MISTRAL: an Information System for Local Public Transport Services in Lombardy

Authors: Elena Foresti (*), Eliot Laniado (**), Giorgio Stagni (*)

(*) Consorzio MIP - Politecnico di Milano

(**) CESTIA - CNR, Politecnico di Milano

Abstract

The local public transport system in the Lombardy Region is to be restructured in order to improve the effectiveness and efficiency of public transportation.

In line with EU and national legislation, public authorities are to be directly responsible for the planning and financial support of public transport, stipulating contracts with train and bus companies setting out specific requirements on both sides for the supply of transportation services (regional authorities for rail transport and local authorities for bus transport).

Monitoring of the transport system is therefore a key activity for the Region in planning local railway services and promoting – in agreement with Provinces – a regional, trans-modal transport network which makes better use of transport facilities.

Mistral is a project which aims to define an information system to support regional and local authority planning of transport activities by:

- monitoring the contracts for transportation services that public authorities are to stipulate with train and bus companies;
- evaluating the transport system through indicators related to mobility and transport demand, bus and train supply (involving both transportation and economic aspects) and all issues affecting public transport (e.g.: distribution of public facilities such as schools, possibility of park-and-ride etc.);
- providing support to decision and negotiation processes with methodologies based on multi-criteria analysis, sensitivity analysis and analytical techniques for solving conflict;
- providing standard information and procedures regarding the regional transport system to public authorities, transport companies and users.

1. Background: Local Public Transport in Lombardy

1.1 The Lombardy Region

Lombardy Region is one of the largest and the most populated among the 20 Italian Regions. It comprises 1546 Municipalities and is divided into 11 Provinces. Last data state a total population of 8,900,000, with a density of 375 inh./km². As the south-eastern part of the region is mainly rural and the northern part is mountainous, population is actually mainly concentrated in a smaller area, namely around Milan, the capital of the Region, and its large, densely urbanised northern outskirts. Some 40% of the regional inhabitants live in the province of Milano, where density reaches a value of 1890.

Total population is quite stable: a low increment (+1.4%) has been recorded in the last decade. Nevertheless, a strong reorganisation in spatial distribution of inhabitants has also been observed. For example, from 1971 to 1991, inhabitants living in towns smaller than 40,000 have increased by 14.2%, while, in the same period, inhabitants living in the 22 cities greater than 40,000 have decreased by 12.9%.

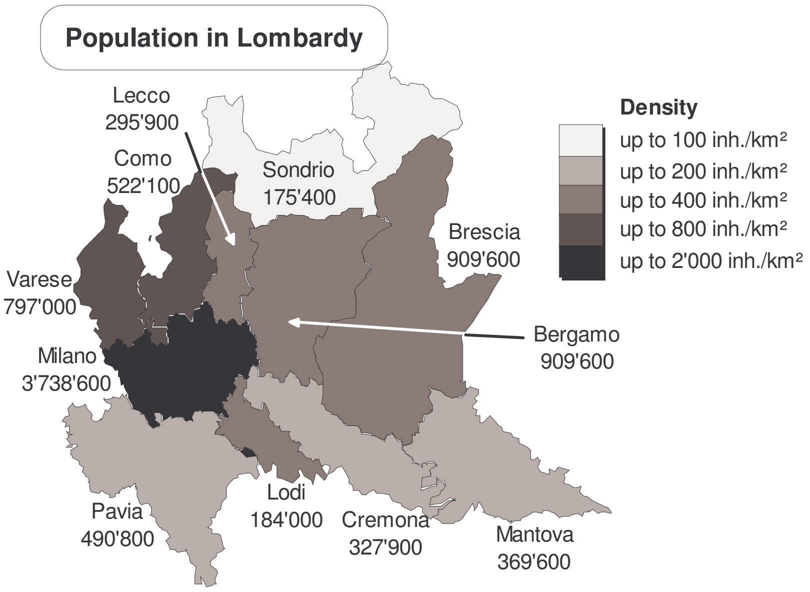

Fig. 1 - Overview of Lombardy Region with population and density (1991 National Census)

1.2 Public Transport Network in Lombardy

Public transport at Regional level in Lombardy involves four modes:

- railway;
- interurban bus network;
- urban network, all accomplished by bus, except for the case of Milan, where tram, trolley-bus and underground networks exist;
- boat services on Northern Lombardy lakes.

Most of the railway system is owned and managed by the Italian National Railways (*Ferrovie dello Stato, FS*); the Regional Government controls a private railway company (*Ferrovie Nord Milano, FNM*) with strong commuting service around the capital of the Region. Interurban bus networks are managed by a great number of public and private companies, often of small and very small size.

Urban networks are generally managed by municipal companies; in particular, the greatest one operates the Milan network (*Azienda Trasporti Milanesi, ATM*) and a number of surrounding interurban routes.

Since the late Seventies, the Regional Government has been responsible for planning and controlling interurban bus networks, with a system of concessions to each bus company. During the Eighties, competence for interurban transport was partially transferred to the Provinces, namely for administrative duties, and keeping only the main long-term planning issues at a Regional level. Railway planning and operating (on FS network) has always been managed by the National Railway Company, although during the last decade, efforts were made to reduce centralisation and establish offices at a regional level, especially for local transport duties.

1.3 A Reform for Public Transport Services

Starting from 1995, the Regional Government has undertaken an important reform in public transport management; a national law in 1997 accelerated this process, and extended it from bus to railway network. The leading ideas of this reform can be summarised as follows:

- competence for public transport planning is to be transferred to a more local level: from National to Regional level for railways, from Regional to Provincial level for bus networks;
- the concession system for bus networks has to be turned into a competition system, in which bus services in each area or route are assigned to an operating company by means of a tender;
- network organisation must better fit the demographic structure in which it works: new services are to be designed for suburban areas around main cities, as well as in low demand areas, where innovative services (e.g. demand responsive services) are also encouraged;
- economic efficiency of expenditure on transport has to be increased.

The Regional Government has thus to face a great challenge in the next years, which asks for new data and instruments in order to manage new aspects of public transport (for example the rail service). Even before the beginning of said reform, the Regional Transport Office was collecting important data on public transport (especially interurban bus services): a small information system was used to manage economic data such as costs and revenues for each line and company.

The introduction of this reform was considered as a good chance to qualitatively and quantitatively increase the level of information, as a basis for managing bus network planning. A complete information system was thus designed: it was called *MISTRAL (Monitoraggio Informativo Sistema di Trasporto Locale = Monitoring Information on Local Transport System)*. The *MISTRAL* system has been planned since the end of 1997; implementation started in mid 1998 and is foreseen to be completed by the beginning of 2000. MIP consortium of Polytechnic of Milan was responsible for designing the system and building up the software applications, according to the technical specifications provided by the Regional Government. First modules of the system are already available and they are currently used by the Transport Offices; this paper will describe both the system architecture and the first available results.

2. *MISTRAL*: Architecture of the Information System

2.1 Objectives of the System

The *MISTRAL* system is a threefold project. *Firstly*, it aims to create an overall database containing all data on public transport under the competence of the Regional Government; *secondly* it aims to use this data in order to compute performance indicators on transport demand and supply, at different levels of detail and aggregation; *thirdly*, it aims to exploit data and indicators for decisional processes dealing with public transport planning, within a decision support system (DSS) based on multicriteria analysis techniques.

Objectives for the database creation are as follows:

- to define standardised procedures for collecting, structuring and redistributing data;
- to ensure consistency among all databases in the transportation field at a Regional level (road network, public transport by bus, railways, boat service);
- to increase the quality level of information given to Provincial Administrations, Municipalities, transport companies, users;

As regards the computing of performance indicators, the following issues are to be considered:

- indicators are to be computed at different levels of details and aggregation, in order to fulfil expectations of different users of the system (e.g. Region, Provinces, Transport Companies), each having its own scope and horizon;
- indicators will have to consider aspects such as mobility of the population, composition of transport demand, level of service of public transport (to each municipality, in each route or origin-destination pair), effectiveness of public network, economic efficiency of transport companies, quality of service or users (both commuting and occasional trips), accessibility to different social facilities, etc.
- it should be possible to create further user-defined indicators, to fit special investigation requirements of each user;
- it should be possible to access indicators in different ways, for example by applying cascade filters, by grouping data according to specific features of the network, or by querying the database geographically.

Finally the decision support system will have to help Public Offices in planning transport services and managing conflicts between all the different political and social subjects involved in transport decisions (for example the Regional Government towards local authorities, bus companies, associations of citizens).

2.2 Technical Structure of the System

The most important issue to be taken into account when designing the information system was the easiness in using it. This was considered a necessary condition in order to guarantee a real use of the system in the Regional Offices. Moreover, the whole information system had to be built up of several sub-systems, which had to be:

- light,
- oriented to solve specific problems,
- flexible,
- modular,
- with user-friendly interface.

The technical solution selected for the whole system was based on the following products:

- Microsoft Access for building and querying the databases, as well as for creating most of the interface;
- Microsoft Visual Basic for creating special interfaces (advanced graphical representations, network graphs, ...);
- ESRI ArcView for the geographical representation of data, in order to make use of the basic layers developed by the Regional GIS Office with ARC/INFO.

This solution guaranteed the whole system to be operative on a standard Personal Computer, with working features consistent with the traditional Windows interface (well known to all Regional Officers); significant advantages in terms of short learning time and low maintenance costs could therefore be achieved.

2.3 Contents Structure of the System

MISTRAL can be subdivided into two main parts:

- monitoring and assessment of local transportation, through a system of performance indicators;
- decision support system for planning transport services.

The monitoring part deals with four groups of data:

- demographics and land use,
- transport demand,
- transport supply,
- transport means, facilities and infrastructures.

Indicators aim to support planning of transport services at the Regional and Provincial level: each Authority will be able to use *MISTRAL* indicators to check, adjust, design transport networks, both urban and interurban, keeping into account issues such as integration among different modes, efficiency of public expenditure, accessibility guaranteed to each Municipality, etc.

3. Mobility in Lombardy

An overview of trips and modal share for commuting mobility in Lombardy is considered a basic data to start with, when designing a monitoring system like *MISTRAL*. The Origin-Destination (OD) matrix from 1991 National Census was therefore acquired: although it is quite old, it is presently the only nation-wide OD matrix existing in Italy, so that it was worth to include it in *MISTRAL* database.

The OD matrix covers all *commuting* trips and is disaggregated by Municipalities: some aggregated data are shown in Fig. 2 and 3. Two aspects can be highlighted:

- the capital of the Region has a strong attraction power: although its inhabitants represent only 15% of regional population, its internal mobility covers 24% of total urban mobility (all modes), and interurban trips with Milan as destination are 21% of total interurban trips; this is further emphasised for rail modes;
- trips directed to Milan have a modal share much more in favour of public transport: this reflects the better supply generally available for connections to Milan with respect to other public transport connections, and proves that, when supply is outstanding, modal share does reward public transport.

	Total commuting trips in Lombardy					*Trips with destination Milan, on total trips*				
Area	*Foot, bike, motorbike*	*Train*	*Tram, Metro*	*Bus*	*Car*	*Foot, bike, motorbike*	*Train*	*Tram, Metro*	*Bus*	*Car*
Urban	1,151,000	8,000	187,000	264,000	890,000	14%	-	97%	30%	18%
Interurban	152,000	207,000	105,000	328,000	1,342,000	8%	58%	78%	17%	13%
Total	**1,304,000**	**215,000**	**293,000**	**593,000**	**2,233,000**	**13%**	**57%**	**90%**	**23%**	**15%**

Fig. 2 - Total trips according to mode, and percentage incidence of Trips having Milan as destination

Furthermore, the radar chart for Milan clearly shows a good performance of train mode and metro mode, for distance greater than 50 km and about 20 km long (as well as for urban trips), respectively; in the chart for the remaining Lombard trips the predominance of car mode is unfortunately relevant for the whole distance range.

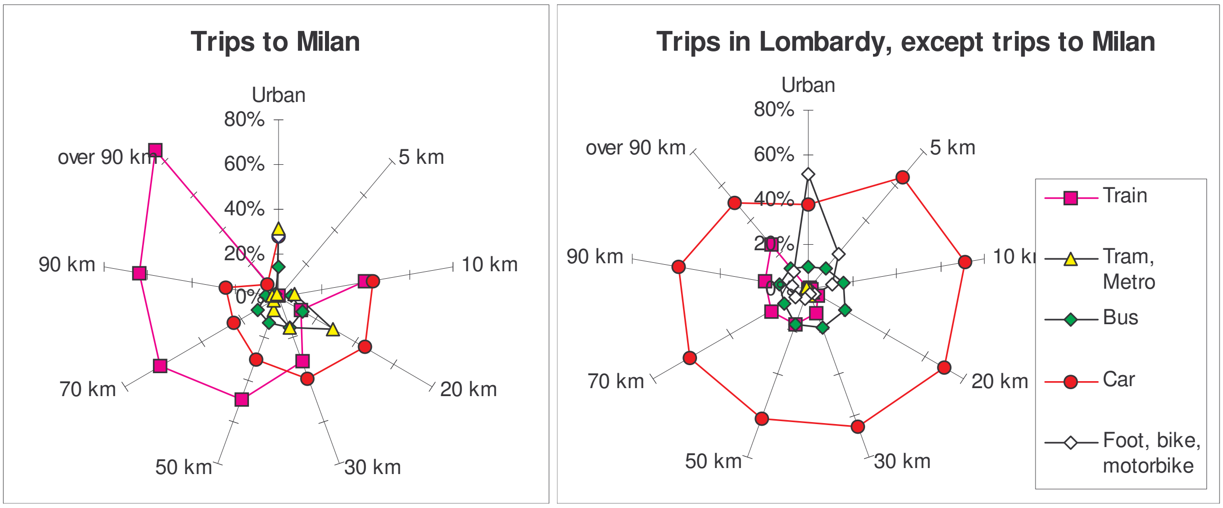

Fig. 3 - Modal share for different trip lengths, for trips having Milan as destination, including Milan urban trips (left) and all other trips in Lombardy (right)

4. First Results, Bus Network

One of the first modules that became available, during 1998, was that dealing with bus services, both urban and interurban. The most recent data available deal with 1996. The level of detail for these networks, within *MISTRAL*, is the single bus line for interurban service and the whole city network for urban service. In the case of Milan, urban network includes not only bus mode, but also tram and underground modes.

This section reports the main results obtained on monitoring the Lombardy bus network, from the point of view of the service structure, extension, costs and revenues.

4.1 Structure of Service and Bus Companies

One of the most remarkable features of the bus network structure in Lombardy is the strong fragmentation of lines into a great number of bus companies, most of which are of a very small size. In more details:

- almost three fourths of (interurban) bus companies manage no more than 5 lines. These companies cover no more than one seventh of total interurban bus kilometres;
- on the other hand, there are 10 large companies, whose share, in terms of number of lines, bus-km and travellers-km reaches the values of 40, 58 e 68%, respectively. This means that companies with the largest number of lines guarantee a supply and transport a number of travellers proportionally still greater;
- distribution of the most important companies' indicators can be represented by means of cumulated curves as in Fig. 4. They state, on y-axis, which percentage of the indicator is given by the first x percent of bus companies (sorted descending). Y value for x = 0 represents the

value of the largest company, i.e. ATM of Milan. For example, the chart shows that the larger 20% companies cover more than 80% of total bus-km and almost 90% of revenues and number of employees; the revenue curve higher than the bus-km curve reveals that the companies with the largest kilometrage carry a number of travellers proportionally still greater (but they also use a greater number of employees).

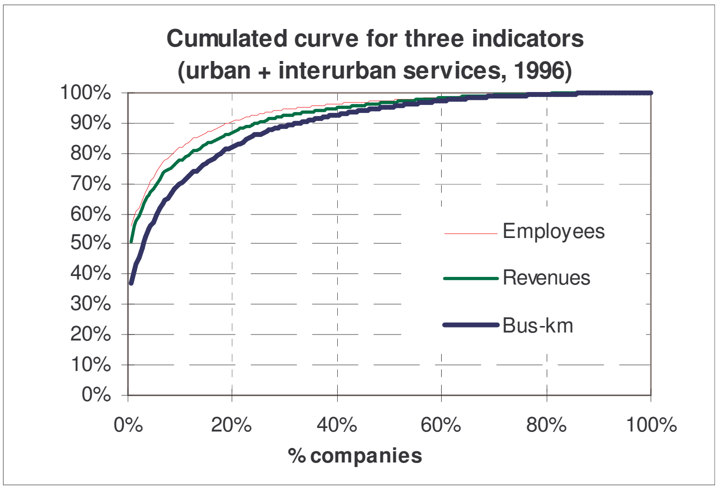

Fig. 4 - Cumulated curves for three companies' indicators

4.2 Transport supply during years

Transport supply can be quantified by means of total distance covered by bus (bus-km per year). Also the resources used to produce this supply – both in terms of manpower and total costs can be analysed. Results are as follows:

- total kilometrage of bus network has remained almost constant in the last years, with a value of some 141 million bus-km for interurban network and 142 for urban network. It should be noted that some 114 million bus-km belong to the ATM urban network in Milan: this company thus represents more than 40% of total kilometrage in Lombardy;
- during years 1992-96, employees have decreased by 11%. Reduction for bus drivers was 4%, so that in 1996 they represented 64% of total employees. Reduction in drivers, total bus-km being constant, has slightly improved the average distance covered per driver (42,000 km/year in 1996);
- *total costs for interurban lines* have remained remarkably constant during the last years (some 391 million Euro per year); reduction in number of employees has balanced a little increase in the average cost per employee (41,100 Euro per year);
- *revenues for interurban lines* have strongly increased (+16%), especially for ordinary tickets (a little less for monthly-passes): this caused a small improvement on total balance (reduced to an overall loss of 137 million Euro in 1996);

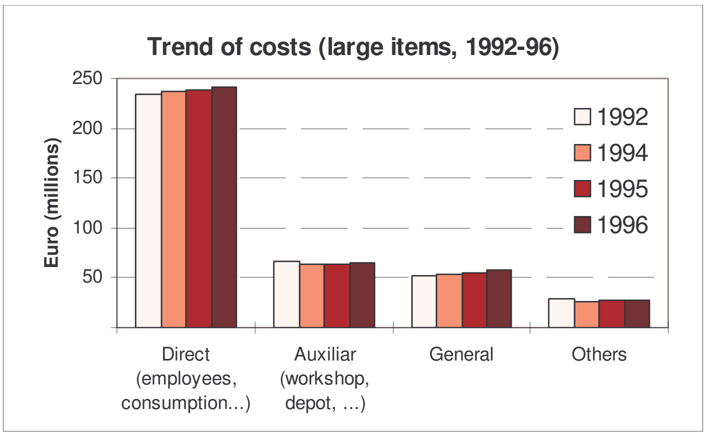

Fig. 5 - Trend of costs (interurban network)

- as regards *urban networks*, a little reduction in total costs was found (only caused by ATM, as all other companies have increased their costs); a very strong increase occurred in revenues (+37%, again mainly due to ATM). This produced a remarkable improvement in total yearly balance, decreasing the global loss to 340 million Euro in 1996 (11% less than loss in 1992);
- revenues/costs ratio inherits the effects of constant costs and improved revenues: it globally improves by 20% (both urban and interurban), up to values of 0.31 and 0.45 for interurban and urban networks, respectively.

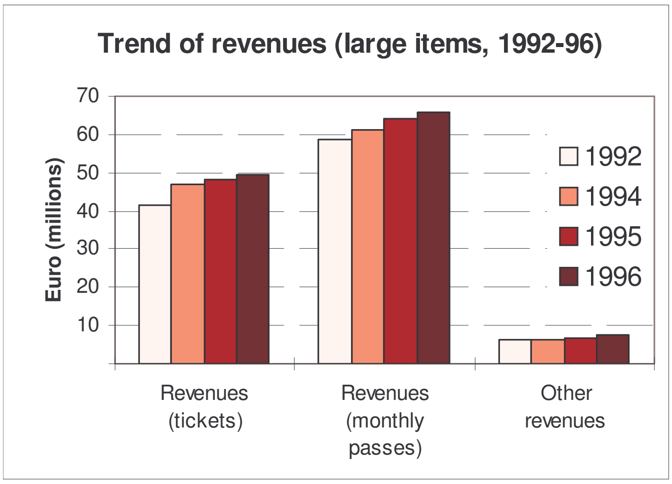

Fig. 6 - Trend of revenues (interurban network)

4.3 Travellers

The number of travellers carried on regional network is one of the main indicators to test performance of public transport. Results show some critical aspects; they can be summarised as follows:

- the *average occupation* of interurban buses (computed as travellers-km/seats-km) is about 23%; it is worth highlighting that 20% of bus-km with lower occupation (14% or less) carry only 7% of total travellers-km; on the contrary, 20% of bus-km with higher occupation (greater than 36%) carry some 32% of travellers-km;
- as far as mobility of population is concerned, an average value of 15 non-commuting bus trips per day per 1,000 inhabitants was found at a regional level. Commuting trips reach a higher value: some 33 trips per day per 1,000 inhabitants;
- during the examined period, although revenues have increased, it should be noted that both travellers and travellers-km have decreased; in particular, interurban travellers-km have decreased by 9% from 1992 to 1995 (in 1996 a new, little improvement was recorded); the largest loss of travellers was recorded for

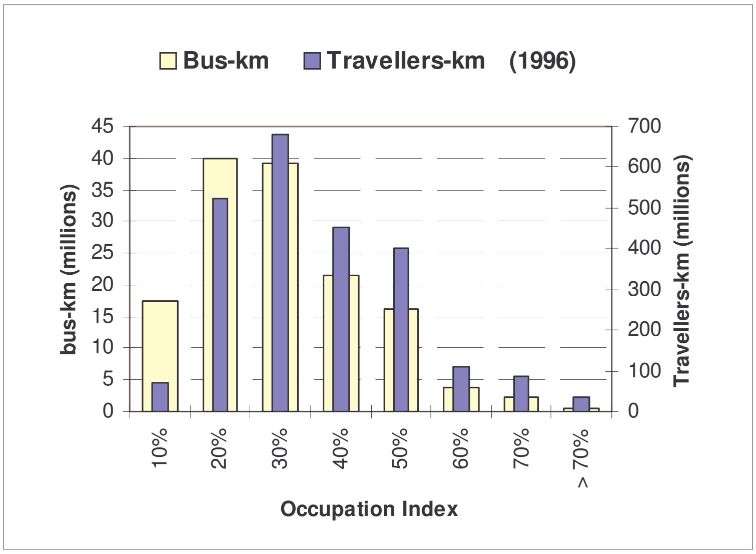

Fig. 7 - Comparison of bus-km and travellers-km, grouped by values of bus occupation

interurban non-commuting travellers (-17% of tickets sold), i.e. in the demand segment where the highest increase in revenues was found. This means that interurban network (especially in non-commuting service) is becoming more and more expensive and is used by a decreasing number of citizens;

- as to urban networks, the situation is a bit more complex: reduction in travellers-km was caused, for ATM network, only by monthly-passes (ordinary tickets remained constant). Other networks recorded a heavy reduction both of monthly-passes and ordinary tickets (globally -19%). The strong relative importance of Milan network has caused the average Regional result to record a global loss of 10% only.

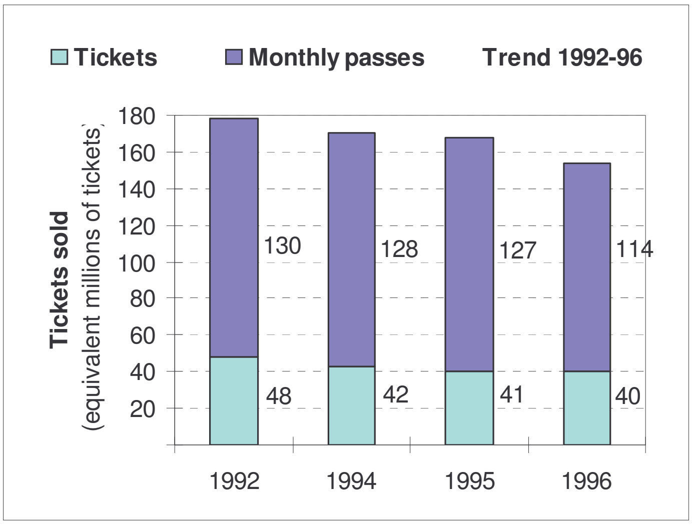

Fig. 8 - Trend in total tickets sold (monthly-passed have been transformed into equivalent one-trip tickets)

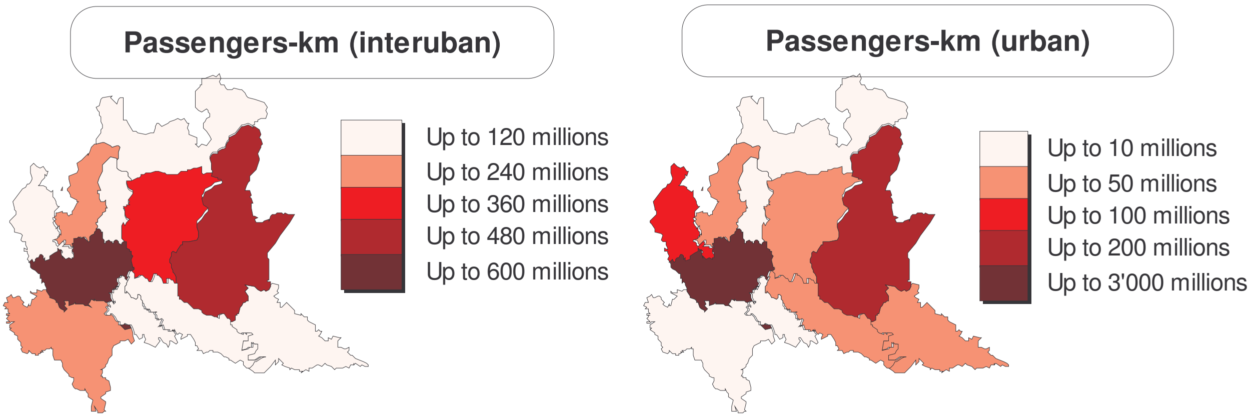

Fig. 9 - Passengers-km in each province (1996, interurban & urban networks)

4.4 Specific economic indicators

MISTRAL is collecting a lot of economic data, regarding costs and revenues disaggregated in terms of bus line or bus company. The following results can be highlighted.

- the average *cost per bus-km* amounts to a value of 2.7 Euro for interurban network (substantially constant during the examined years), and of 4.3 Euro for urban networks. The latter result is strongly influenced by the high value for ATM (4.6 Euro);
- a different situation is found for revenues per bus-km, which are increasing due to the increase of total revenues, bus-km being constant. For interurban network, a value of 0.8 Euro per bus-km was observed, while the average value for urban network was of 1.7 Euro (up to 1.9 for ATM).

Chart in Fig. 10 shows values further disaggregated according to the administrative type of company;

- the reduction in total travellers causes a worsening in the value of costs per travellers-km: for instance, a figure of 0.18 Euro was found for urban network, some 16% more than in 1992 (the cost for interurban network, 0.16 Euro in 1996, remained more constant); on the contrary, revenues per travellers-km are strongly increasing: +50% for urban and +16% for interurban, due to the contemporaneous travellers' reduction and fare increase.

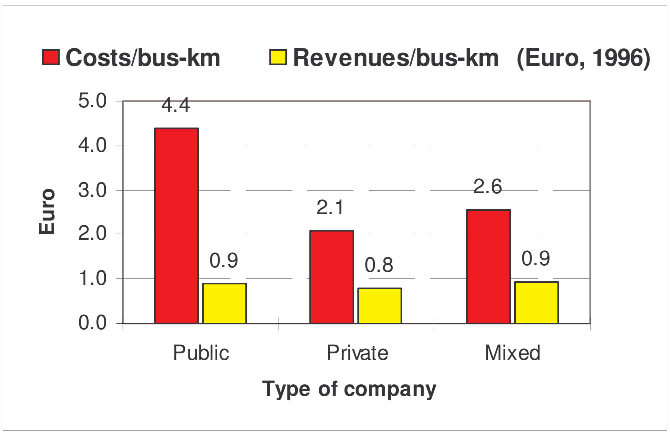

Fig. 10 - Comparison of costs per bus-km and revenues per bus-km, according to the type of company

5. First Results, Railway Network

The second module developed in 1998 deals with the railway service. It was a topic initially not included in this project, and added later on, when new National and Regional laws strongly extended the competence of Regional planning to railway transport. A significant difference with respect to bus mode can be found in data available at the Regional Offices: as Regional Government has become responsible for managing railways only during these months, it can rely upon a set of data more limited than the available data for buses. In particular, only very aggregated data are available for costs and revenues; on the contrary, the most important data come from a survey that FS makes twice a year, counting the number of travellers getting on and off each train in each station. First results described in this section mainly come from such surveys.

First of all, Fig. 11 gives an overview of the total railway supply (FS network only) in Lombardy, during a standard winter week. Supply decreases by some 47% in number of seats from weekdays to Sunday, mainly due to reduction in regional trains, while demand is reduced by some 67%. This causes the average number of passengers per train to decrease from 264 to 170, the average number of seats being almost constant (about 700 seats for interregional trains and 400 for regional trains).

	Trains per day			*Seats per day*			*Travellers per day*		
Day	*Interreg.*	*Regional*	*Total*	*Interreg.*	*Regional*	*Total*	*Interreg.*	*Regional*	*Total*
Weekdays	142	1069	1211	99000	442000	541000	92000	227000	320000
Saturday	130	780	910	90000	321000	411000	53000	101000	153000
Sunday	130	491	621	89000	201000	289000	56000	49000	105000

Fig. 11 - Aggregated supply and demand for Lombardy railway network (winter timetable 1998-99)

More interesting information on usage of trains can be found if further indexes are considered. For example, for each train *MISTRAL* considers two data: the maximum number of passengers, recorded during the trip, and the average number of passengers (given by travellers-km divided by km). Three indexes can be therefore computed:

- *occupation index*, as average number of passengers divided by seats,
- *crowding index*, as maximum number of passengers divided by seats,
- *peak index*, as crowding index / occupation index.

The second index, in particular, gives a useful information on the maximum crowding level recorded by the train during its trip, which is the most evident feature for the user and is generally helpful for dimensioning the service. The last index analyses how much travellers are concentrated only during a fraction of the whole trip.

A cumulated curve is the most suitable way to analyse the global crowding of trains on the whole network. This is done in Fig. 12 and 13: for example, it can be observed that in weekdays some 120,000 passengers (38%) travel on trains with a crowding index greater than 1 (i.e. with not enough seat places, at least for part of the trip), and this corresponds to some 25% trains-km. Crowding during Saturday and Sunday is much lower (no more than 9% passengers on Sunday, where some tourist routes have a lot of traffic anyway, and even less on Saturday).

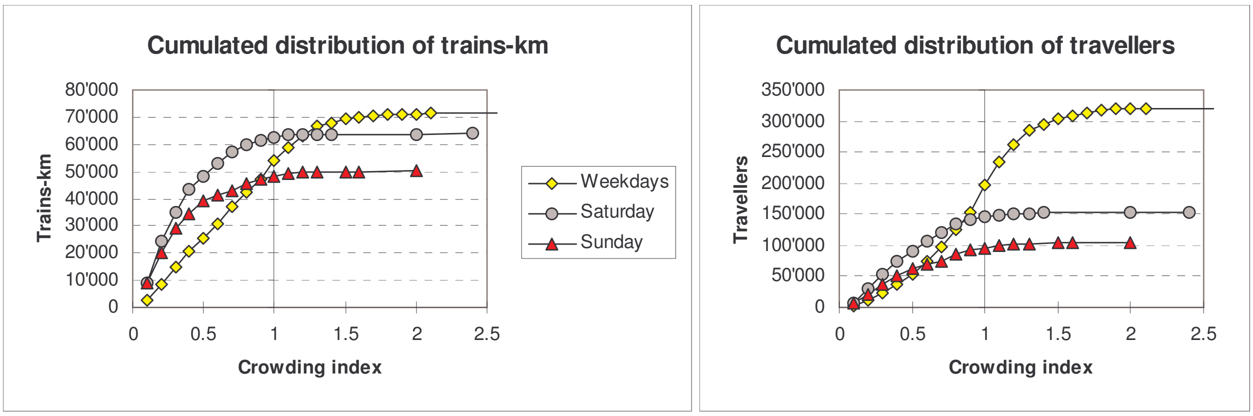

Fig. 12 - Cumulated curve for trains-km and travellers vs. crowding index (winter 1998)

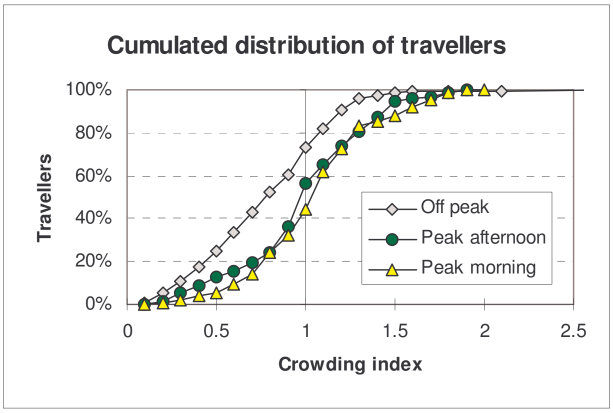

Fig. 13 - Cumulated curve for travellers vs. crowding index (winter weekday 1998)

Furthermore, crowding is clearly more critical during peak hours, especially in the morning (7-9h), where some 56% of passengers travel with an index greater than 1.

It should be noted that all this data, shown here for the whole network, can be obtained interactively at different levels of detail, by means of the *MISTRAL* software interface: for example, crowding can be analysed route by route, for each type of train (interregional, regional), or even for single trains during the week, or finally a comparison can be made between different years.

Behaviour of train usage during different hours of the weekday and on weekends can be observed in Fig. 14: the morning and afternoon peaks gain the highest number of passengers per train and of (average) crowding index. Hours 12-14 are mainly interested by commuting students' trips.

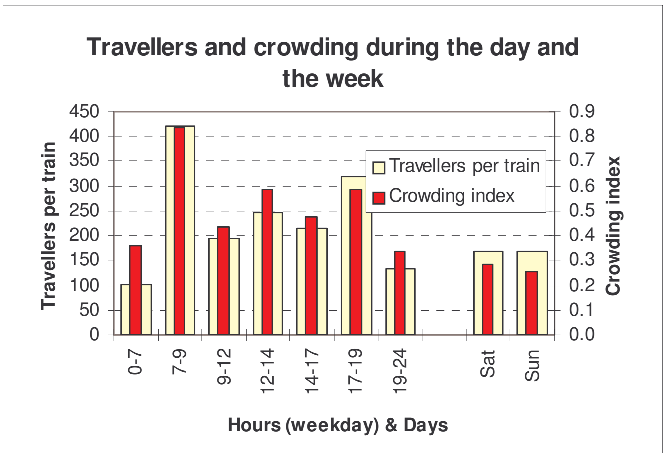

Fig. 14 - Average travellers per train and crowding index during a weekday, on Saturday and on Sunday

The *MISTRAL* system includes geographical databases as well. For example, a graph of the railway network was created, in order to represent data such as number of trains, seats, passengers on each route and station, and related indicators (e.g. crowding). Also technological features of railway branches can be represented (signalling systems, maximum speed, capacity, ...). In Fig. 15, each station shows the number of travellers counted during a standard weekday: the great mobility of the metropolitan area north of Milan can be clearly seen, with a high number of users in the stations on the Varese, Lecco and Bergamo branches (it should be noted that real mobility is even greater, as no data is presently available for the FNM routes to Como and Varese). On the contrary, in the southern part of the Region, high mobility is much more concentrated in single towns (e.g. Cremona and Pavia).

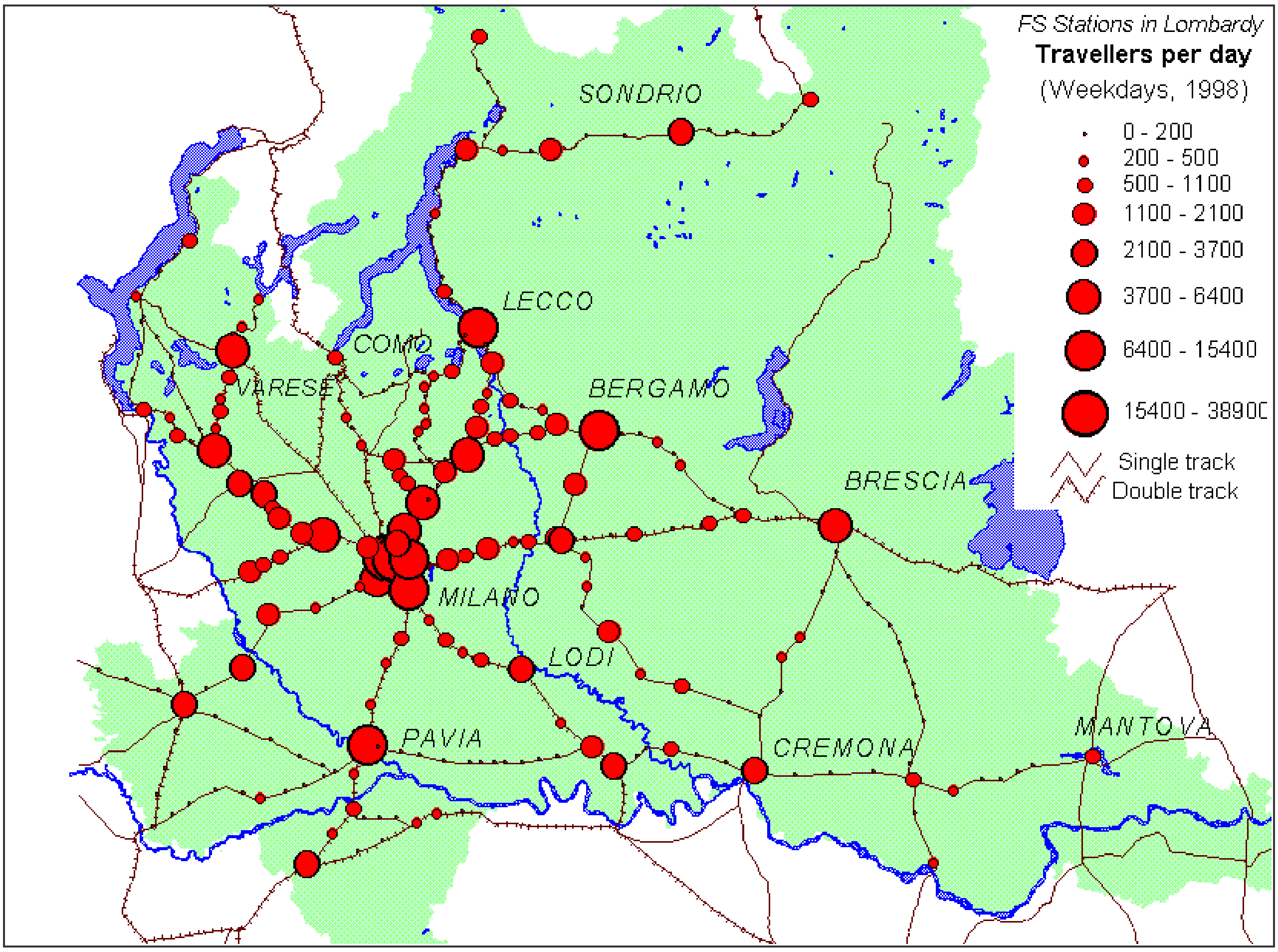

Fig. 15 - Passengers' movement in Lombardy railway stations: travellers getting on train

6. Conclusions

Regional Government started thinking of a complete monitoring system for local public transport in 1997, to coincide with an important reform in organisation of public transport, which is going to change most of the competencies for planning and managing bus and railways networks. The monitoring system, called *MISTRAL*, was developed starting from 1998, and will be finished by 2000. It had to be a modular system, easy to use, decentralised, able to support decisions both at a Regional and a Provincial level. It is implemented with a Microsoft Access database, using an Access / Visual Basic interface, plus ArcView for geographical features.

One of *MISTRAL* aims was to reorganise data from different sources (transport companies, statistics bureau, Regional Offices, ...) in a unitary and consistent structure, so that each subject involved in the transportation field could easily access them.

First results from monitoring are already available, both for bus and railway networks. As to bus network (especially interurban), they show a worrying decrease in number of travellers, the total supply being roughly constant. Costs have also remained constant in the last five years, with an average cost per interurban bus-km of 2.6 Euro (a bit more for urban networks). On the contrary, revenues have increased, due to a strong fare tightening-up: this has balanced the mentioned reduction in travellers, but certainly cannot be considered as a good result.

On the contrary, data from railways, which are more disaggregated with respect to transport demand, clearly show that a good modal share is easily reached when there is a substantial and well designed supply; cases of overcrowding of main routes in peak hours are not infrequent.

Summing up, a critical situation can be observed as to interurban bus lines; a slightly better situation is found for urban networks, with positive results for the largest urban network (i.e. that of Milan); railway services seem able to capture a high amount of trips, but they can be still expanded to completely exploit their possibilities. All these critical aspects are occurring in a regional context where total mobility is still increasing, and private car mode has already reached unsustainable levels on great part of the wide metropolitan area from Milan to its northern provinces. Up to now, it is too early to state whether the transport reform being undertaken will answer these issues or not: one of *MISTRAL* aims is to give instruments and above all data to verify it time after time.