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CityMobil

Towards advanced transport for the urban environment

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Executive Summary

The global objective of the CityMobil project is to achieve a more effective organisation of urban transport, resulting in a more rational use of motorised traffic with less congestion and pollution, safer driving, a higher quality of living and an enhanced integration with spatial development. For this aim, four different technologies are tested and evaluated in the project: Personal Rapid Transit (PRT), CyberCars (CC), High Tech Buses (HTB), and Dual-mode Vehicles (DMV).

This deliverable is the third deliverable of the workpackage 5.3 (included in the Sub-project 5, named Evaluation) of the project, which concerns the evaluation of the case studies of the project. This deliverable reports the ex-ante evaluation of the Uppsala case study (a PRT system for the Bolanderna district of the Swedish city of Uppsala) and the comparison with the case studies previously evaluated in the deliverable 5.3.1b.

It is made of five sections, including the first introductive section.

The second section reports a brief description of the Uppsala case study, showing the main features of the city of Uppsala, the area in which the system was studied (named Bolanderna), and the system itself. The Bolanderna district main activities are shopping, small industries, warehouses and offices. About 9 500 people work at the moment inside Bolanderna, and about 25 000 people per day are estimated to be attracted in the only shopping area. Such last figure has been estimated to grow up to 40 000 people per day in 2020, due to the foreseen shopping area enlargement.

On the basis of such figures, the main PRT network features are:

- 9.4 km of tracks (11 km including the station tracks)
- 16 stations on the main network (18 in total)
- 130 vehicles for 4 sitting passengers
- 36 km/h as average speed (45 km/h on the straight segments)
- 400-600 m between the stations
- 300 m of walking distance to the station (at the most).

The PRT network is aimed at replacing the local bus network within the Boländerna district and to be operating in 2020.

The third and the fourth sections are the core sections of the deliverable.

The evaluation of the Uppsala case study is reported in the third section. The case study was simulated through PRTsim, an advanced micro-simulation model especially designed to handle PRT networks and the demand and supply.

Six indicators were collected through the simulations performed: number of passenger trips, modal share, non-car modal share, number of accidents, capital costs, Business Case Result (BCR).

The PRT vehicles circulating on the network provide about 36 000 daily passenger trips (3 800 of them in the peak hour) and about 36 500 daily passenger·km travelled. The consequent PRT modal share in Bolanderna is 20%. 25% is the slow modes (walk/bike) modal share, and 55% the car modal share, thus providing 45% (20% PRT plus 25% slow modes) as non-car modal share. A reduction of 8000 car trips per day in 2020 is foreseen due to the introduction of the PRT system instead of the bus system. Considering 3.1 km as average car trip length, an average load factor of 1.7 passengers per car, and 0.36 accidents per one million car vehicle·kilometres, the car trips reduction foreseen means a 21% reduction (from 11.1 to 8.7) of the annual accidents due to the PRT introduction.

The capital costs were estimated on the basis of previous PRT experiences and were provided in a range, considering three scenarios: low costs, high costs and average costs, this last obtained as the average value of low and high costs. Such values are: 68 millions € as low capital costs, 85 millions € as high, and about 76 millions € as average. The BCR provided is positive, 1.29, according to the present values of the costs and the benefits calculated.

In the fourth section the cross-comparison between the Uppsala case study and the Trondheim case study is reported. Such comparison was done because of the similar features of the cities of Uppsala and Trondheim and of the two PRTs studied. The Trondheim case study was simulated in two scenarios, actual (year 2010) and future (year 2035), whereas the Uppsala scenarios were referred to 2020.

The number of daily trips were similar in the peak hour for Uppsala (3 800 trips) and for the actual Trondheim scenario (4 200 trips in the year 2010). In the future Trondheim scenario, such value grows to 5 500. During the entire day the Uppsala PRT passengers calculated are about 36 000, whereas in Trondheim they are about 73 000 in 2010 and about 82 000 in 2035.

The modal share foreseen for Uppsala is 20% in 2020 and for Trondheim 27% both in 2010 and in 2035. The difference between the two case studies can be considered as directly linked with the modal shares of the modes of transport different from PRT, mainly for the car modal share (55% in Uppsala and 30% in Trondheim after the PRT introduction).

The non-car modal shares are different for the two case studies. In Uppsala its value is 45%, while in Trondheim such value is 70% in 2010 and 2035. It seems to be due to the different use of car and slow modes, with Uppsala needing further measures to push people not to use their private cars.

No comparisons can be made between the two case studies with regards to the number of accidents.

The capital costs were similar for the two case studies. In Uppsala the costs assumed as real were those of the low cost scenario, 68 millions €, whereas in Trondheim the costs are little higher, 76 millions €.

The Business Case Result (BCR) of the Uppsala case study provided positive value, 1.29. The Trondheim value was higher, 2.30, meaning higher benefits for the system.

The fifth section of the deliverable reports the fifth release of the Passenger Application Matrix, filled with the locally focused evaluations of the entire Sub-Project 5, made of demonstrations, showcases and case studies, and the main findings of the cross-comparison between Uppsala and Trondheim, inserted in three cells of the matrix (trips from city centre to city centre, from city centre to inner suburbs and vice-versa, and from inner suburbs to inner suburbs).

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First update on the evaluation report for the ex-ante study (focus on Uppsala)

1 Introduction

The objective of Work Package 5.3 is to evaluate the extent to which a city-wide implementation of advanced transport systems (ATS) contributes to the development of sustainable urban transport.

The technologies (Cyber Cars, PRT, High-tech bus and Dual Mode Vehicles), passenger application scenarios (Inner City Cyber Cars, PT Feeder Cyber Cars, High-Tech Bus and Dual Mode Vehicles), context scenarios (Do nothing, Medium and High Growth with and without complementary measures), indicators, evaluation process and tools (MARS modelling, Business Case analysis, Multi-Criteria Analysis), and the Passenger Application Matrix (PAM) tool were illustrated in the deliverable 5.3.1a. The evaluations of four case studies (Gateshead, Madrid, Trondheim, Vienna), the cross-comparisons between the evaluation results, their insertion in the Passenger Application Matrix, and the main findings on the benefits on the transport due to the Automatic Transport Systems adoption were reported in the deliverable 5.3.1b.

This deliverable reports the evaluation of the Uppsala case study, based on a PRT system for the district of Boländerna, inside Uppsala.

After a brief description of the city of Uppsala and the PRT system studied in section 2, the evaluation of the system is reported in section 3, according to the indicators chosen and used to perform the different ATS studies in the previous deliverables of WP 5.3 (D5.3.1a and D5.3.1b). Such indicators take into account transport patterns and sustainability aspects (social, environmental and economic), permitting to perform a satisfactorily exhaustive analysis of the performances of the ATSs.

The cross-comparison between the results of the Uppsala case study and those provided by the previous evaluated case studies (Gateshead, Madrid, Trondheim and Vienna in D5.3.1b) is reported in the fourth section of this deliverable.

The final step of the evaluation process will consist in integrating the analysis reported in this deliverable with the experience from the on-going demonstrations, and produce a generalised evaluation of the extent to which ATS contribute to make urban transport sustainable, and provide a road map for their gradual adoption and implementation in urban environments (WP 5.4). The tool used to this aim is the Passenger Application Matrix, filled with the results of demonstrations, showcases and case studies of the CityMobil project, and updated with the new evaluations during the project. The fifth section of this deliverable reports the fifth release of the Passenger Application Matrix.

2 Brief description of the Uppsala case study

This section reports a brief description of the PRT case study of Uppsala, reporting the main features of the city, the area in which the system was studied for, and the system itself. The complete and more detailed description of them is reported in the deliverable 1.5.6.2 "Report on the Uppsala Boländerna PRT feasibility study.

Uppsala is Sweden's fourth largest city with 119 000 inhabitants. It is situated in the Stockholm-Mälar region, the most prosperous and densely populated part of Sweden, a region with 3.0 million inhabitants. Travel between Uppsala and important international trade centres is fast and easy and the ride from the International Airport into the city centre of Uppsala takes 20 minutes.

The industrial town lost most of its manufacturing industries during the 1970s and 1980s, and the fastest growth since then has taken place in the knowledge-intensive sectors, first and foremost in Life Sciences. One example of this change is the Boländerna district which now is in rapid change from an industrial site into a shopping area and into an area for advance biotech industries.

Every day over 350 000 trips are made in the City of Uppsala (year 2005). This equals to about 3 trips per inhabitant and day. The trips are divided on the transport modes with a pedestrian share of 19%, a bicycle share of 27%, a bus share of 11% and a car share of 40%. The remaining 3% for example include the train share. The total market share for public transport in the three statistic areas that are covered by the PRT network at Boländerna is 6%, a decrease with 2 percentage units from the year 2000.

The public transit share in the County of Uppsala (passenger-kilometres) is 12% (year 2007).

The main activities in the Boländerna area are shopping, small industries, warehouses and offices. There are about 9 500 people working in the area but almost no people living there. The adjacent areas Fyrislund and Kungsängen have a similar structure with a number of workplaces but very few inhabitants.

There are a large number of shops within the area, for example IKEA, and these shops are mainly concentrated to the east part of the area. The total shopping area is estimated to 60 000 square metres. This in turn is estimated to attract about 25 000 persons per day. The planned changes for the Boländerna are devoted to an expansion of the present shopping area. The total shopping area is estimated to total to 100 000 square metres in the year 2020. This in turn is estimated to attract about 40 000 persons per day. The increase is 60%.

Figure 1 illustrates a proposed PRT network for Boländerna. The network includes 9.4 km of single track and 16-18 stations.

The proposed PRT network is mainly a single track system with elevated guideways completely separated from other traffic. Where the guideways cross busy roads a free height of 5.1 meters is needed but on other sections 2.7 metres is sufficient. On a few locations it is possible to place the guideways and stations on ground level but then a protective fencing is needed.

The single track system results in some detours but is still acceptable considering the high and even speed (average speed 36 km/h) during the entire trip. Compared to a double track system a larger area can be reached using the same length of total guideways. All the stations are placed on separated tracks and hence passing vehicles do not have to stop. The proposed PRT network has 16 stations on the main network and another two in the adjacent area Fyrislund.

The distance between the stations is 400-600 metres and the walking distance to the stations are 300 metres at the most.

Elevated guideways and stops consume a minimum of space on the ground. Load-bearing posts of about 50 cm in diameter are placed at intervals of 15-20 metres. The detached stations will also need space for a staircase and a lift. For some of the stations it is instead possible to incorporate the stations into existing buildings.

The network has been placed on municipal land but it is possible to locate the stations on private property if the owners so wish. Our judgement is that this should be attractive for the owners of commercial properties in order to offer a high availability.

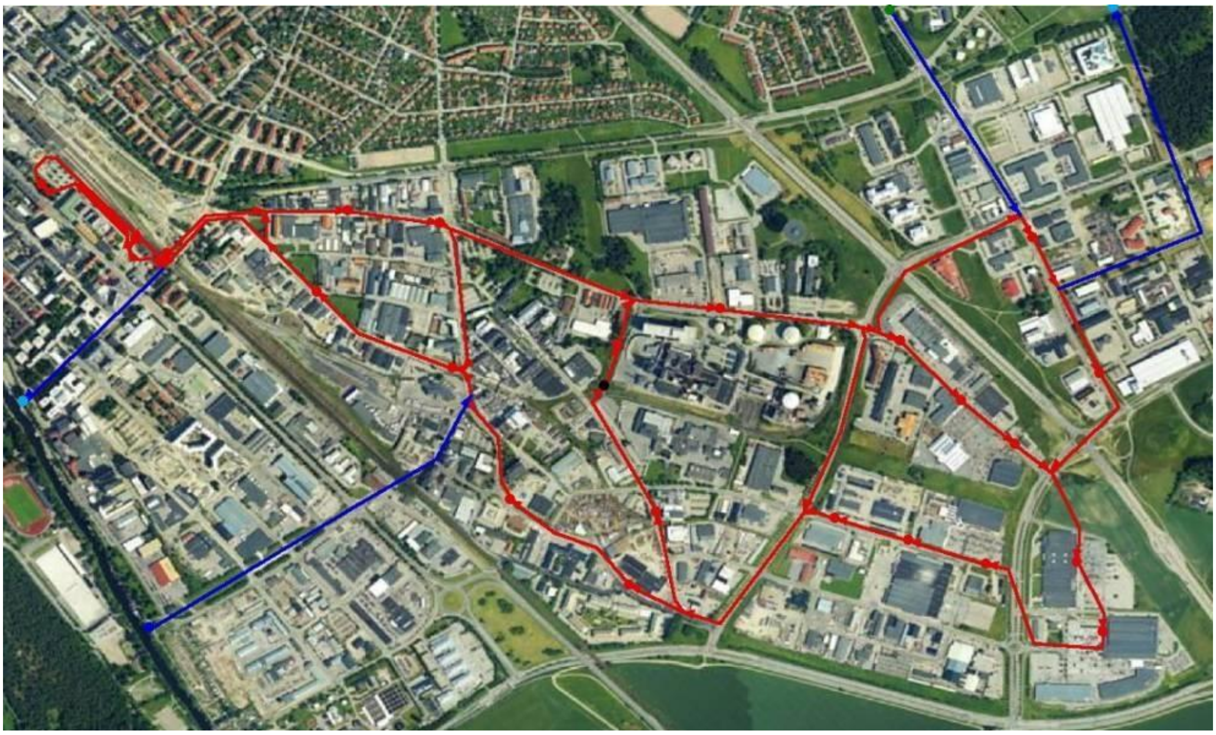

Figure 1 The Uppsala PRT network

The entire network is designed to have merge and diverge points on the same level, thereby eliminating the need for level crossings and high constructions.

The PRT network is designed for gradual extensions, primarily to the northeast and southwest. The control system is decentralized so that it does not restrict a later extension of the network.

There is also a possibility to condense the network within the growing shopping area so that the each shop can have a PRT station of their own (at their own expense). This does not increase the travel time for those already travelling with the system, since all the new stations are placed on separated tracks. A condensed network within the shopping area makes it easier to move from one shop to another, and this could reduce both the external and internal car use.

A summary of the proposed PRT network design:

- 9.4 km of tracks (11 km including the station tracks)
- 16 stations on the main network (18 in total)
- 130 vehicles each one with 4 places
- 36 km/h as average speed (45 km/h on the straight segments)
- 400-600 m between the stations
- 300 m of walking distance to the station (at the most).

The PRT network is aimed at replacing the local bus network within the Boländerna area.

However, most existing bus lines also serve areas outside the Boländerna area.

According to those characteristics and to the zone the PRT network was designed for, the Uppsala case study has to be considered to cover trips from city centre to city centre, from inner suburbs to city centre and vice versa, and from inner suburbs to inner suburbs, as reported in section 5 in the Passenger Application Matrix.

3 Evaluation of the Uppsala case study

The Uppsala case study was simulated through PRTsim, an advanced micro-simulation model especially designed to handle PRT networks and the demand and supply. The first input is a PRT network designed with tracks, stations and merge/diverge point. Another type of input is a demand station-to-station matrix. The model simulates the route choice within the PRT network, the distribution of waiting and in-vehicle travel times, as well as the needed vehicle fleet, in order to fulfil goals of average or maximum waiting times. It also keeps track of vehicle movements and delays, and vehicle queuing at stations, and has algorithms for empty vehicle management. The model has been developed by Professor Ingmar Andréasson at LogistikCentrum, Sweden.

The indicators collected for the Uppsala case study, of those reported in D5.3.1b in section 3 Table 19, were:

- Number of trips
- Modal share
- Non-car modal share
- Number of accidents
- Capital costs
- Business Case Result (BCR)

Two further indicators were calculated other than those used to compare the previously simulated case studies: average waiting time and average journey time.

Number of trips

The PRT would serve the network with a pure PRT service, without intermediate stops. According to the simulations performed on the PRT network reported in the previous section 2, 130 PRT vehicles on the network provided 15 225 daily PRT trips, with an average trip length of 2.9 km and about 36 500 daily passenger·km travelled.

Each PRT vehicle makes between 5 and 6 missions per hour.

The PRT system carries more than 13 persons per vehicle·hour. More than 13 persons per vehicle per hour and 5-6 missions per vehicle per hour mean an average occupancy of 13:6 = more than 2 persons/vehicle, therefore 15 225 daily PRT trips mean about 36 000 daily passenger trips.

In the peak hour about 1 600 PRT trips were estimated, with an average occupancy of 2.4 passengers per vehicle. Such figures lead to more than 3 800 passengers trips in the peak hour. Furthermore during the peak hour the more congested link is served by 552 PRT vehicles (considering each vehicle passing in average more than 4 times for such link in the peak hour).

The average occupancies estimated are very high, both for the peak hour and the entire day, meaning in percentage a value of about 60%. This value can be obtained only if the PRT is used properly as a public transport system, with the stops close to the destinations of the trips and the passenger trips including intermediate stops. In such way it is possible to consider 60% of vehicle occupancy rate; otherwise considering a "pure" PRT service (each passenger trip going from origin to destination without intermediate stops), empty PRT trips have to be considered and consequently the average occupancy would decrease.

A possible solution to obtain such occupancy rate with a pure PRT service would be to increase the number of vehicle circulating on the network. Such solution would not be however suitable, because increasing the number of vehicle on the network could cause congestion and safety problems. According to the Uppsala study with an average speed of

36 km/h the time gap between two vehicles in the peak hour is about 6 seconds; increasing the number of vehicles such distance would decrease, resulting in a congested and unsafe situation on the network. This confirms that the figures about the average vehicle occupancy on the network can be reached only by shifting from the pure PRT service to the public transport PRT solution, as previously reported in this section.

The PRT in Uppsala aims at replacing the existing bus service. The present modal split in the area interested by the new PRT system, Bolanderna, is the following: Car 65%, Walk/Bike 30%, Bus 5%.

Modal share and non-car modal share

PRT aims at replacing the bus service and at the same time attracting some of people using the car, the bike and going on foot today. According to the simulation results, the modal split foreseen for 2020 with the introduction of the PRT system is: Car 55%, Walk/Bike 25%, PRT 20%. Such values were calculated directly with the simulation software used to study the PRT network. According to the results obtained, the car users decrease (-10%) as the walk/bike travellers do the same (-5%). It means that the PRT aims at completely replacing the bus service attracting its actual modal share of 5%, plus attracting 10% of people now using the private car and a further 5% of people now walking or using the bike to make their trips.

The consequent modal share indicator of the system is 20%, and the non-car modal share indicator is 45% (20% PRT and 25% Walk/Bike).

The improvement due to the replacement of the existing bus service with the studied PRT is shown also by the average waiting time and the average journey time calculated, respectively 1.7 minutes and 6.3 minutes. The correspondent times measured with the bus system are 7.5 minutes and 15.5 minutes. The PRT system would allow to reduce the average waiting time of 77%, and the journey time would decrease of 59%. The walking time would not change shifting from the bus to the PRT (5 minutes in average).

Number of accidents

According to the simulation results, a reduction of 8 000 car trips per day in 2020 is foreseen due to the introduction of the PRT system instead of the bus system. Considering 3.1 km as average car trip length, an average load factor of 1.7 passengers per car, and 0.36 accidents per one million car vehicle·kilometres, the car trips reduction foreseen means a reduction from 10.3 to 8.7 annual car accidents.

The accident risk for bus trips according to Danish studies was estimated as 0.19 accidents per million passenger·kilometres. Considering 4.2 millions of passenger·kilometres travelled by bus, further 0.8 annual accidents due to the use of bus would be avoided by introducing the PRT system.

The fatality risk for the PRT system in Uppsala has been verified by Vectus Intelligent Transport (the PRT provider for the Uppsala system - www.vectusprt.com) as 0.15 fatalities per billion passenger·kilometres. The 36 500 daily passenger·kilometres travelled by PRT mean 13.3 million per year, which would provide no accidents with the unit value of 0.15 fatalities per billion passenger·kilometres adopted (13.3 million passenger·kilometres mean $2 \cdot 10^{-3}$ accidents per year).

Considering such contributions to the accidents (car, bus and PRT), a 21% reduction of the annual accidents (from 11.1 to 8.7) is due to the PRT introduction.

Capital costs

With regards to the capital costs, they were estimated on the basis of previous PRT experiences, as reported in D1.5.6.2. The resulting capital costs were provided in a range, considering three scenarios: low costs, high costs and average costs, this last obtained as the average value of low and high costs. Such values were: 68 millions € as low capital costs, 85 millions € as high, and about 76 millions € as average.

The economic life spans considered are: 60 years for the guideway and the depot, 25 years for the stations, 15 years for the vehicles, which provide an annuity factor of 6.31%. From such figures, the annual calculated capital costs are 4.3 millions € in the low cost scenario, 4.8 millions € in the average, and 5.3 millions € in the high.

The operating costs were estimated without a range, and their value is 1.7 millions €/year. Considering the 13.3 millions of passenger·km travelled by PRT according to the calculations done, the operating costs correspond to about 0.13 €/pax·km. According to the "Viability of Personal Rapid Transit in New Jersey - Final Report" and the Stockholm Transit Data the average operating costs for a PRT vary from 0.11 to 0.39 €/pax·km, with an average value of 0.19 €/pax·km. This means that the operating costs estimated for Uppsala are lower than the average ones and the simulated PRT could be maintained without high annual costs.

Business Case Result

The benefits were calculated in the same three scenarios considered for the capital costs, but for all of them the calculated value was 10.6 millions of €.

They are made of: travel time gain (51% of the total benefit value), comfort gain (23%), ticket revenue (20%), traffic safety gain (4%), and environmental gain (2%).

The travel time gain is made of the time saved by using the PRT instead of the bus. The total travel time was considered made of three terms: walking time, waiting time, and in-vehicle time. The travel time was calculated for an "average travel" in Bolanderna, from the most remote part of the district to the railway station, of about 4.8 km. The travel time measured for the bus was 38 minutes, whereas the travel time calculated for the PRT was 19 minutes. According to the composition of the trips in Uppsala, the travel time value was calculated to be 5.9€ per hour, thus the yearly travel time benefit shifting from bus to PRT (with 15 225 PRT trips per day) is 5.4 millions of €.

The comfort gain was calculated according to Swedish stated preference studies. With the ticket cost of 0.66€ adopted in Bolanderna, the consequent comfort value per trip on the basis of the mentioned studies is 72% of the ticket cost, meaning 0.48 €. Such value means 2.4 millions of € as correspondent yearly benefit.

The ticket revenue benefits were obtained directly from the number of daily trips calculated for the PRT (15 225) and provided by the bus (4 200). Considering the ticket cost of 0.66€ in Bolanderna (both for the bus and the PRT), the bus annual revenues are 0.85 millions of €, and the PRT annual revenues would be 3 millions €, meaning an annual benefit of 3-0.85 = 2.15 millions of €.

The traffic safety gain were calculated directly from the annual accident reduction (from 11.1 to 8.7 annual accidents) due to the PRT introduction. The road accident monetary value considered is 0.18 millions of € per accident, meaning 0.18·(11.1-8.7) = 0.4 millions of € as annual benefit.

Concerning the environmental gains, with 0.17 €/g as monetary value of CO_2 reduction the annual benefit for such reduction is about 0.2 millions of €.

Assuming 60-year economic life for fixed investment, an average annual traffic growth rate of 1% and 4% as discount rate, the costs estimated are 129 millions of € and the benefits 295 millions of € (both of them as present values). The consequent BCR calculated is (295 M€ - 129 M€)/129 M€ = 1.29.

4 Cross-comparisons between the Uppsala case study and the other case studies

Considering the four case studies reported in D5.3.1b (Gateshead, Madrid, Trondheim, Vienna) and the ATSs tested in them (PRT, Cybercars, High-Tech Buses, Dual-Mode Vehicles), the Uppsala case study has been compared to the city centre to city centre, inner suburbs to city centre, and inner suburbs to inner suburbs PRT applications of the Trondheim case study. Such comparison was done because of the similar features of the cities of Uppsala and Trondheim and of the PRT studied.

The first similar feature is the size of the two cities: both Uppsala and Trondheim can be included in the small/medium cities category (Uppsala has about 120 000 inhabitants, Trondheim about 150 000). Furthermore they are both Scandinavian cities, Uppsala belonging to Sweden and Trondheim belonging to Norway, and represent a similar environmental context.

The similarity between the PRT schemes designed for the two cities is the second feature which lead to compare such two case studies. The Trondheim PRT scheme presents the following characteristics:

- 18 km as network length
- 32 PRT stops on the network
- 40 km/h as average speed
- 4-place vehicles circulating on the network
- PRT system segregated from the other traffic

Even if the Trondheim network length is little less than two times the Uppsala one (18 km against 9.4 km), and consequently the number of stops in Trondheim are two times those of Uppsala (32 against 16), the average speeds of the vehicles are similar (40 km/h in Trondheim and 36 km/h in Uppsala), and the vehicle capacity is the same in the two case studies.

Although in Trondheim the conventional bus would not be replaced by the PRT as in Uppsala, such features allow to make a comparison between the two case studies.

Number of trips

For the Uppsala case study about 36 000 daily passengers trips were calculated, of which 3 800 in the peak hour.

In the Trondheim case study, considering the trips estimated for the year 2010, in the three scenarios considered the daily passengers travelled in the off-peak hours were about 69 000, and about 4 200 in the peak hours, meaning 73 200 total daily passengers travelled. Slight differences between the scenarios with and without complementary measures were calculated (about ±200 off-peak trips and ±50 peak trips).

Concerning the trips estimated for the year 2035, the off-peak hour passengers grow to about 82 000, while the peak hour ones are about 5 500. The differences between the scenarios with and without complementary measures are the same calculated for the year 2010.

Such figures report that although on the entire day the differences between the two networks are shown also in the number of trips (the Trondheim PRT in 2010 would provide a number of passengers two times larger than that calculated for Uppsala PRT in 2020), in the peak hour the number of passenger trips are similar in 2010, with a difference of about 10%, whereas in 2035 the difference grows to about 1 700 passengers.

However the Uppsala calculations were made considering the future scenario in the year 2020, whereas for the Trondheim case study the future scenario is the year 2035, and the different years of the future scenarios affects the differences between the two case studies. Considering the difference of 13 000 off-peak hour passengers between the 2010 and 2035 Trondheim scenarios, meaning an increase 520 passengers per year, in 2020 it can be considered that about 74 000 passengers would be travelled in the off peak hour. With the same calculations, about 4 700 passengers would be travelled in the peak hour, thus reducing the differences between the Uppsala scenario and the future Trondheim scenario.

Modal share

The introduction of the PRT in Uppsala leads to a modal shift with 55% of people using car, 25% using slow modes as bike or walk, and 20% using PRT. As reported in section 3, such situation means a decrease in car use of 10% and in slow modes of 5% if compared with the present situation. Such percentages will be attracted by the PRT, which will also serve the 5% of people previously using the bus PRT is going to substitute, thus resulting in 20% PRT modal share.

In Trondheim the modal share was evaluated both for the peak hour and the off-peak hour, at local level and area wide. The results were provided for the actual scenario (in year 2010) and for the future (year 2035), both with and without complementary measures. In all the three scenarios considered the trends of the modal shares were about the same.

Considering the local level evaluation, which is the kind of evaluation regarding also the Uppsala case study, the Trondheim results of the two scenarios were the same, thus both of them have been used to make the comparison with Uppsala.

In Trondheim the percentage of people using the PRT in the peak hour is between 10% and 11%, with a decrease of car usage between 3% and 4% and a decrease in slow mode usage of about 7%.

During the entire day, the percentage of people using PRT becomes about 27%. The car usage would be reduced of about 10%, resulting in a car modal share of about 30%, and the slow modes would be reduced of about 15%, resulting in a modal share of about 38%. The remaining 5% would be the bus modal share.

Such values are reported in Table 1, together with the corresponding values calculated for the Uppsala case study.

Table 1 Modal shares and variations in Uppsala and Trondheim

	UPPSALA (2020)		**TRONDHEIM (2010 and 2035)**	
Mode of transport	**Modal Shares after PRT introduction**	**Modal share variations due to PRT introduction**	**Modal Shares after PRT introduction**	**Modal share variations due to PRT introduction**
PRT	20%	+20%	27%	+27%
Car	55%	-10%	30%	-10%
Slow Modes	25%	-5%	38%	-15%
Bus	0%	-5%	5%	-2%

Considering the entire day, the car usage reduction is the same in Uppsala and Trondheim, whereas the higher Trondheim reduction in slow modes (three times the Uppsala one) contributes significantly to the highest PRT modal share (27% in Trondheim against 20% in Uppsala).

As reported in Table 1, in Uppsala people use the private car more than in Trondheim. Considering the modal shares before the PRT introduction, according to the figures of Table 1 in Uppsala 65% of people used the private car and 30% the slow modes (the remaining 5% used the bus), whereas in Trondheim 53% of people used the slow modes and 40% the private car (and the remaining 7% the bus). Thus even if the PRT introduction would produce the same car usage decrease in the two cities, in Uppsala the percentage of people using the car would be however more than half the population. Furthermore the total reduction of the use of modes different from the PRT is directly reported in the PRT modal shares, 27% in Trondheim and 20% in Uppsala. A public transport PRT service, as reported in section 3 to obtain a high occupancy rate, could be useful to increase its modal share and to decrease car modal share, together with push measures such as high parking fees and limited traffic zones.

Non-car modal share

As reported in Table 1, the Uppsala non-car modal share after the PRT introduction is 45%, made of 20% PRT plus 25% slow modes, whereas the correspondent Trondheim value is 70% (PRT 27%, slow modes 38%, bus 5%). As for the system modal share, the main cause of such difference seems to be the use of private car in place of slow modes. In Uppsala 65% of people used the car and 30% the slow modes before the PRT introduction, whereas in Trondheim the correspondent figures were 40% car and 53% slow modes. After the PRT introduction, people using car are 55% in Uppsala and 30% in Trondheim, meaning that Uppsala people need further measures to push them out of their cars.

Number of accidents

In Trondheim the PRT implementation does not produce appreciable impacts on the number of accidents according to the results provided in D5.3.1b, thus no comparisons can be made with the Uppsala case study regarding such topic.

Capital costs

The capital costs of the Trondheim case study are 75.4 millions € for all the three PRT scenarios considered (city centre to city centre, inner suburb to city centre, inner suburb to inner suburb).

Such value is very similar to the average costs scenario value of the Uppsala case study, which is 76 millions €. Even if the Trondheim network is two times longer than the Uppsala one and the stops required are double, the large number of vehicles required for Uppsala made the capital costs growing.

However even if the best cost scenario for Uppsala is the low costs one (68 millions € as capital costs), which has also been evaluated as the most likely to be made, the little difference of the costs for such two different PRT networks could be directly linked with the system performances. In fact the Uppsala PRT is able to serve a number of passengers similar to those served in Trondheim during the peak hour in 2010, and it is due to the large number of vehicles circulating on the network, as also reported in section 3.

Business Case Result

As for the capital costs, the Business Case Result of the Trondheim case study is the same for the three scenarios considered and it is 2.30.

The capital costs of the two case studies compared are very similar, as reported in the previous sub-section, thus such BCR value means that the benefits of the Trondheim PRT are larger than the benefits linked with the Uppsala PRT, which provided 1.29 as BCR.

The Uppsala value is however a positive value, meaning that the PRT would be useful and viable once it was made. Furthermore an improvement in the service could be provided by shifting from a pure PRT service to a public transport PRT service (as previously reported in section 3), and such service improvement could also give a significant contribution in BCR increasing.

5 The Passenger Application Matrix on the basis of SP5 evaluations

This report has presented the results of the evaluation of the Uppsala PRT case study.

Such case study was simulated for the Bolanderna district of Uppsala, thus including trips from city centre to centre, from inner suburbs to city centre (and vice-versa), and from inner suburbs to inner suburbs.

On the basis of the obtained results the Passenger Application Matrix has been updated (

Destination→ **Origin ↓**	City centre	Inner suburbs	Outer suburbs	Suburban centres	Major transport node	Major parking lot	Major service facility	Major shopping facility	Major leisure facility
City centre	ICCC (Gateshead. Madrid. Trondheim. Vienna) **PRT** (**Gateshead. Madrid. Trondheim. Vienna, Uppsala**) DMV (La Rochelle, Orta)								
Inner suburbs	ICCC (Gateshead. Trondheim) **PRT** (**Gateshead. Trondheim, Uppsala**) HT-bus (Gateshead. **Madrid**. Trondheim. **Vienna**) DMV	ICCC (Gateshead. Trondheim) PTFCC (**Gateshead**. Madrid. Trondheim. Vienna) **PRT** (Daventry, Gateshead. **Trondheim, Uppsala**) HT-Bus (Gateshead. **Madrid**. Trondheim. **Vienna**) DMV)							
Outer suburbs	PTFCC (Trondheim) PRT (Trondheim) **HT-bus** (**Madrid**. Trondheim, Castellon) DMV (Madrid. **Trondheim**)	PTFCC (Trondheim) PRT (Trondheim) **HT-bus** (**Madrid**. Trondheim, Castellon) DMV (Madrid. **Trondheim**)	PTFCC (Trondheim) **PRT** (Trondheim) HT-bus (Trondheim) DMV						
Suburban centre (within an intermediate distance range)	HT-bus (Gateshead)	HT-bus (Gateshead)							
Major transport node (e.g. airport, central station)	HT-bus (Gateshead) CC (Vantaa)	HT-bus (Gateshead)							
Major parking lot				CC (Rome)	CC (Rome) PRT (Heathrow)				
Major educational or service facility (e.g. University campus, hospital)	PRT (Trondheim) HT-bus (Castellon)	PRT (Trondheim)	PRT (Trondheim)				CC (Trondheim showcase)		
Major shopping facility	ICCC (Gateshead) **PRT** (Gateshead) HT-bus (Gateshead)	ICCC (Gateshead) **PRT** (Gateshead) HT-bus (Gateshead)		HT-bus (Gateshead)					
Major leisure facility (e.g. amusement parks)	HT-bus (Castellon)								
Corridor	**HT-bus** (**Gateshead. Madrid. Trondheim. Vienna**) DMV	**HT-bus** (**Gateshead. Madrid. Trondheim. Vienna**) DMV	HT-bus (Trondheim) DMV	HT-bus (Gateshead) DMV					

Figure 2). The cells with the thicker border are the urban transport passenger applications covered by the Uppsala PRT and for which it was possible to carry out a cross-comparison.

As reported in the previous section 4, the cross-comparison was done with the Trondheim case study, reported and evaluated in the deliverable 5.3.1b, because of the similar features of the cities (Trondheim is expanding towards outer zones and has no appreciable rail mode) and of the PRT networks.

The cross-comparison reported in this deliverable confirmed the robustness of the implementation of ATSs across cities by assessing for each available indicator how a new ATS as PRT performs compared to the conventional systems (do nothing scenario).

The main findings of such comparison are the following:

- The number of daily trips were similar in the peak hour for Uppsala (3 800 trips in the scenario considered for the year 2020) and for the actual Trondheim scenario (4 200 trips in the scenario for the year 2010). In the future Trondheim scenario (year 2035), such value grows to 5 500. During the entire day the Uppsala PRT passengers calculated are about 36 000, whereas in Trondheim they are about 73 000 in 2010 and about 82 000 in 2035;
- The modal share foreseen for Uppsala is 20% in 2020 and for Trondheim 27% both in 2010 and in 2035. The difference between the two case studies can be considered as directly linked with the modal shares of the modes of transport different from PRT, mainly for the car modal share (55% in Uppsala and 30% in Trondheim after the PRT introduction);
- The non-car modal shares are different for the two case studies. In Uppsala its value is 45%, while in Trondheim such value is 70% in 2035. It seems to be due to the different use of car and slow modes, with Uppsala needing further measures to push people not to use their private cars;
- The capital costs were similar for the two case studies. In Uppsala the costs assumed as real were those included in the low cost scenario, 68 millions €, whereas in Trondheim the costs are little higher, 76 millions €;
- The Business Case Result (BCR) of the Uppsala case study provided a positive value, 1.29. The Trondheim value was higher, 2.30, meaning higher benefits for the system;
- A public transport PRT service would be useful in Uppsala to have the vehicle occupancies foreseen after the case study simulation, thus reducing the number of empty vehicle trips and offering a performing service to the users.

All such findings (and the corresponding indicators reported in the previous sections of this deliverable) have to be considered included in the cells of the Passenger Application Matrix containing both the Uppsala and the Trondheim case studies.

Destination→ **Origin ↓**	City centre	Inner suburbs	Outer suburbs	Suburban centres	Major transport node	Major parking lot	Major service facility	Major shopping facility	Major leisure facility
City centre	ICCC (Gateshead. Madrid. Trondheim. Vienna) **PRT** (**Gateshead. Madrid. Trondheim. Vienna, Uppsala**) DMV (La Rochelle, Orta)								
Inner suburbs	ICCC (Gateshead. Trondheim) **PRT** (**Gateshead. Trondheim, Uppsala**) HT-bus (Gateshead. **Madrid**. Trondheim. **Vienna**) DMV	ICCC (Gateshead. Trondheim) PTFCC (**Gateshead**. Madrid. Trondheim. Vienna) **PRT** (Daventry, Gateshead. **Trondheim, Uppsala**) HT-Bus (Gateshead. **Madrid**. Trondheim. **Vienna**) DMV)							
Outer suburbs	PTFCC (Trondheim) PRT (Trondheim) **HT-bus** (**Madrid**. Trondheim, Castellon) DMV (Madrid. **Trondheim**)	PTFCC (Trondheim) PRT (Trondheim) **HT-bus** (**Madrid**. Trondheim, Castellon) DMV (Madrid. **Trondheim**)	PTFCC (Trondheim) **PRT** (Trondheim) HT-bus (Trondheim) DMV						
Suburban centre (within an intermediate distance range)	HT-bus (Gateshead)	HT-bus (Gateshead)							
Major transport node (e.g. airport, central station)	HT-bus (Gateshead) CC (Vantaa)	HT-bus (Gateshead)							
Major parking lot				CC (Rome)	CC (Rome) PRT (Heathrow)				
Major educational or service facility (e.g. University campus, hospital)	PRT (Trondheim) HT-bus (Castellon)	PRT (Trondheim)	PRT (Trondheim)				CC (Trondheim showcase)		
Major shopping facility	ICCC (Gateshead) **PRT** (Gateshead) HT-bus (Gateshead)	ICCC (Gateshead) **PRT** (Gateshead) HT-bus (Gateshead)		HT-bus (Gateshead)					
Major leisure facility (e.g. amusement parks)	HT-bus (Castellon)								
Corridor	**HT-bus** (**Gateshead. Madrid. Trondheim. Vienna**) DMV	**HT-bus** (**Gateshead. Madrid. Trondheim. Vienna**) DMV	HT-bus (Trondheim) DMV	HT-bus (Gateshead) DMV					

Figure 2 Fifth release of the Passenger Application Matrix

6 References

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