

Tendering problems of suburban rail systems

Recently Connex' offer for the separated operation of one third of the Berlin S-Bahn and Melbourne's discussion of how to re-unify the suburban rail system split in two tendering batches has focussed the attention on a sector that has dribbled tendering quite well. Only very few suburban rail systems have been tendered, the well-tested Melbourne and Stockholm and the future Mannheim. What the really big systems concern, something began to move with the Connex' Berlin offer.

This paper tries to find out the reasons of this delay. In the first part it recalls definitions of suburban rail, timetabling and tendering. The second part is dedicated to the Milan case, a substantially new system to set up in tendering conditions.

Definitions

Suburban rail system

Suburban railways constitute a very heterogeneous category just as the areas that they serve have very different characteristics. They can be set between urban metro (for service pattern and signalling) and full size national railway (for dimension and using national tracks). The then German State railway Deutsche Reichsbahn (DRG) defined in 1926 a criteria catalogue for a high performance suburban rail system, which was the basis for the Berlin suburban network electrification carried out between 1926 and 1929:

- a. Functional vehicles with high acceleration rates and sufficient capacity for peak hours by adequate interior designing
- b. Quick passenger entering and alighting in short station stops by level entrances from 96 cm high platforms
- c. Efficient signalling system for high speed and short train headways (down to 100 sec)
- d. Basic interval timetable
- e. Short station distance (1 to 4 km, in the centre 500 to 800 m)
- f. Special tracks with as few as possible operational contact points with the other railway traffic, no level crossing with any other transport mean.

The Berlin network gave the trademark S-Bahn for suburban transport even out of Germany. But many other systems with this trademark have to work in much less favourable conditions, the key points are the operational conflict points with heavy national rail traffic, a typical European issue:

- Closed systems use exclusively separated tracks, often for technical reasons: Berlin, Hamburg, Copenhagen, Liverpool, Barcelona FGC, Naples SFMS
- Semi closed systems use separated tracks in the centre and on the most congested lines, and mixed tracks elsewhere: Paris, Stuttgart, Frankfurt, Munich, Barcelona RENFE, Naples SEPSA
- Open systems have separated tracks only in the centre and all-purpose tracks elsewhere: Zurich, Hanover.

Namely the semi-closed systems like the future Milan one constitute an excellent compromise between high infrastructure cost and its immediate best use. The critical point is how to organise the timetable that has to consider slow suburban trains and fast national trains on the same often congested tracks.

Timetable path

Timetable path is the temporary concession of track use for the passage of a train. It depends on both the infrastructure characteristics and the rolling stock performance. In case of congestion overtaking and delay recovery time must be added.

Conditions determined by the infrastructure provider:

- Maximum speed given by the section layout (curve, gradient)
- Minimum headway given by the signalling system (protection distance)
- Delay recovery time given by the possibility to enter or leave the section (flat junctions or flyovers)

Conditions determined by the train operator:

- Maximum speed of the rolling stock (tilting technology)
- Acceleration and breaking efforts of the rolling stock (motor axles, power distribution)
- Station dwell times for entering and alighting (level entrance, door width, licensing times)

Conditions determined by both:

- Overtaking of suburban trains by faster trains (not necessary for freight trains)
- Priority in conflicting points

Rarely the rolling stock has a maximum speed of more than 140 km/h, absolutely sufficient for the short station distance. Only in certain central sections the suburban rolling stock is able to go faster than the infrastructure allows. Therefore the rolling stock performance is determined by the possibility of reducing acceleration, deceleration and station stop time.

Data collection and analysis for setting up

Demand analysis, operation planning and economical appraisal have to be merged in an iterative process before setting up a new system. In the metropolitan areas on one hand increasing road traffic congestion has led to a renaissance of light and heavy rail transport but on the other hand making the best use of spare heavy rail capacity is less expensive than constructing new infrastructure. Therefore the data collection and analysis has to make the quadrature of the circle designing a system without overcapacity and congestion.

- Demand analysis. Its data collection is a quite expensive operation that should include all mobility actors: private car, bicycle, walking, and other public transport. The potential demand estimation tries to estimate future traffic flows in probable economical and population growth scenarios. Peak hour capacity need calculation and daily traffic volume projection conduce to the final act of demand analysis, the service pattern modelling.
- Operation planning. The infrastructure survey finds out if and how the service pattern can be accommodated on the given infrastructure, where the critical points are and which of them need which kind of improvement like better signalling or flyovers or even new tracks. A particular attention is paid to the inserting of new stations and its implication on the running times. Rolling stock need calculation considers capacity, running times and costs. At the end train path finding needs a draft timetable for finding out of critical points.
- Economical appraisal. The revenue estimation considers the ticket sale of the demand analysis and the public contribution in form of service contract. The operation cost estimation considers employment, operation, energy, general costs and track use. The rolling stock cost estimation considers the

investment and its depreciation, which can be oriented to the service contract's duration or the life cycle of the goods.

The data collection and analysis is composed of several iterative steps. The demand analysis is based on indications about the operation programme. The operation programme reflects the chosen technical solutions. The technical solutions depend on the economical feasibility. The process starts with the most obvious alternative, examining if these choices are practicable, to join a right equilibrium.

Data collection and analysis actors in tendering regime

Before tendering was introduced, the railway monopolist usually carried out the data collection and analysis. Besides being part of the public administration, the national railways had an important own interest of setting up such systems, which were able to rationalise the network simplifying the service and reducing the costs. The rethinking of mobility behaviour in the seventies conducted to a real suburban rail boom. In Paris, Munich, Frankfurt, Stuttgart and Zurich rail regained the population that moved to the outskirts getting as important as the urban metro.

In tendering regime those data collection and analysis is divided among the three main actors of the applied public transport liberalisation: the tendering administration who distributes public money, the railway operator who bids for the public money and the infrastructure provider who has gotten public money for the construction and now has to manage the track use by subsidised and not subsidised rail traffic.

- Demand analysis. The tendering administration has to carry it out and to make it public for the bidders.
- Infrastructure review. The infrastructure provider has to make sure that such a system can be supported by the infrastructure. If not, improvements have to be proposed to the tendering administration.
- Rolling stock choice. To use the most suitable rolling stock is the real challenge for the bidder. The high investment and long life cycle namely for not universally usable electric traction stock induce to alternative property models, which often involve the tendering administration (Stockholm). But also for normal diesel stock the tendering administration can delimit the choice acting on the specifications.
- Economical risk analysis. The bidder has to look if it is worth to make an offer.
- Public expenditure forecast. The tendering administration has to calculate if it has enough money to pay the service.

The procedure with five different analysis' distributed in a not uniform way on three different bodies has lost the short information flow. For some aspects there should be no information flow at all, because it could influence the bids and alter the tendering result. This interruption is not so important if all necessary information is obvious (like in already existing systems) or guaranteed (eliminating the competitive advantage of the bidding previous service holder). It can be very dispersal if the system is still on the paper and the actors do not know what really they want.

First problem: The global approach of planning a new system has been outsourced

Case study Milan

The Milan suburban rail tunnel has been partially opened in 1997, once completed it will link four northwestern with three southeastern rail lines. Two other northeastern and one southwestern lines are isolated from the Tunnel. All lines have at least two tracks of standard gauge and 3 kV DC overhead wire electrification. The completion of the Tunnel will unify the networks of FS (8 lines) and FNM (2 north-western lines), unfortunately in the pre-tendering period no detailed operation programme was made for the Tunnel services.

Notwithstanding that the Tunnel is designed for a common rolling stock project, the TAF class, a four car double deck EMU for 469 seated and 841 total passengers with a level entrance from the 55 cm high Tunnel platforms. Two units can be coupled to a 210 m long train able to carry 1682 passengers. FNM has 27 units, FS has in service around Milan only 9 of the ordered 150 units.

The public expenditure is 167 million € for the FS services and 56 million € for the FNM services, in total 223 million € a year. FNM receives also 68 million € a year for the infrastructure and 202 million € for a recent rolling stock renewal programme. The FS infrastructure investments and the rolling stock expenditure are hard to estimate for the local level.

Capacity estimation

Lombardy's regional administration, the body who will tender the rail services, commissioned a potential demand research, which has been delivered in 2001. It is based on the monitoring of the existing 1999 rail demand and two 2010 demand forecasts based on a low and a high economical growth scenario. The research merged the passenger counts made by the train staff what the existing FS network concerns and the ticket sale data what the smaller FNM network concerns. It could not consider the Milan intern rail traffic, simply because not existing in 1999.

The 1999 max hourly inbound load has a range from more than 3,600 passengers on the FNM lines from Saronno and Seveso down to 600 on the FS line from Pavia. Considering 15 minutes headway, the FNM lines need a train capacity of more than 900 passengers and for the Pavia line a capacity of 150 is enough. The lower 2010 forecast has a range from 7,500 on the FS line from Gallarate down to 3,522 on the FS Seregno line for a train capacity range from 1,900 down to 880. The (less probable) higher 2010 forecast ranges from 8,500 for the FS Gallarate and Mortara lines down to 4,600 of the Seregno line calling for extra services on six of the ten lines in case of TAF class utilisation (Figure 1).

	survey		lower forecast		higher forecast	
	max load per hour	train capacity	max load per hour	train capacity	max load per hour	train capacity
S1 Novara	1,845	461	5,251	1,313	6,703	1,676
S2 Gallarate	2,438	610	7,517	1,879	8,650	2,162
S3 Saronno	3,692	923	4,085	1,021	6,190	1,547
S4 Seveso	3,617	904	5,629	1,407	7,071	1,768
S5 Seregno	1,128	282	3,522	880	4,581	1,145
S6 Carnate	1,765	441	5,131	1,283	7,133	1,783
S7 Treviglio	2,045	511	4,422	1,105	5,993	1,498
S8 Lodi	1,202	300	6,751	1,688	7,864	1,966
S9 Pavia	600	150	5,936	1,484	7,121	1,780
S10 Mortara	1,186	297	5,589	1,397	8,440	2,110

Figure 1: Rush hour train capacity need in Milan

	trips per inhabitant and day		
	0.11	0.30	0.40
S1	0.11	0.37	0.43
S2	0.32	0.38	0.54
S3	0.20	0.24	0.30
S4	0.04	0.16	0.21
S5	0.14	0.52	0.69
S6	0.12	0.54	0.74
S7	0.12	0.85	1.02
S8	0.09	0.59	0.76
S9	0.05	0.20	0.30
S10	0.25	0.30	0.41
FNM	0.09	0.40	0.51
FS	0.12	0.38	0.49
total	0.12	0.38	0.49

Figure 2: Reliability

The daily traffic volume of the 10 line suburban service should increase from 200,000 passengers in 1999 up to 630,000 for the lower and 820,000 for the higher 2010 forecast. The increase of trips per inhabitant and day of the suburbs from 0.12 to 0.38 and 0.49 reflects the Munich data of 0.22 before and 0.42 after opening of the S-Bahn system (Figure 2). The increase for the two FNM lines is quite modest as FNM today offers an acceptable suburban service. The high increase for the eight FS lines reflects the insufficient today's service.

But the reliability of demand figures in general for a still not existing system and these figures in particular for Milan is not so clear, Figure 2 shows some figures decidedly out of range: S5, S10 and S4 for the low values;

S8, S9, S7 and S6 for the high values (line numbers working identification). As well the minimal increase of the FNM lines is astonishing.

Second problem: The demand forecast for a new suburban rail system must be reliable

Network design: line matching

Line matching is important for optimising the rolling stock use without time wasting in the central area. Approaching lines with the same headway and the same train composition at both ends of the central tunnel are suitable for matching. But many of the theoretically possible scenarios don't pass the exam of the infrastructure constraints, to understand this there is no other method than elaborating the timetable paths.

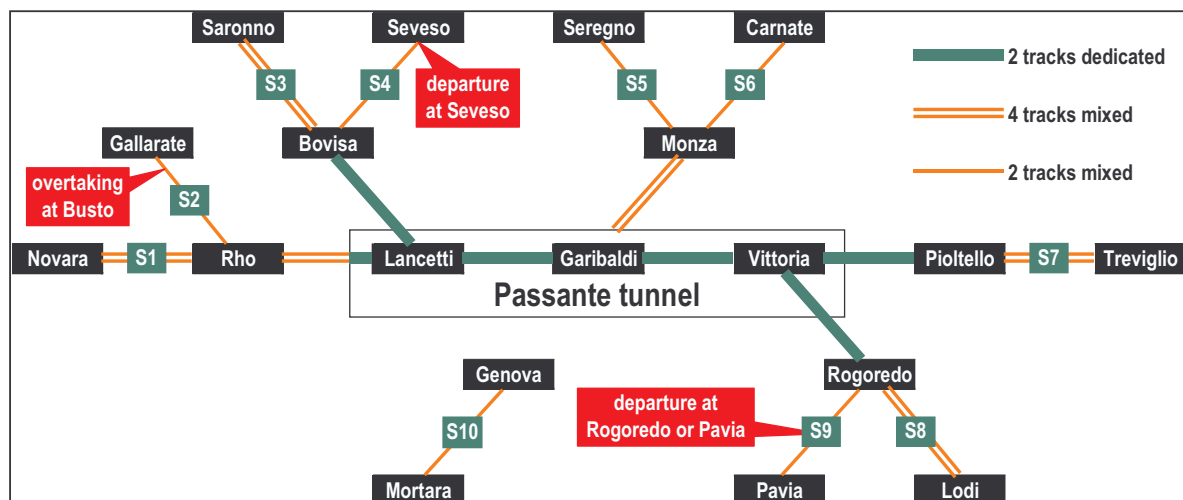


Figure 3: Milan suburban network and its conflicting points

Elaborating the timetable, the semi closed suburban rail system has to consider the remarkable national and international passenger and freight traffic around Milan. This issue is very common in central Europe for its geographic configuration and its population density. Many metropolitan areas in Europe divided these traffic flows by constructing separated tracks for the suburban traffic, in Italy the new tracks are dedicated for the high speed traffic so that the suburban traffic gains more residual space on the historical lines.

The timetable constraints, which consider the relationship with other train categories, are

- Basic interval timetable
- International symmetry at minute 00
- IC path not changeable

The timetable criteria, which consider the suburban system intern priority, are

- Equal headways on multiline sections (e. g. Rho – Lancetti)
- Self containing lines
- Low roundtrip times
- Operation stability
- Demand equilibrium of the matched lines

Line matching is more complicated as it seems, namely because the operation stability is hard to forecast. The Munich S-Bahn from the first planning in 1963 on has changed often the matching of the seven western and five eastern tunnel approach lines, at least in 2003 (Figure 4).

western approach	line	eastern approach					
		plan 1963	plan 1969	oper 1972	oper 1997	oper 2003	plan 2005
Freising/Flug.	S1	Ostbf.	Ismaning	Kreuzstr.	Kreuzstr.	Ostbf.	Ostbf.
Petershausen	S2	Ostbf.	Erding	Deisenhofen	Holzkirchen	Holzkirchen	Erding
Nannhofen	S3	Deisenhofen	Deisenhofen	Ismaning	Ostbf.	<i>no service</i>	Ebersberg
Geltendorf	S4	Kreuzstr.	Kreuzstr.	Ebersberg	Ostbf.	Ostbf.	Flughafen
Herrsching	S5	Erding	Ostbf.	Ostbf.	Ebersberg	Ebersberg	Holzkirchen
Tutzing	S6	Ebersberg	Ebersberg	Erding	Erding	Erding	Kreuzstr.
Wolfratshsn.	S7	Ismaning	Hauptbf.	Hauptbf.	Ostbf.	Kreuzstr.	Ostbf.
Pasing	S8	<i>no service</i>	<i>no service</i>	<i>no service</i>	Flughafen	Flughafen	<i>no service</i>

Figure 4: Munich line matching schemes (black destinations are on the central section)

Third problem: The line matching needs a maximum of flexibility given only by one sole batch

Running time estimation

At present all FNM timetable paths are made for the slowest stock. In this way the basic interval timetable with equal running times all over the day is maintained and even the 1928 EMUs can circulate liberally. Therefore the running times on the FNM network are slow but well tested.

FS at present is still introducing a basic interval timetable and therefore the running times vary from train to train. Unlike FNM, which has 85% EMUs and 15% loco trains, FS uses EMUs mostly in the outskirts and, besides the small TAF class group, most trains are composed by elderly locos with up to 8 double deck car or even longer single deck car reversible units. The TAF class EMU runs only the Gallarate line and needs 28 minutes for the Gallarate – Rho instead of the 32 minutes of a loco train gaining 4 minutes. This gaining is due to the better acceleration and braking effort, maximum speed and station dwell times should be the same. On this basis the suburban train paths on the other FS lines must be recalculated, it's not possible to calculate the delay recovery time without running an operation simulation of the whole FS network.

In the Tunnel itself FNM and FS have different running times, the FNM EMUs (TAF class and stock from the eighties) need 9 minutes for the 5 km and 5 stations from Lancetti to Dateo (the present Tunnel end), the FS stock (TAF class and new loco trains with 6 double deck cars) needs from 10 to 12 minutes! Two different running times for the same EMU class on the same section needs some clarifying.

Fourth problem: The running time estimation hardly can calculate conflicts and delay recovery times

The running times between the constraint points, Busto and Seveso on the west and Rogoredo on the east, are fundamental for the line-matching scheme. A TAF class EMU should need 52.9 min for the Busto – Rogoredo and 43.3 min for the Seveso – Rogoredo excluding a Gallarate – Pavia matching and inducing a Seveso – Pavia matching. But without certain running times no definite line matching can be made.

Fifth problem: The running times between the constraint points are fundamental for the line matching

Rolling stock choice

The initial choice of the TAF class as standard EMU for Milan's suburban rail network is on the way to be abandoned. FS has ordered a great quantity, but the initial delivery of 9 units for Milan has never been increased. FNM recently has ordered a new double deck EMU class with a better power distribution and a little more space around the doors.

Figure 1 shows that in the lower forecast scenario the needed capacity exceeds the nominal capacity of the TAF class on two lines. In the higher forecast scenario the TAF class is inadequate for 6 of the 10 lines. The nominal capacity considers 6 standing passengers for m², it is not known how many standing passengers can be carried without risking to choke the narrow door spaces in the Tunnel section with its short station distances and high passenger exchange in each station.

Sixth problem: The future Milan suburban service has no suitable rolling stock

Confronting the TAF class with other suburban service EMUs that circulate in European metropolitan areas (Figure 5), it is distinguished namely for the lowest capacity, the highest comfort of 56% of all passengers seated, the worst power distribution of only 25% motor axles and the slowest acceleration of 0.6 m/sec². The door width per passenger is the same of the rugged Naples high capacity single deck, but only two thirds of the German single deck S-Bahn and half of the Paris double deck EMU. The Paris RER and the German S-Bahn have large experience with short station distance and high passenger exchange.

	FNM/FS TAF	RATP MI2N	DB 420	DB 423	SEPSA E82
type	double deck	double deck	single deck	single deck	single deck
cars	2 x 4 cars	2 x 5 cars	3 x 3 cars	3 x 4 cars	4 x 2 cars
weight	420 ton	518 ton	420 ton	315 ton	340 ton
motor axles	25%	60%	100%	80%	50%
acceleration	0.6 m/sec ²	1.1 m/sec ²	1.0 m/sec ²	1.0 m/sec ²	1.0 m/sec ²
seated passengers	938	952	582	576	288
standing passengers	744	1028	1143	1584	2200
total passengers	1682	1980	1725	2160	2488
percentage of seated	56%	48%	34%	27%	12%
total door width per side	24 m	54 m	36 m	47 m	33 m
door width per passenger	0.014 m	0.027 m	0.021 m	0.022 m	0.013 m

Figure 5: Suburban EMUs in Europe (calculated for 210 m length)

Therefore Figure 5 invites to a reflection on double deck or single deck EMUs for the Milan case. Another issue to discuss is the division of a 210 m long composition in two 103 m long four car units or in three 66 m long three car units, namely in off peak service smaller units can save costs.

Turning back to the running times, the rolling stock choice can change the service design. Recently Connex made a proposal for the separated operation of the Berlin circular S-Bahn. From its electrification in 1930 to its closure in 1961 due to the Berlin Wall it took 70 min to go around. After the 2002 reopening the running time could be reduced to 63 minutes, which is not compatible with any basic interval timetable. DB has solved this problem merging the circle lines with inbreaking lines from radial sections. But for running such a complicated service pattern also the infrastructure must be more complicated.

For the scope to avoid flat junctions with heavy operation constraints, the pre-war Northern Cross, which had only two flyovers, has been reconstructed with four flyovers. In this case the reconstruction was planned by the infrastructure provider, part of the railway holding DB, following indications of the train operation company, also part of the holding of the former railway monopolist. The Berlin government approving and financing the infrastructure reconstruction had made no conceptional alternative for their own. The Connex offer, which needs a simpler infrastructure, came much later.

Connex' key idea is to squeeze the circle running time down to 60 minutes using faster EMUs. This is possible substituting the EMU class 485 (50% motor axles, 0.7 m/sec² acceleration) with faster new stock (100% motor axles, 1.1 m/sec² acceleration). 60 minutes round trip time is ideal for nearly any basic interval timetable, it permits an independent operation of the circle line. Clearly the Berlin circle S-Bahn is a very specific case, first because circular lines need a very accurate operation planning and second because the Berlin S-Bahn is a closed system without any conflicting point with other rail traffic and nearly no flat junction having even better conditions than the London Underground circle line.

A similar simulation for Milan's suburban network substituting the TAF class (25% motor axles, 0.6 m/sec² acceleration) with faster new stock (100% motor axles, 1.0 m/sec² acceleration) brings significant results only on the Tunnel lines, the total need decrease from 128 TAF units to 122 units (plus 10% reserve) is not so enthusiastic. But the increase of the layover time percentage of the round trip time from 21% to 24% promises a better operation stability.

Having an anyway largely insufficient number of TAF class EMUs located at the present service holders and excluding that a new entry will come with a hundred of four car EMUs, the rolling stock choice falls back to the public administration. Acting on the tendering specifications, in any case it can influence the choice, but in the Milan case the responsibility is greater, because the high performance system needs homogenous still not existing stock. Having no skilled staff for doing that this must be delegated to a body, which is qualified in rolling stock questions and railway operation.

Seventh problem: Who has to choose the rolling stock?

Rolling stock property

Stockholm has tendered the whole suburban system in a sole batch, won by a new entry. The property of the 146 two car EMUs (50 m) passed to the tendering administration, which has also leased 15 three car EMUs (66 m) from Munich S-Bahn. This operation is possible as the market for the 15 kV AC high platform EMUs is much larger than that for the Milan standard. But the weak point of this property construction is the maintenance: how can be guaranteed that it will be done in the best way?

Eighth problem: How to guarantee adequate rolling stock maintenance?

Melbourne has tendered the suburban system in two batches based on depot and rostering criteria, won by new entries. Unlike the European tendering, it includes also the infrastructure. An independent body at contract's beginning and expiration estimates their value. In this way a maintenance in-state-of-the-art should be assured. But the expected advantages of operation competition revealed to be inferior to the friction effects of a split operation, so that now a return to a united operation in a sole batch is in discussion.

Ninth problem: Commercial or utility value for the rolling stock at contracts end?

Mannheim has tendered a still not existing system, won by the ex-monopolist. Unlike Milan the new infrastructure is limited to a simple improvement of the existing lines reducing substantially the unknown figures. The rolling stock property is of the bidder, but the service contract is practically open end. The minimum duration is 12 years renewable each 2 years. In absence of other bidders, this construction allows a reasonable depreciation for the 50 four car EMUs (66 m). Otherwise the value of partially by the tendering public administration financed rolling stock must be estimated for a future use.

Tenth problem: How to conciliate operation flexibility and rolling stock depreciation?

The Regional Administration of Lombardy is got aware that the particular technical specifications of the Milan EMUs constitute an entrance barrier for new bidders and that only the present service holder Italian state railways FS dispose of a sufficient number of the needed stock of about 600 cars. Therefore it is trying to attract new bidders besides FS by splitting the great quantity of transport services in smaller batches. But, as seen above, the splitting of the operation in up to four vertical tender batches has a high risk of compromising the flexibility of a delicate system like this in case of changes in demand or operation.

Conclusions

Milan is in the difficult situation to have the ex-monopolist railway amongst the bidders like Mannheim, no suitable rolling stock on site or to lease elsewhere like Stockholm and a complicated operation full of conflicts with other rail traffic unlike Melbourne.

- Milan's 3 kV and 60 cm platform height are unusual out of Italy, therefore a Milan EMUs' reuse elsewhere is difficult
- Considering a hundred of EMUs, 9 years of service contract are not enough for depreciation
- Splitting the Tunnel lines in four batches is not possible as there is no certainty on running times and line matching
- Dividing the other lines in two batches is no problem as faster EMUs don't change operation

Therefore the problems listed above must be fronted in a trade-off between rolling stock investments and operation flexibility. To maximise the benefits of the liberalisation a division into a short duration (9 years) whole network train operation batch and a long duration (around 25 years) rolling stock supply batch seems to be the most suitable solution.

The Milan case evidences that suburban rail system set up in tendering conditions is quite different from a normal rural line tendering. The main differences of a high performance system are a very precise operation full of conflict points and an enormous quantity of often very specialised rolling stock. The boom of new suburban rail systems has finished in Europe before tendering came up. Latecomers like Milan will have some more problem than the systems established before.

- Dividing the monopolist railway in operation and infrastructure sacrificed the symbiosis of planning of new systems
- Now the tendering public administration has to coordinate the system planning without having adequate staff and skills
- The great quantity of specialised rolling stock constitutes a natural monopoly like the infrastructure
- Splitting the high performance system in tendering batches the flexibility for demand and operation changes is sacrificed

The Milan case shows that the splitting of the monopolist railways has left a great gap on the conceptual planning level. This level must be reconstructed.