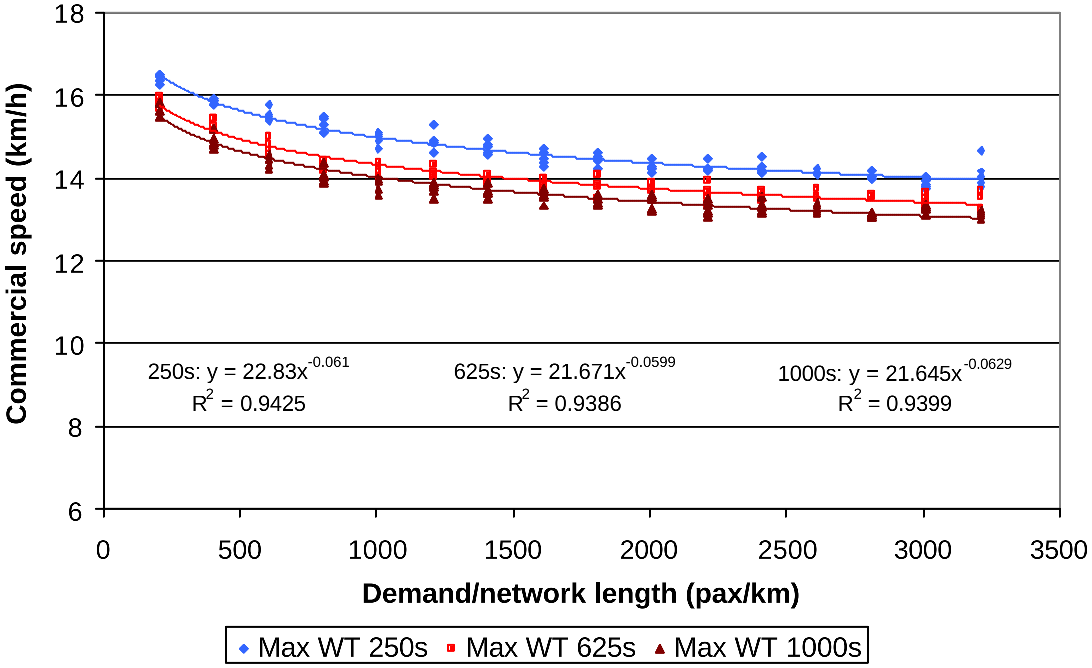

Figure A1.44 Commercial speed with 10-place vehicles and 30 km/h maximum speed

For 20-place vehicles the R^2 of the equations reported in Figure A1.45, Figure A1.46, Figure A1.47 and Figure A1.48 varied from 0.85 to 0.95. The best approximation was obtained for 25 km/h, where it went from 0.94 to 0.95.

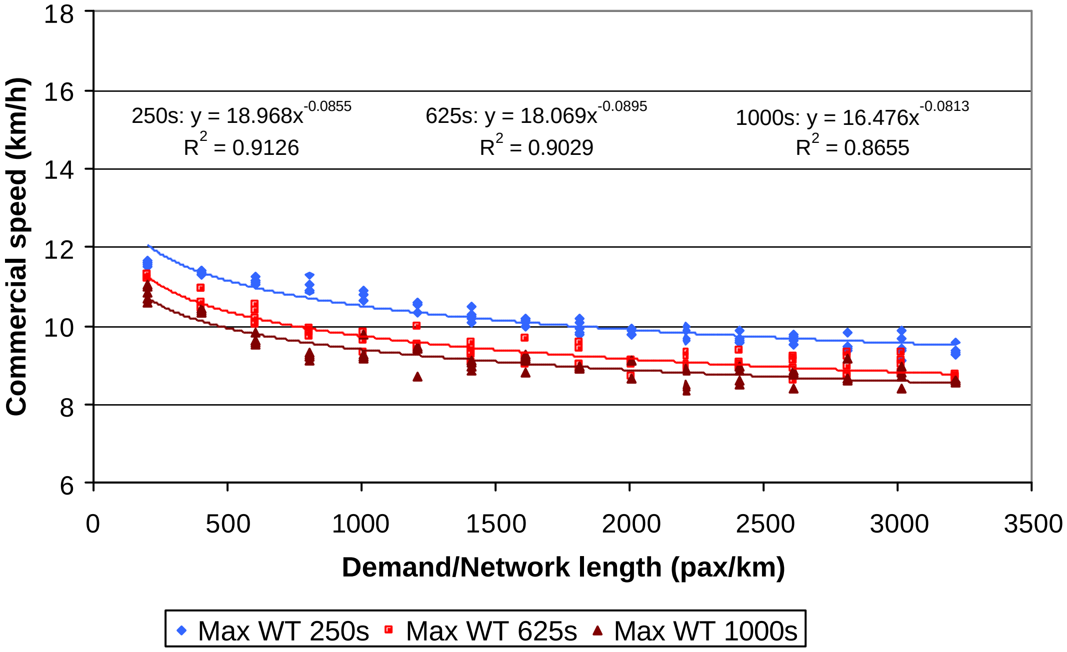

Figure A1.45 Commercial speed with 20-place vehicles and 15 km/h maximum speed

Concerning the level of service, with 1000 s maximum waiting time R^2 varied from 0.85 to 0.95, whereas for 250 s and 625 s the variations were smaller, being R^2 respectively between 0.89 and 0.95 and between 0.88 and 0.94.

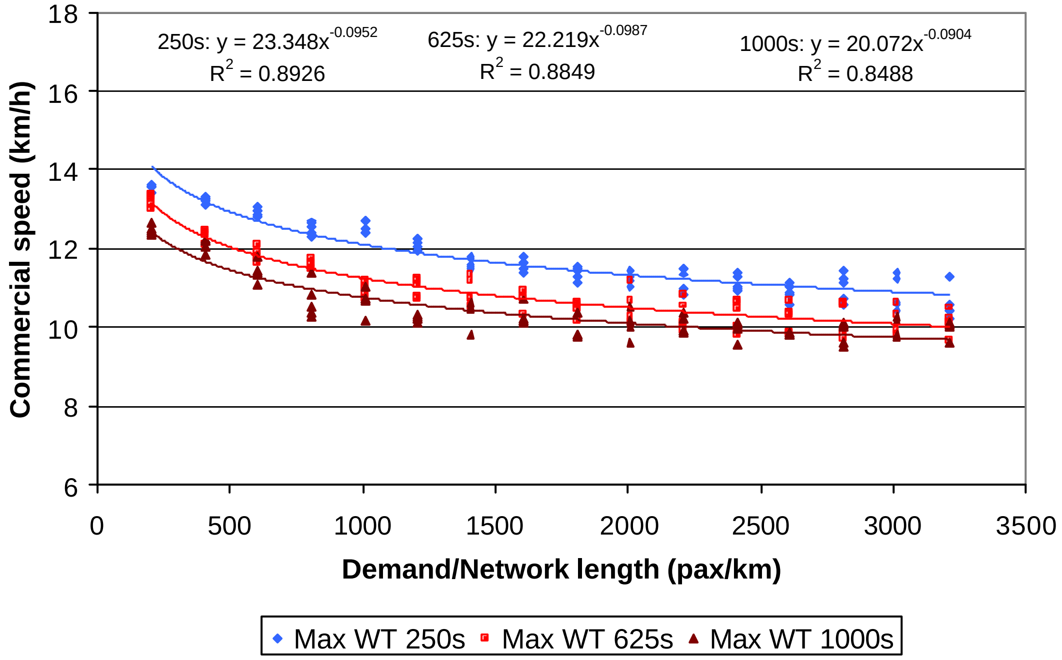

Figure A1.46 Commercial speed with 20-place vehicles and 20 km/h maximum speed

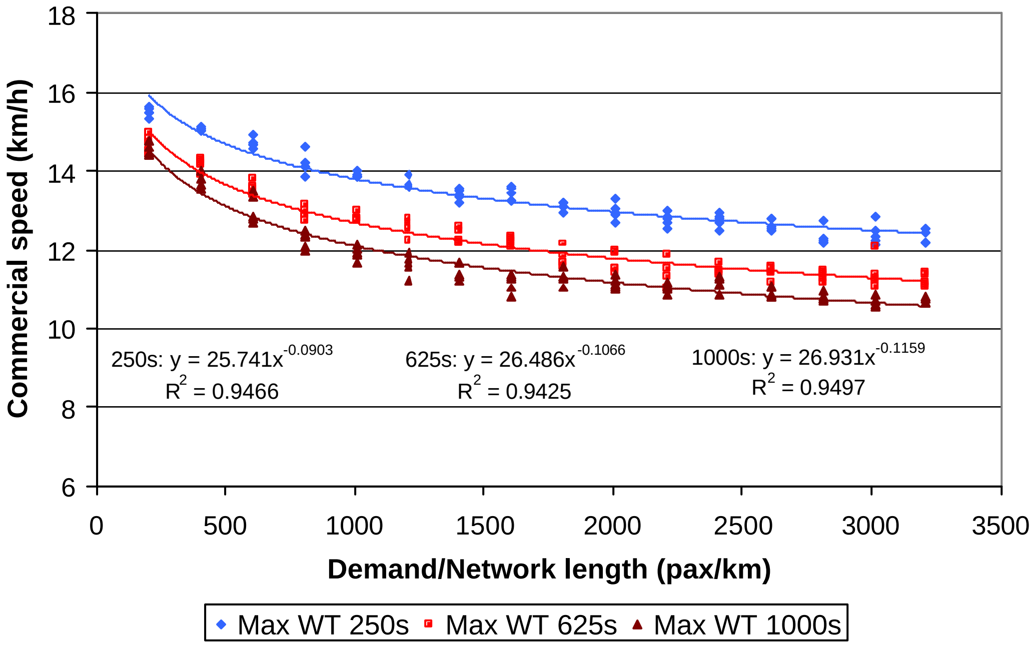

Figure A1.47 Commercial speed with 20-place vehicles and 25 km/h maximum speed

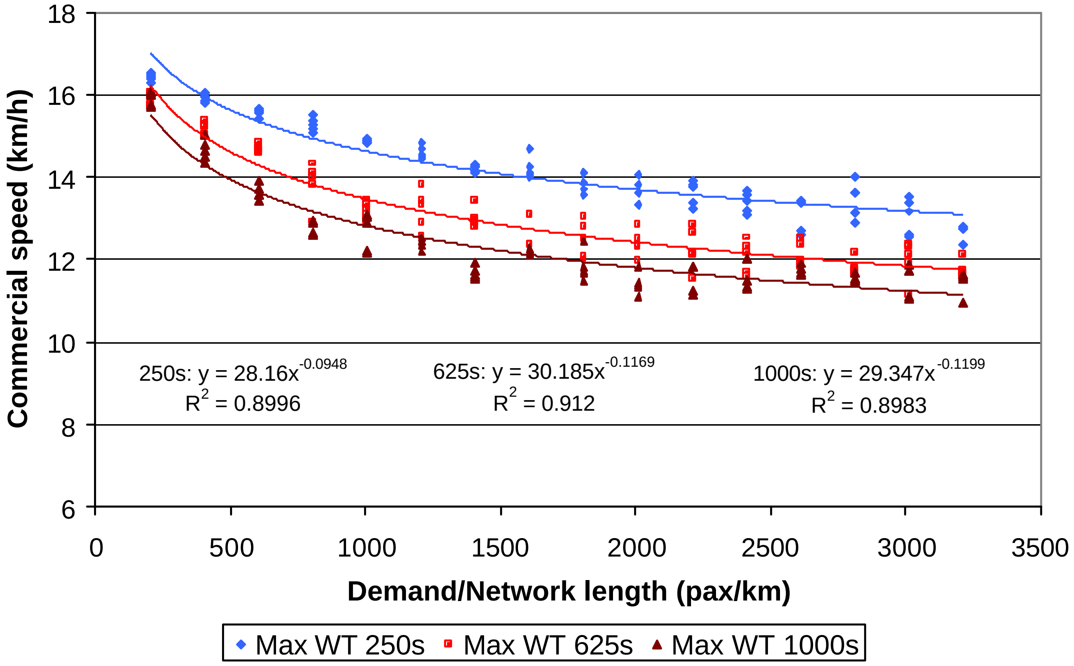

Figure A1.48 Commercial speed with 20-place vehicles and 30 km/h maximum speed

A1.5 Occupancy rate

Figure A1.49, Figure A1.50, Figure A1.51 and Figure A1.52 report, for a CTS with 4-place vehicles, the relationships between the vehicle occupancy rate and the ratio demand/number of vehicles for 15 km/h, 20 km/h, 25 km/h and 30 km/h maximum speed respectively, each one for the three levels of service.

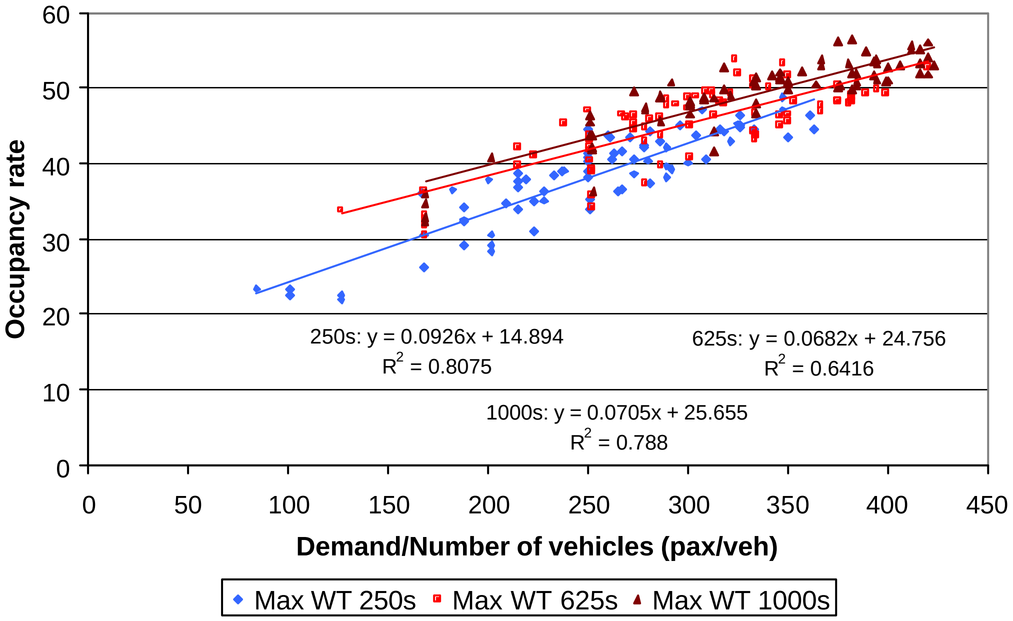

Figure A1.49 Occupancy rate with 4-place vehicles and 15 km/h maximum speed

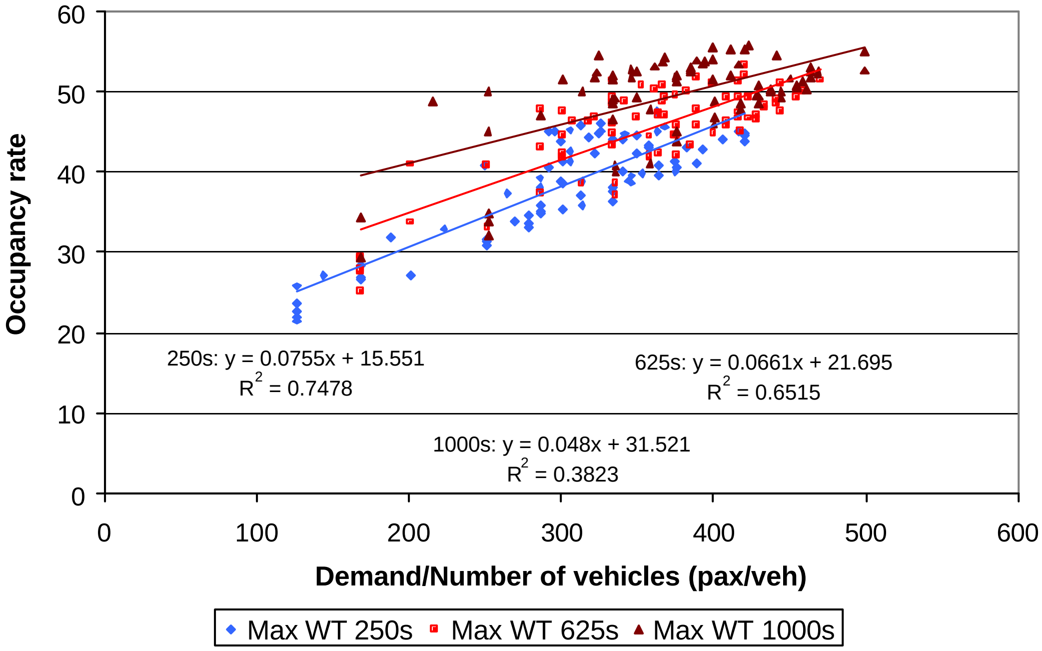

Figure A1.50 Occupancy rate with 4-place vehicles and 20 km/h maximum speed

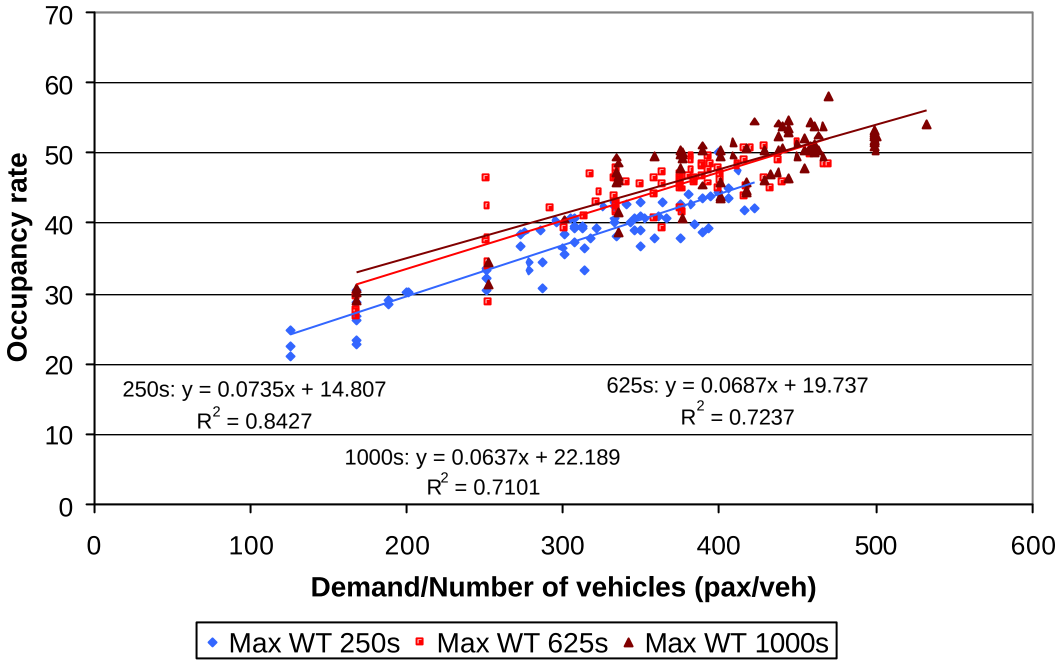

Figure A1.51 Occupancy rate with 4-place vehicles and 25 km/h maximum speed

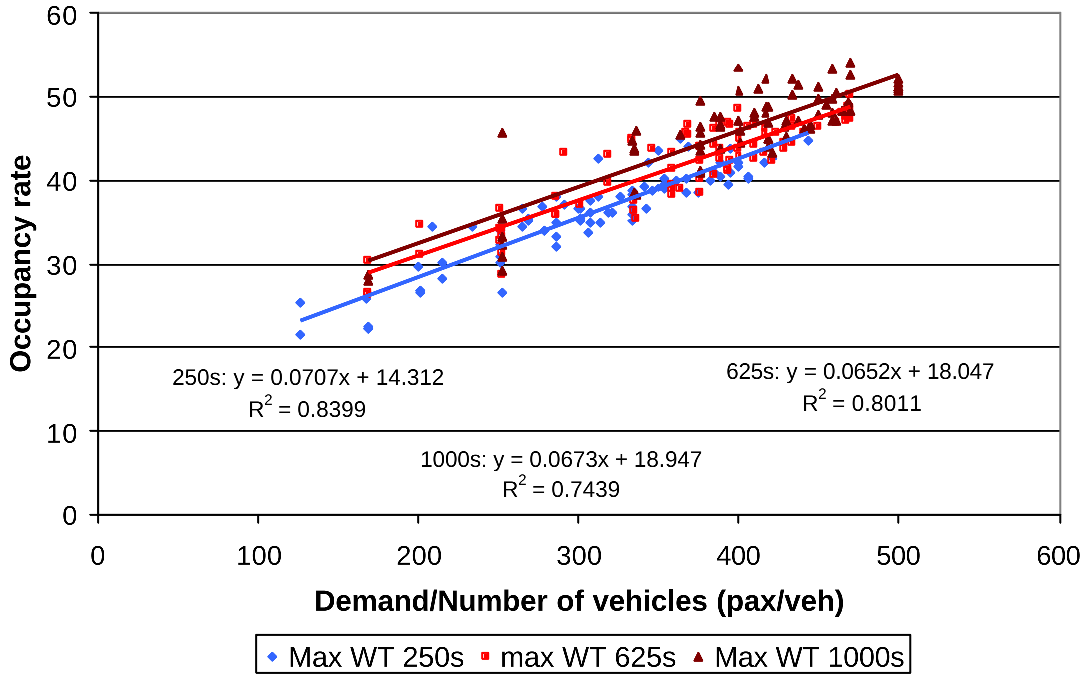

Figure A1.52 Occupancy rate with 4-place vehicles and 30 km/h maximum speed

The correlation was generally lower than those obtained for the previous steps. With the exceptions of 625 s maximum waiting time for 15 km/h and 20 km/h maximum speed, where R^2 was respectively 0.64 and 0.65, and 1000 s waiting time with 20 km/h maximum speed, where R^2 was very low, 0.38; all the other cases had R^2 varying from 0.71 to 0.84.

Figure A1.53, Figure A1.54, Figure A1.55 and Figure A1.56 represent, for a CTS with 10-place vehicles, the relationships between the occupancy rate of the vehicles and the ratio demand/number of vehicles for 15 km/h, 20 km/h, 25 km/h and 30 km/h maximum speed respectively, each one for the three levels of service.

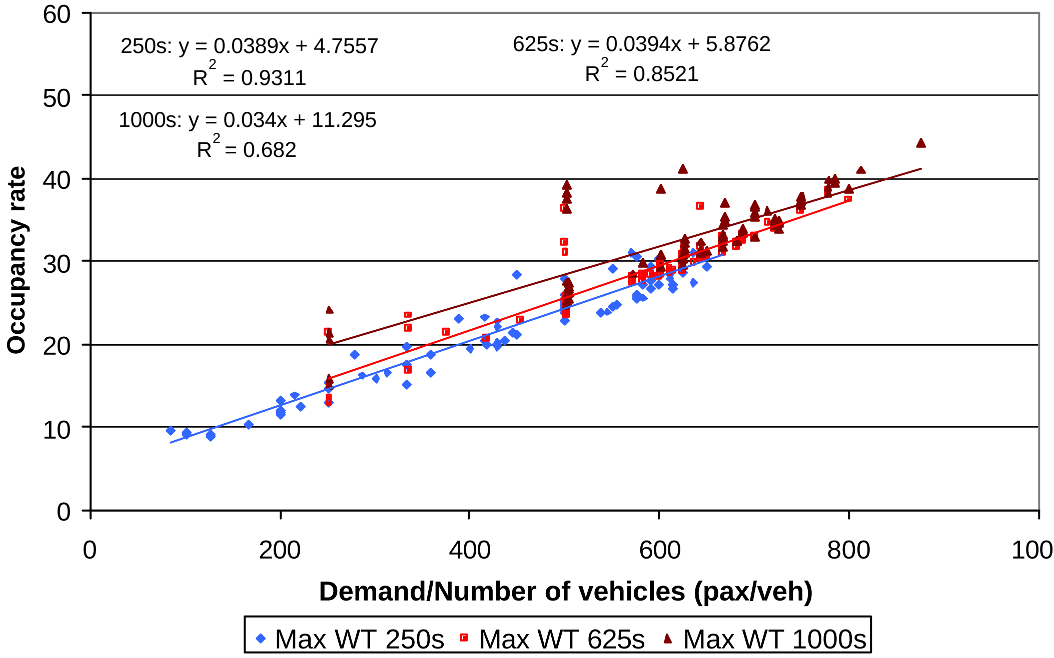

Figure A1.53 Occupancy rate with 10-place vehicles and 15 km/h maximum speed

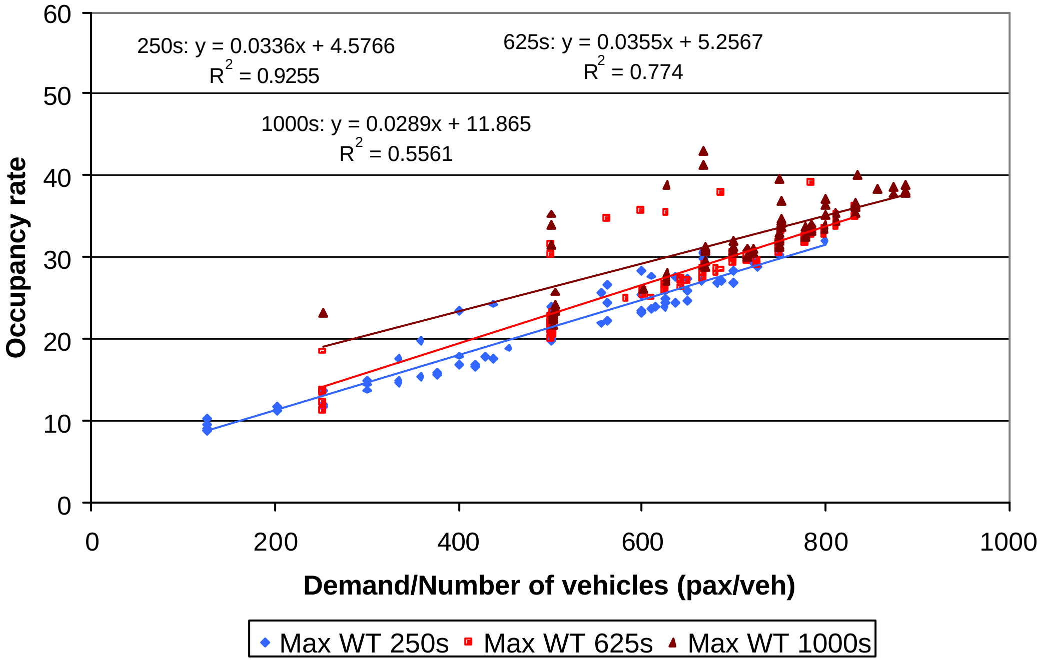

Figure A1.54 Occupancy rate with 10-place vehicles and 20 km/h maximum speed

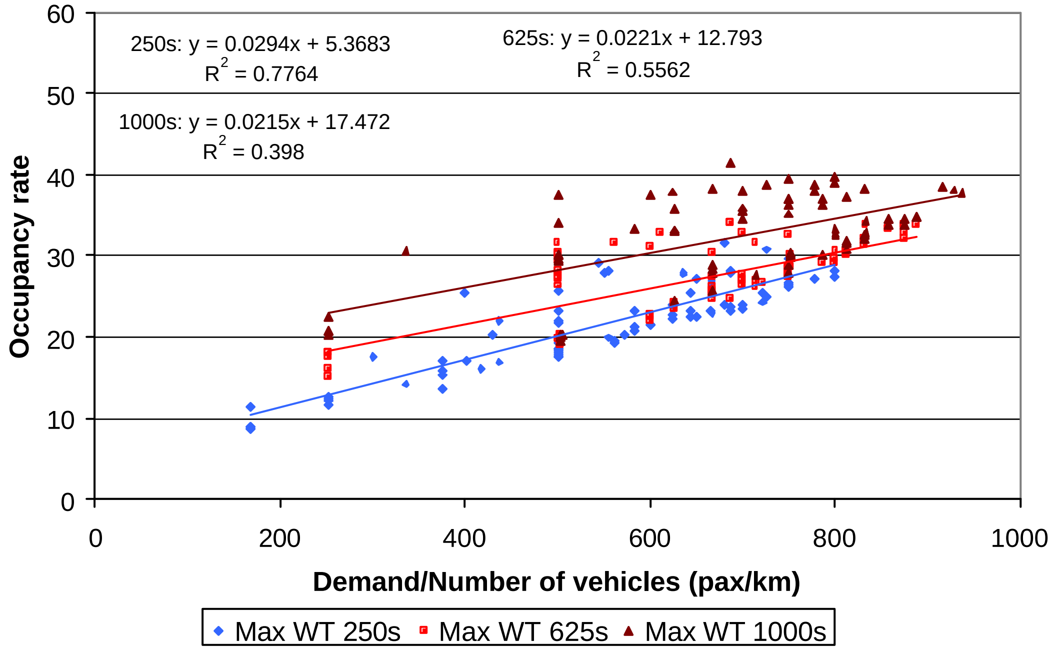

Figure A1.55 Occupancy rate with 10-place vehicles and 25 km/h maximum speed

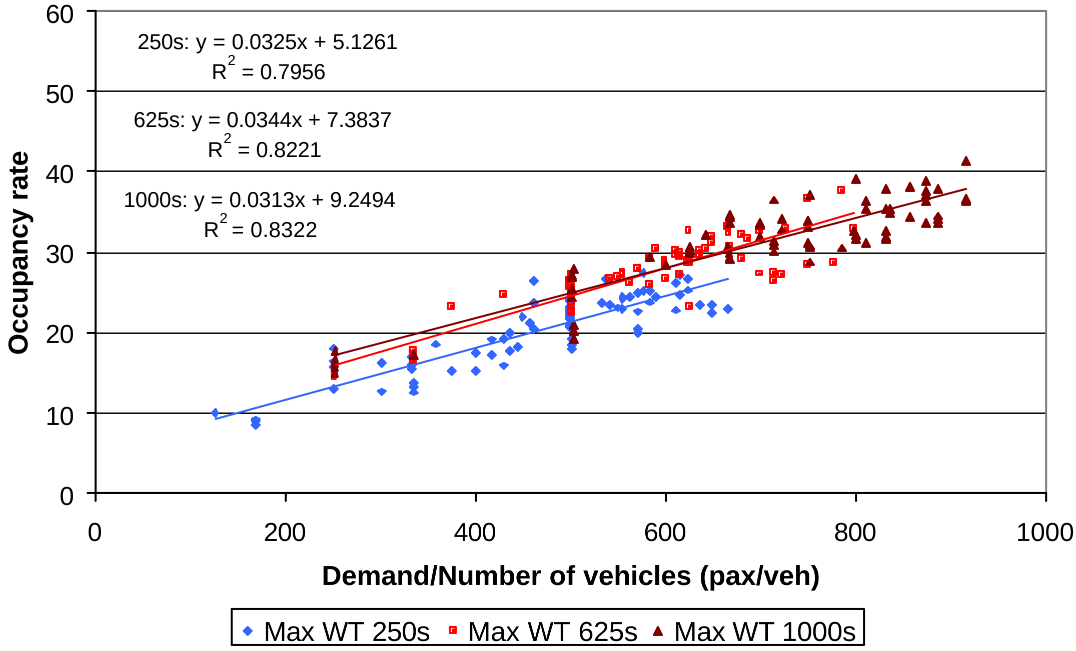

Figure A1.56 Occupancy rate with 10-place vehicles and 30 km/h maximum speed

As for 4-place vehicles, the coefficient R^2 varied in a big range, from 0.40 for 25 km/h maximum speed and 1000 s maximum waiting time to 0.93 both for 15 km/h and 20 km/h maximum speed and 250 s maximum waiting time.

This last was the level of service with the best approximation: R^2 varied between 0.78 and 0.93, whereas for 625 s it was between 0.56 and 0.85 and for 1000 s from 0.40 and 0.83.

In Figure A1.57, Figure A1.58, Figure A1.59, Figure A1.60 the same relationships are shown for 20-place vehicles.

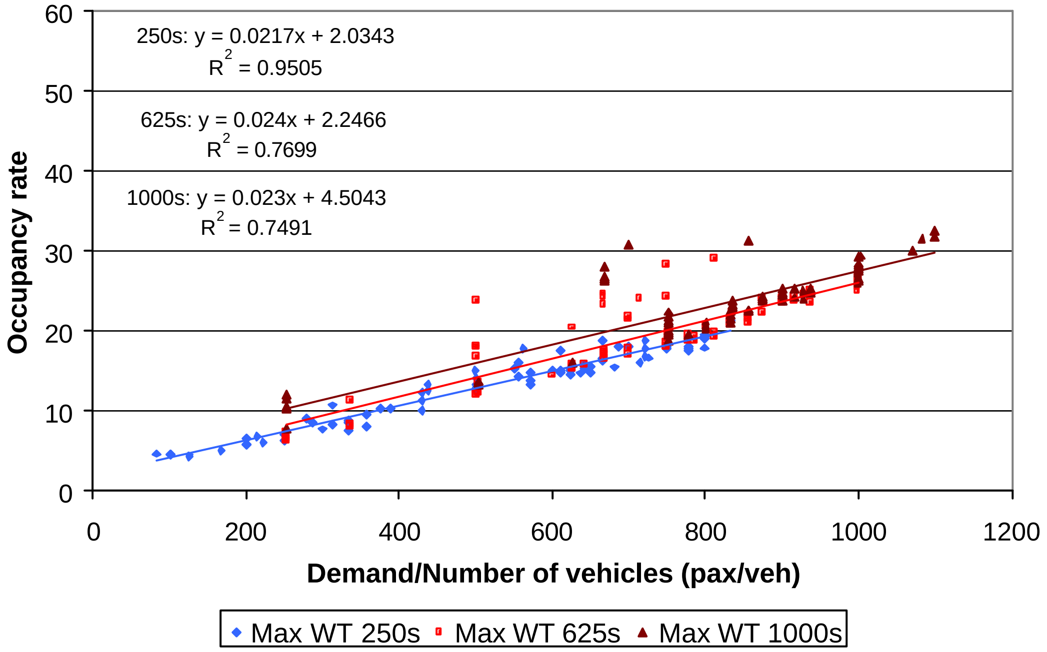

Figure A1.57 Occupancy rate with 20-place vehicles and 15 km/h maximum speed

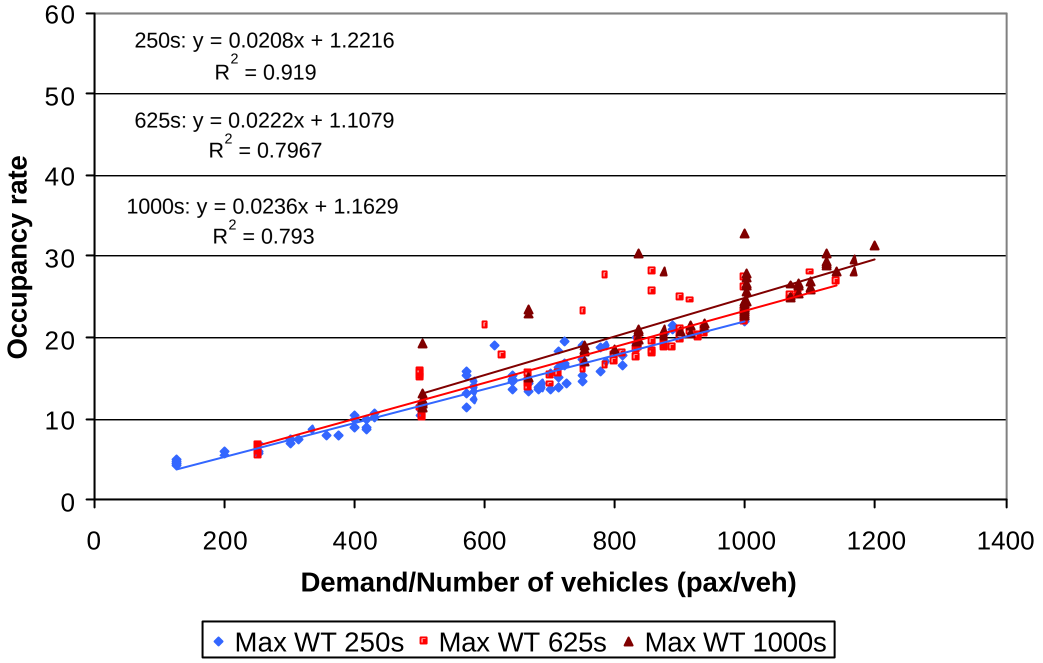

Figure A1.58 Occupancy rate with 20-place vehicles and 20 km/h maximum speed

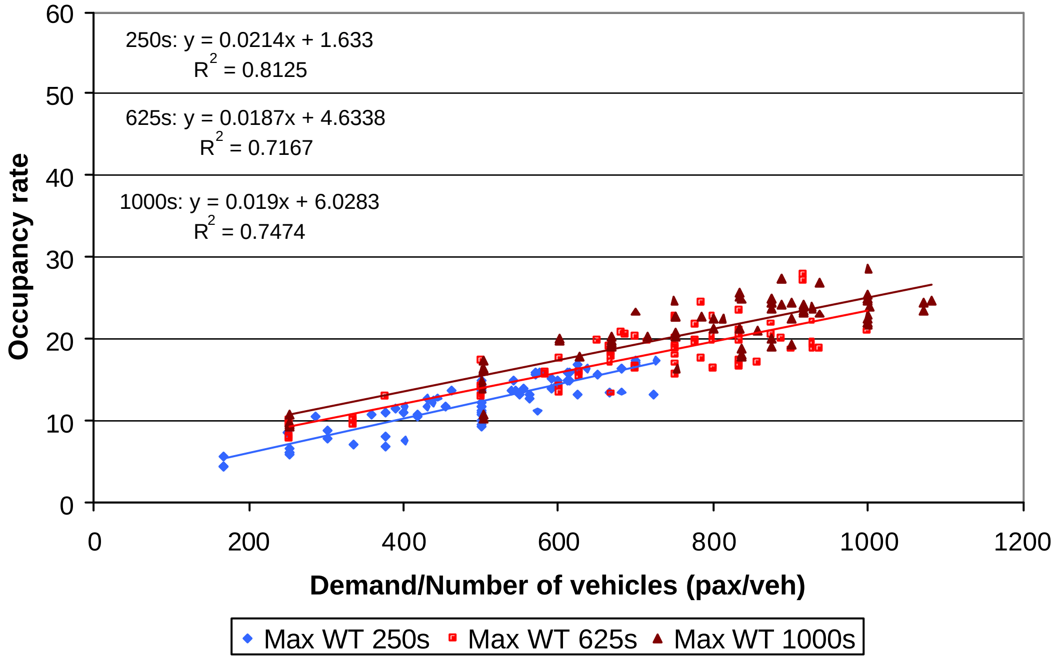

Figure A1.59 Occupancy rate with 20-place vehicles and 25 km/h maximum speed

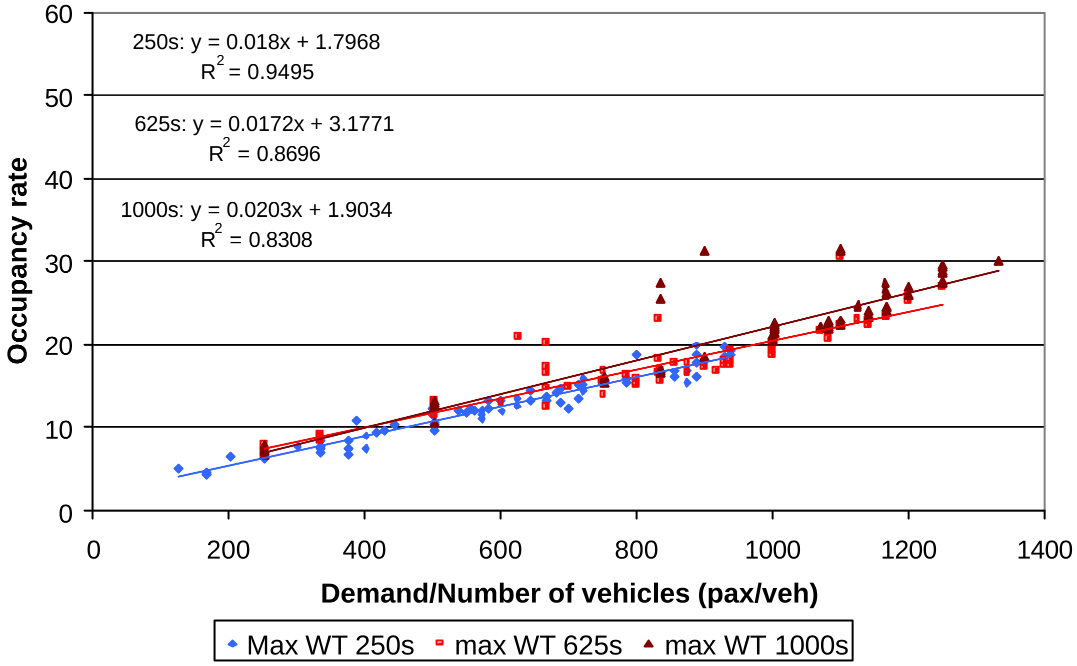

Figure A1.60 Occupancy rate with 20-place vehicles and 30 km/h maximum speed

Differently from 4-place and 10-place vehicles, the correlation coefficient was higher. The best results were provided for 250 s maximum waiting time, with R^2 varying from 0.81 to 0.95. For 625 s R^2 varied from 0.72 to 0.87, whereas for 1000 s it varied from 0.75 to 0.83.

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GLOSSARY

(P/D)	A pilot or demonstration (P/D) project is the innovative application and assessment under real life conditions of a transport system or systems.
Application	Particular CTS system to be implemented in a site within the project.
CTS	Cybernetic Transport System in CyberMove context refers to a transport system based on CyberCars.
Demonstration	Assessment under real life conditions of the particular application the project deals with.
Feasibility study	The “study” assessing technical and financial feasibility of a CTS application in a given site; in CyberMove framework someone of the sites will not carry on the project till the field trial but will use the experience gained by the other projects to forecast the impacts of a CTS application in the site.
Field trial	Field trials are demonstrative tests to ascertain whether or not a proposed application is worthy of full implementation. They will be required by public and regulatory bodies to ensure that proposed applications are safe, environmentally sound, and provide benefits to the public that outweigh their costs. They will also be required by manufacturers to demonstrate their products to the public and investors and to establish their likely profitability. One main requirement of a field trial is that it takes place in conditions that replicate, as far as is practicable, conditions that will be found in possible real implementations. It is the demonstration on field of the CTS application, from site selection to project design, conduction and final evaluation. The field trial verdicts are transferred to other sites willing to implement a system based on a CTS application.
Indicator	Indicator is the quantity to measure in evaluation. It can either be quantitative or qualitative. One or more of it are used to measure each impact.
MAESTRO	Monitoring, Assessment and Evaluation Scheme for Transport Policy Options in Europe. MAESTRO is a European Commission strategic initiative addressing the evaluation of transport pilot and demonstration projects. The central purpose of MAESTRO is to aid decision-making by providing a practical manual for the selection, design and evaluation of pilot and demonstration projects (referred to as P/D projects).
Objectives	The set of goals the project wishes to achieve within CyberMove framework.

Problems	All transport policy issues that motivated CyberMove proposal and motivated the single site to promote a CTS application project within CyberMove framework.
Project	In the context of these guidelines the word project is used to address the site CTS application study, implementation and run; unless otherwise specified.
Site	A city, zone or a generic facility involved in transport issues in which a transport problem is identified and proposed to solve running a field-trial for a CTS application.
Site objective	The particular aim of the project related with the site.
Site responsible partner	The CyberMove consortium partner having the role of finding a site, establishing and managing contacts, reporting about the project.
System	The Cybernetic Transport System implemented in the specific site