

# NEW MOBILITY PATTERNS AS A RESULT OF THE HIGH-SPEED RAIL SERVICE IN MID-SIZED TOWNS

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**Abstract:** The first high-speed line in Europe and particularly the French network was designed with the objective of linking two towns that represent the poles of the line and its size justifies the infrastructure investment. At the same time, it is expected an increase of the extra high-speed train traffic regarding to the old ones, resulting in a modal shift from air to rail mode. In short, it concerns to compete with the air transport, so the new lines must link the two stations located in the extremes (which correspond to an important metropolis) in the minimum time possible with high frequencies. This demands to reduce the number of stops between these two extremes. The distances that are considered ideal under this exploitation system are the corresponding to a journey between two or three hours. It is not strange to defend the theory about towns located in the middle of the line, and particularly small towns, where the high-speed has no effect on the mobility: It is not possible the development of new behaviours, because the new travel opportunities that are introduced by new rails, in particular the possibility of a trip in the same day, near these stations next to metropolis are not new, since it can be done by car.

However, from the studies we have realized about the Swedish case (the Svealand line) that introduces the concept of “regional high-speed” and the Spanish case (the rail corridor Madrid-Ciudad Real-Puertollano) by which the new rail infrastructures give service in journeys less than an hour, it is checked that in these cases the new offer means a reduce of the transport costs for the user and consequently an increase of the trips and the niche market of the railway. In both cases, the supplementary flow gained can be identified as the result of the change in the trip habits produced for journey times less than 1 hour and 30 minutes.

**Keywords:** High speed train, mid-sized cities, mobility patterns, modal shift, induction traffic, commuters

## 1. THE SWEDISH CASE: SVEALAND LINE

The Svealand line covers the route Stockholm-Eskilstuna (a distance of 115 km) in an hour with five stops. The time-distance relation indicates clearly that it is not a high-speed line. In fact, the trains that operates in this line, which has been specifically built for high-speeds, do not exceed 200 km/h. Nevertheless, the service is considered “regional high-speed”.

There is no doubt that this infrastructure has its own characteristics that are not found in any other line because they are not common in the international perspective. The

Svealand line was built to provide and increase the commuter trips from home to work made between Stockholm and each town where a stop is established. This was supposed to extend the “great labour market” that offers the capital to other areas through the accessibility improvement, and particularly small towns such as: Eskilstuna (58,000 inhabitants), Strängnäs (11,000 inhabitants), Mariefred (3,700 inhabitants), Åkers styckebruk (2,800 inhabitants) and Nykvarn (6,000 inhabitants).

The new infrastructure implementation has had an important effect on the demand as shown in the following table (table 1). During the rail track construction (Autumn 1993-Spring 1997), the old trains were replaced for buses that made the same journey with the same frequency as the new high-speed trains will make in summer in 1997. The knowledge of the offer, in this case the service frequency, was the main cause in the users’ behaviour regarding to a new infrastructure. In that way, it was achieved that the citizens knew the number of trains and the timetables of the Svealand line many years before its opening.

Period	Number of trains (in each sense)	Travel Time	Fare (euro)	Number of trips (thousands per year)	Factor of increase of flow
<i>Spring 1993</i>	8 trains	1h40'	12,73	230	1
<i>Autumn 1993-Spring 1997</i>	18 buses	1h55'-2h20'	11,63-13,3	440	2
<i>Summer 1997</i>	17 HST	1h	6	1400	6
<i>Autumn 1997</i>	17 HST	1h	12,2	1200	5
<i>2001</i>	18 HST	1h02'	12,5-15	1600	7

**Table 1. Offer and demand evolution in the Svealand line. Source: Fröidh**

The trips by train were increased up to seven times in 2001 in comparison to the trips made before the construction of the Svealand line. This important additional demand came from the modal shift 70% and 30% from the new users. Between the new users, 15% used the car before and 55% used the bus.

The high percentage of the modal shift to the new railway is due to the replacement of the railway service by buses during the period of works in the Svealand line. Nevertheless, 55% of the travellers could be divided into 30% of users that used buses SJ (prepared by this company as replacement of the trains which stopped giving service in 1993), and 25% of users that travelled in independent vehicles from the regional public transport service, that operated before and during the construction period of the Svealand line. Once the Svealand line was inaugurated both services stopped operating.

The information given do not allowed to determine the modal shift degree or induction produced when the Svealand line came into service. It is not possible to establish that 30% of passengers from SJ buses were also users of the old trains SJ, as the offer modification in 1993 (when the line works started and the change of trains by buses was

realized), was important enough to think the same with the consequences on the demand. This is corroborated with the fact that the number of travellers by bus annually doubled the number registered before with the old trains.

If it were estimated the transfer between forms and the new travellers regarding the year 1993 (year in which the bus offer modification have not been produced yet), and not regarding the spring of 1997 (a few before the Svealand line came into service), both values, the modal shift and the new users, would be considerably higher.

The new train service supremacy regarding other public transport ways, specifically regarding the bus, was evidenced in 2001 when the connexion between Eskilstuna and Stockholm was re-established with bus from Örebro, city located in the West of Eskilstuna. The new offered was 5 or 6 diary vehicles, that in 1 hour 45 minutes and a fare of 8.3€, linked Eskilstuna with Stockholm.

		Eskilstuna- Strängnäs	Strängnäs- Läggesta	Läggesta- Nykvarn	Nykvarn- Södertälje	Södertälje- Estocolmo
1996	<i>SJ bus</i>	350	400	430	450	420
	<i>SL bus</i>	260	190	170	170	50
	<i>LT bus</i>				590	
1998	<i>SJ tren</i>	1030	1090	1200	1310	2440
	<i>SL bus</i>	45	45	40	40	
	<i>LT bus</i>				570	
2000	<i>SJ tren</i>	1300	1370	1540	1680	3120
	<i>SL bus</i>	40	40	40	40	
	<i>LT bus</i>				510	

**Table 2. Number of annually travellers per thousand in 1996, 1998 and 2000.**

**Source: Fröidh**

The number of passengers that chose this service was 100,000 opposite 1,600,000 that used the Svealand line, which offered the same journey in an hour and cost 12.7€. The previous table shows the number of passengers annually in each public transport service that operates in different journeys along the corridor. In all the cases the bus lost market regarding the train.

The important change of the offer with the service of the Svealand line, increased the number of trips made in train compared to the other ways, at the same time it was produced a decrease in the use of the private vehicle.

The connection by road along the corridor it is established by the dual carriageway E20 that was in operation in 1999. The trip between Eskilstuna and Stockholm lasts about 1 hour 15 minutes and 1 hour 30 minutes, without taking into account the possible congestion in the roads leading into and out of Stockholm, as well as the delays as a result of the traffic in the city centre.

	1993	1996	2000
<i>Private vehicle</i>	91%	85%	65%
<i>Public Transport</i>	9%	15%	35%
<i>Bus LT</i>	2%	2%	
<i>Train SJ</i>	7%		
<i>Bus SJ</i>		13%	
<i>High speed train SJ</i>			35%

**Table 3. Modal distribution of the traffic between Eskilstuna/Strängnäs and Södertälje/ Stockholm. Source: Fröidh**

Despite the private vehicle is the way most used, the impact of the Svealand line on the users is clear as shown in the previous table. According to the estimates realized about the modifications in the mobility guidelines as a result of the new infrastructure, the group of people that have changed more their trip habits are those who have always access to a car, regarding to those with a car available more or less frequent or those who have no access to a private vehicle.

Specifically, in 1997 from the total of trips in public transport made along the corridor, 15% corresponded to those who had always access to a private vehicle, 40% to those with a car sometimes available and 45% to those who had no the possibility of travelling by car. In 2000, the most important change was produced in the first group, the group with a car always available, as they were presented in the public transport in 5%.

The new offer, consequently, is attractive enough for the group of people that traditionally travelled by car, travel by train now. At the same time, the users of the other two groups also increased the frequency of their journeys by rail. Moreover, the researchers made in the corridor shown that this effect was more noticeable between those usual drivers who lived next to the station (they could go on foot). In that way, the number of cars per house decreased in these areas with regard to the rest of the country.

The Svealand line impact on the mobility in mid-sized towns where there is a stop is undeniably. The offer modification that produces these effects is compound by “hard” elements, which are those concerning the journey time, frequency and fare, and “soft” elements concerning the image that shows the new infrastructure: security, comfort, possibility of working during the trip and the punctuality. In short, the greatest effects are produced if the journey time is short, the frequency is high, the fare is low and the comfort level is high at the same time.

The impact that the new line had on the demand it has been stand, until now, in an increase of the traffic as a result of the modal shift and the new users that did not travel by the corridor before the new infrastructure appeared. However, the decrease of the journey time and the rapprochement of the cities served by the new rail to Stockholm generated other guideline that is clearly seen along the Svealand line: the increase in the dairy journeys from home to work in the railway. One of the more noticeable consequences in the increase of accessibility is the marked growth of the commuters from Eskilstuna and Strängnäs to Stockholm. The Svealand line has put Eskilstuna in the commuting distance of Stockholm.

## **Commuter trips from home to work**

The Svealand line is a clear example of new infrastructure that enables and increases the commuter migrations. The improvement in the accessibility between the cities connected along this track, as well as the proximity of Stockholm compared to the previous location, and the monthly ticket offered by SJ with the possibility of including in the same ticket the services of urban transport in Stockholm (bus and underground), have produced an important increase in commuters trips. In this way, some of the aims expected with the new rail service were achieved: the “great labour market of Stockholm” extension to the region across the Svealand line.

Eskilstuna and Strängnäs are the cities along the corridor in which the effect on the commuters flow was more important. From the comparison between 1996 and 2001 in the number of people registered with addresses in different places to those of the work place in both cities, the commuter number has significantly increased several times over 2.25 between Eskilstuna and Stockholm and 1.4 between Strängnäs and Stockholm.

These figures have been compared with those observed in Nyköping,<sup>1</sup> city that is not in the Svealand line and which was taken as referent because the number of people who travel diary from this city to the place of work is approximately the same as those who travel from Eskilstuna and Strängnäs, about 5,000. The result of this comparison is understood as an evidence of the effect that the new infrastructure has on the commuter migrations flow for Eskilstuna and Strängnäs, because in the same period, between 1996 and 2000, the commuters increase in Nyköping was hardly 20%.

The main commuter movements have been produced between Eskilstuna, Strängnäs, Södertälje and Stockholm. However, the different relations between Eskilstuna and each of the other towns have increased more the commuters flow. Specifically, the increase of the residents in Eskilstuna that work in Stockholm was unusual, from 550 in 1996 to 1,200 in 2000.

The decrease of the journey time as a result of the new rail service have mainly had an effect on those cities where the journeys by car were too long to make possible the commuter journeys. This is the reason why the effect was deeper on Eskilstuna than Strängnäs. Nevertheless, the layout to be commuter (from the surveys realized) was stronger in Strängnäs than Eskilstuna, due to the journey time shorter in the first case. At the same time, from the surveys realized, the conclusion was the offer that enabled the increase of the commuter journey number from home to work should be defined by a high frequency, season tickets that reduced the ticket price and made more flexible the trip and the possibility to go into the station on foot. It is possible to declare that the journey time, the frequency and the fare were more important for the commuters than the means of transport.

The reasons to commute are related to the difference in the salaries which can be enough high that the diary journeys are advantageous economically, and the people think in other members of their family and this led them to decide the place of residence or the journey is comfortable at the time it can be used to work. Nevertheless, the surveys realized by the use of the declared preferences technique, came to the conclusion that since the Svealand line operates, the inhabitants from the different

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<sup>1</sup> Nyköping is located 115 km far from the Southwest of Stockholm and it has a population of 27,000 inhabitants.

towns where there is a station would increase their willingness to travel daily to Stockholm if they found there a job.

Despite the most important commuters flow along the line is between Eskilstuna, Strängnäs and Stockholm, mainly from the two cities before mentioned to the capital, in Eskilstuna was observed in the first year an increase in the commuter migrations in the opposite direction, from Stockholm, due to new jobs from the capital to the region, as well as the expansion of the university Mälardalen in Eskilstuna.

This expansion was closely related to the increase of the staff that works in the centres, teaching and administrative staff (from 113 in 1997 to 271 in 2001). In small towns the availability of qualified professionals is limited regarding the most important cities. As result of the accessibility improvement by the new railway service between Stockholm and Eskilstuna, it is admitted that the majority of the staff of this university, mainly teaching staff, comes from different places to Eskilstuna, preferably Stockholm. Moreover, the group of teachers who live in Eskilstuna decreased between 1997 and 2001, from 62% to 49%. This happened in opposition to the increase of teachers, from 73 to 163. It is also important to say that the group of higher qualification professionals travelled more.

When the number of teachers who lived in Eskilstuna decreased, the number of teachers who lived in Stockholm increased, from 11% to 20%. It was observed changes in the proportion of the teachers' residence in Stockholm and Eskilstuna, but not in other residences located in towns not included in the Svealand line. Despite the lack of information, it is possible to say that these changes are the result of the increase in the possibilities of commuting along the Svealand line.

## **2. THE SPANISH CASE: MADRID-CIUDAD REAL-PUERTOLLANO LINE**

The effect on the mobility produced by the high-speed transport in Ciudad Real and Puertollano (line Madrid-Seville) has been caused by the shuttle train service and, in particular, by its high frequency and its price policy carried out by the company.

The circulation of these trains (shuttle AVE) is the most characteristic aspect in the high-speed service in Ciudad Real and Puertollano if we consider the low population in these towns -nearly 60,000 inhabitants-. It started in November 1992 and came up as a consequence of a big demand of travellers in these two towns. This demand, unexpected and mainly based in relations with Madrid, upset the long-distance line Madrid-Sevilla. Because of this and with the objective of segregating the traffic in the line Madrid-Ciudad Real-Puertollano from the traffic in the long-distance lines, the shuttle service started to run. The offer of this service in the stations of Ciudad Real and Puertollano is characterized by a high frequency and a price policy whose objective is to get the segregation of traffics: 0.1 euros/km for the shuttle service against 0.15 euros/km for the long-distance trains. This service is "peculiar" because of two aspects: it presents a bigger similarity with a high-speed suburban service and it is the only high-speed line in Europe in which the traffics are segregated in such an explicit way.

The shuttle trains represent, therefore, a unique case in the European high-speed network because for the time being no rail company offers such an exclusive and diverse service to the points in the extremes of a high-speed line.

There would be some similarities with the Svealand line because both services (Svealand line and shuttle) have the objective of getting closer the mid-sized towns with the capital of the country, with high frequency and competitive prices. However, the new infrastructure built between Madrid and Puertollano, as well as the rolling stock which runs in these tracks have characteristics that allow the trains reach a speed of 270 km/h.

This affects the reduction of the journey time that is introduced by the new trains comparing to the traditional ones. For that, although Eskilstuna is 60 minutes far from Stockholm, Ciudad Real 50 minutes from Madrid and Puertollano 20 minutes more, the percentage of time saved with regard to the services prior to high-speed is more noticeable in the Spanish case where the trip time has dropped nearly a third part.

	<i>Madrid-Ciudad Real</i>	<i>Madrid-Puertollano</i>	<i>Estocolmo-Eskilstuna</i>
<b>Travel time by conventional train</b>	2h20 (year 1987)	3h05 (year 1987)	1h40 (year 1993)
<b>Travel time by high speed train</b>	50 minutes	70 minutes	60 minutes
<b>Percentage of travel time saved in high speed train compared to conventional train</b>	63%	63%	40%
<b>Travel time by private car</b>	2h (year 1992)	2h45 (year 1992)	1h20 (year 1999)
<b>Percentage of travel time saved in high speed train compared to private car</b>	58%	58%	25%

**Table 4. Comparison of the journey time studying the different means.**

The detail analysis we have made in the Madrid-Ciudad Real-Puertollano corridor shows that the high-speed shuttle services have generated an important repercussion, being the quantitative one the most noticeable in the Spanish case than in the Svealand line.

In Ciudad Real and Puertollano the high-speed shuttles have generated an important number of commuter trips, similar to what happened in the Svealand line. The previous high-speed rail service did not allow these migrations, because 200 km distance between Ciudad Real and Madrid and 240 from Puertollano to Madrid were impossible to travel daily. Because of this, as a result of high-speed service in the corridor, we consider the commuters one of the most noticeable effects on the mobility patterns.

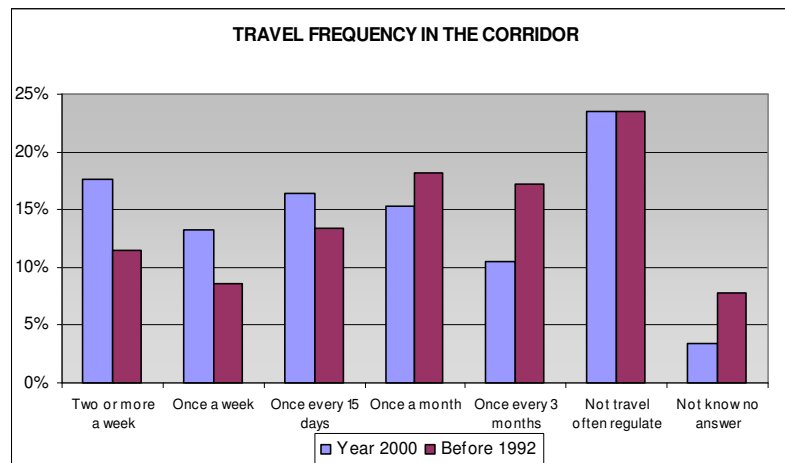
There are three reasons for the presence of commuters between these towns: the journey time reduction, the high frequency of daily trains in the corridor and the price of the ticket, with special offers for the most regular users.

It is obvious the high-speed shuttle effect on the mobility regarding the commuters. But, according to a survey made to the users, we have identified and quantified other behaviours apart from the ones specified before.

We have evaluated the influence of the high-speed trains according to two aspects: new trips in the corridor and increase of the travelling frequency in the case of those users who used to travel in these routes before.

	Yes	No	Not traveled
<i>Has the high speed service influenced on their travels?</i>	21,5%	5%	70,6%
<i>Do you do this travel before year 1992?</i>	27%	-	70,6%

**Table 5. Influence of shuttle service on the journeys.**



**Fig. 1. Comparison of the travel frequency in the corridor.**

Unlike other systems, like the French one, the Spanish high-speed line is not characterized by its repercussion in the modal shift and the increase of the trip frequency. However, the offer introduced by the shuttle service has been basically translated into new users who did not travel on this line before.

There has been a modification in the trip frequency for those who travelled before 1992, although it was not as important as in the French corridor and it can be defined as an increase of trips made more frequently (mainly in the period between two or more per week and one per month) against a decrease of the less frequent ones. According to the commuters, there has been a transfer from the less frequent trips to the commuters.

According to the following table, it is necessary to indicate that the difference up to 100% is compound by 2.5% of the answers given do not know/ do not answer. On the other hand, the total of users is divided into commuters, transfers to other ways and new users. So, the frequency increase considered as a category of induction, could be due to the modal shift of some users. It is not strange that old users change the way and

increase the number of trips. In this specific case it was predictable because the old rail line was replaced by the high-speed line.

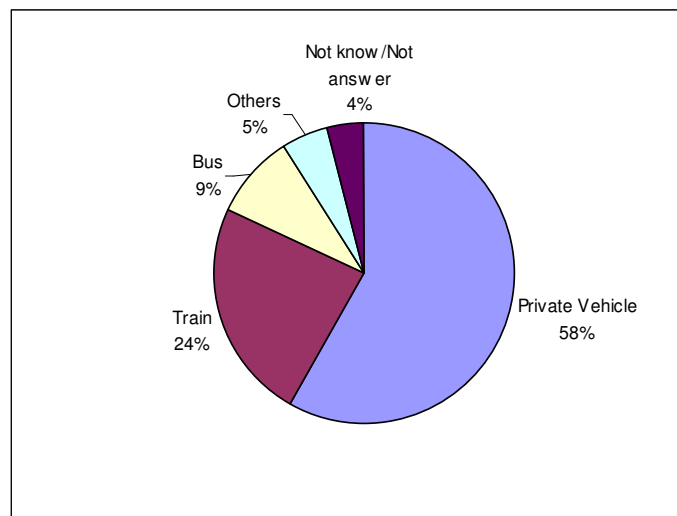
NEW MOBILITY PATTERNS		
<i>Commuter trips</i>		15,5%
<i>Modal shift</i>		21%+6% <sup>(*)</sup>
<i>Induced traffic</i>	<i>New users</i>	55%
	<i>Increase of the trip frequency</i>	9%

**Table 6. New mobility patterns in the corridor.**

(\*) This second term refers to the percentage of users transferred from the traditional rail.

The modal shift has been mainly produced from the private vehicle, which was the main transport used in these trips. From the total number of transferred users 15% travelled by car before 1992, 6% by train, 3% by bus and 3% has answered the category others or do not know/do not answer.

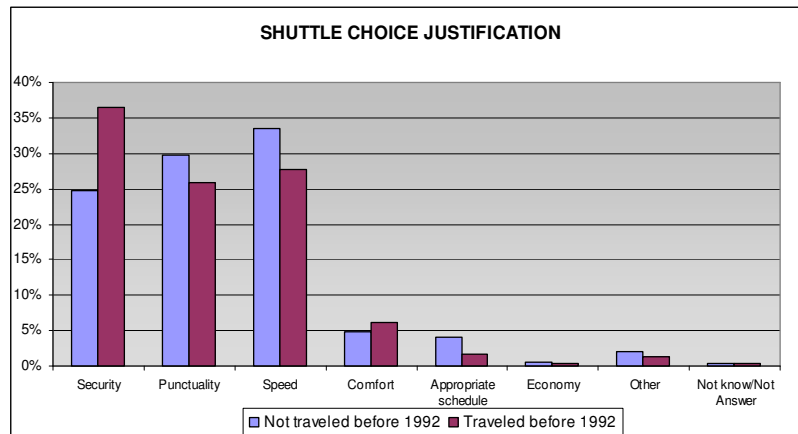
If we expressed the same figures regarding the total number of transferred users, the results are clearer: 58% used the car, 24% the traditional rail and 9% the bus.



**Fig.2. Means of transport used by the users transferred to shuttle trains**

The study and quantification of the new mobility guidelines in the corridor have been complemented with the analysis of some aspects related to the means choice, the incentives why the users travelled in the shuttle and the fidelity to this service.

The reasons why users have chosen travelling in the shuttle rather than other way are more interesting comparing the incentives of new users and the users of other way or those who have been transferred. New users appreciate the new trains speed most and old users choose the shuttle train because of the security.



**Fig. 3. Shuttle choice justification.**

It is observed in figure 3 the comfort has been included as a possible cause of choice. In the Swedish case we referred to the importance of the new image shown by high-speed trains. In the Spanish case, comfort is not the main cause to choose this service.

Purpose travel	New Mobility Patterns		Relation Madrid-Ciudad Real	Relation Madrid-Puertollano	Relation Ciudad Real-Puertollano
<i>Professional</i>	Commuter trips		14%	10%	13%
	Modal shift		8%+2%	2%+1%	7,5%+4%
	Induced traffic	New users	28%	21%	17%
		Increase of the trip frequency	3%	4,5%	0%
<i>Studies</i>	Commuter trips		1%	1%	18%
	Modal shift		0,85%+0,05%	2%+0%	4,5%+1%
	Induced traffic	New users	6%	3,5%	13%
		Increase of the trip frequency	0,5%	1%	4%
<i>Personal</i>	Commuter trips		0%	0%	0%
	Modal shift		7%+2%	6%+1%	4%+3%
	Induced traffic	New users	28%	31%	10%
		Increase of the trip frequency	4%	3%	4,5%

**Table 7. New mobility patterns in each corridor relations**

The table 7 shows for each relation and reason of travelling the quantification of every identified mobility guidelines. The reason of travelling *studies* is a new key in our analysis deduced from the research made in the Madrid-Ciudad Real-Puertollano corridor and we cannot avoid.

The main difference in opposition to the bibliography about the trips made between two big urban conurbations where the reason of travelling is a determining factor, is that the reason of travelling do not explain the mobility pattern developed in the relations established by the shuttle trains. For the three possible categories, it is “new users” the main behaviour.

### **3. NEW MOBILITY PATTERNS IN MID-SIZED STATIONS AND WITH A TRIP TIME LESS THAN 1H30**

From the Swedish experience and mainly through the research carried out about the Madrid-Ciudad Real-Puertollano corridor, we have identified and quantified the new mobility patterns developed in small towns and its attractor centre for journeys realized in about an hour trip time.

The research carried out allows us to conclude that the increase on the rail demand produced by the service of new trains is mainly the result of the induced traffic and specifically the component “new users”. Apart from this new guideline, it is necessary to add the appearance of commuters that is the second behaviour after induction, according to the percentage. However, this effect could be considered the most important one qualitatively above new users, because it is a trip standard impossible to develop before 1992.

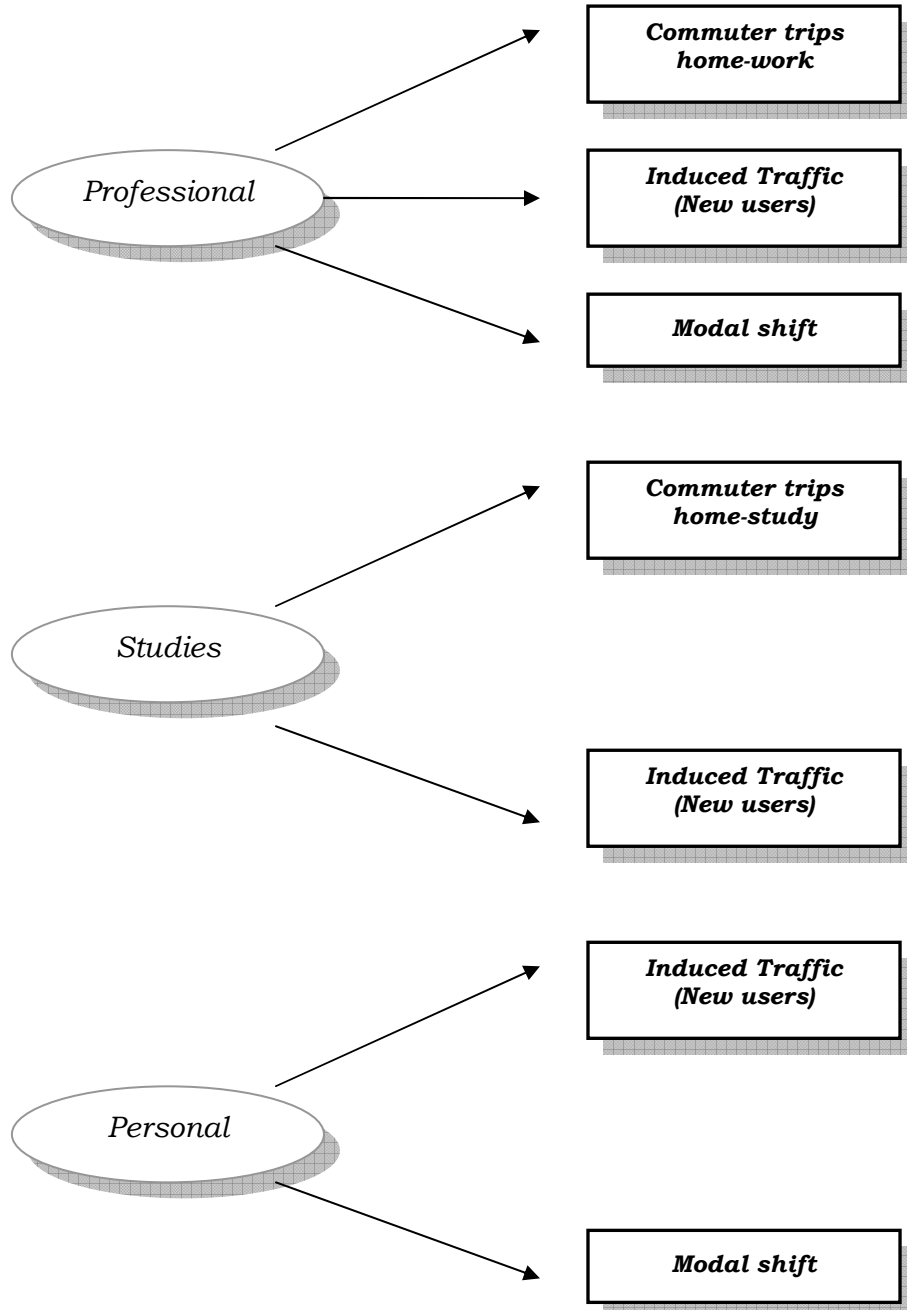
On the other hand, the modal shift and the trip frequency increase, that have been defined as the new mobility guidelines highly developed between great metropolis and trip times between two and three hours, are not important in small stations.

With this, it is not only define the new services influence for this type of relations, but also the French theories, which declared that on this kind of stations high-speed trains did not produce important effects on the mobility, lose strength. At the same time, the mobility patterns developed in the relations in which one of the extremes is a small town and close to the attractor centre are different from the guidelines between big metropolises distant between two and three hours.

Despite the predominance of new users independently to the trip aim, the reasons allow us to classify the mobility guidelines. In this way, the commuters are produced in the professional and study categories while the personal trip aim does not produce daily commuters. On the contrary, the modal shift has no sense in the journeys made for study reasons because they are trips realized in a very specific period (from three to five years) and it is not probable that these trips were realized before high-speed, because of the surveys year. Finally, the trip frequency increase as second element of induction cannot be shown as a guideline with an effect observed in some of the reasons proposed, because in the journeys with study reasons the quantification is lower.

These arguments allow us to end with the following outline.

***Pattern Mobility in accordance with the purpose of travel***



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