REDESIGN AND IMPLEMENTATION OF THE URBAN BUS NETWORK OF LLEIDA (SPAIN)

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ABSTRACT

We present a strategy to improve bus service in urban networks that gives equal or better transit service and saves public resources: a win-win strategy. It consists on changing from "direct lines" to mobility centers from each quarter of the city to a bidimensional "network structure" and from "schedule based" management to "frequency based" management. The implementation in Lleida, a 140,000 inhabitant city of Spain, has proven that it is possible to save 15% of the resources providing equal or better door-to-door service, but a final fine-tuning has found the proper equilibrium between "network structure" and "direct lines" to better fit the users' perception.

1. INTRODUCTION

Lleida is a city in the west of Catalonia (the region with Barcelona as capital), Spain, with about 250,000 inhabitants in the metropolitan area and 137,400 inhabitants (as of 2010) in the capital city. Lleida is one of the oldest towns in Catalonia, with recorded settlements dating back to the Bronze Age period. The area served as a settlement for the Iberian people (the Ilergetes) that gave name to the Roman municipality Ilerda after their conquest of the Iberian Peninsula. Indibil, king of the Ilergetes, and Mandoni, king of the Ausetanes, defended the Iberian tribe against the Carthaginian and Roman invasions and they are considered heroes in the city.

The city seats next to Segre river and has its "center", shopping area and City Hall (locally called "Paeria") along the old cathedral ("Seu vella", inaugurated in 1278) on top of a small hill and the river. All the quarters of the city want to have accessibility to that "center" plus the bus and train stations and the hospital. This quarter-decision making made a redundant bus network structure, especially around the old cathedral hill: most of the bus lines used to circle that hill…

Since the transit and traffic speeds are acceptable (bus commercial speed is higher than 13 km/h), resources are proportional to bus-kilometers. Due to the economic recession, the City Hall needed to reduce subsidies for most of the public services including transit. The obvious strategy of "service cuts" has a high political risk. The City Hall decided to study a new transit network structure and management that could be interpreted as a re-engineering exercise of the whole network and service.

Our CENIT (Center for Innovation in Transport) research group at BarcelonaTech University (Technical University of Catalonia) applied our previous theoretical research for optimal bus network structures in radial cities (Badia et al., 2014) to Lleida after analyzing the origin-destination (OD) flows and after performing an ABC analysis of supply (veh-km/day) and demand (pax/day) for each bus line.

The new bus network in Lleida was implemented in mid April 2013, creating a challenge of a sudden change and saving resources (most of successful changes are evolutive and/or imply more resources during a transition period). The process is currently been closed with a second iteration: to increase public acceptance, a large 3,000 phone interviews have been performed in April 2014, that will bring the criteria for the final changes. The final network structure is a compromise between the "direct services" and the "hub and spoke" or "transfer" network (radial plus orbital structure), but the savings are still large (about 15%).

2. BACKGROUND

Since 2009, Lleida had been locally improving the bus network without an integrated approach: the Council and the operator agreed to extend the service for each line provided that resources were available and the "social need" was being shown. Frequencies and routes where adapted to demand expectations like a tailor-made suit. Economic recession reduced budged availability but service cuts were politically unfeasible: a re-engineering approach was applied to save resources minimizing the impact on demand perception. The official lemma is *"Lleida is remodeling the bus network to modernize it and better match current demand needs"*.

We did not have much detailed info about transit OD flows, nor about "political weights and constraints" or "perception filters" either. These information limits together with some deficiencies in the "change process" and the bus schedule management information system and bus tracking system, created certain rejection that is currently being answered with information from a phone survey (CATI).

We decided to supply minimum thresholds for space coverage (people should walk less than 300m or 4.5min, respecting current average bus stop separation of 160m, all quarters should have access to center, bus and train stations and hospital in competitive time), and time coverage (distinction between rush and non-rush hour services, frequencies proportional to demand, value of time weights of 2 for access time and 3 for transfer time).

With a network structure the bus service has better readability, better service frequency (necessary condition for a network with transfers), and any complex city is better off (with several mobility patterns along the day, multipolar and a percentage of non-home based mobility greater that the home-based mobility). Commuters may perceive that they worsened off though: since they only travel twice a day (or four times a day) at certain times, they prefer direct services at fixed (infrequent) times (they “learn” the schedules) rather that more frequent services from many origins to many destinations, but with higher probability of transfers. Effectively, a poor service of a 30min headway but direct (no transfers) is preferred by commuters because they wait 5 min (they reach their bus stop 5min earlier than the scheduled bus time passing by that stop), as opposed to a more frequent bus service with 15min headways (but no schedules at the stop) that implies an average waiting time of 7.5min with no headway fluctuations.

Bus headway fluctuations produce bus pairing: we give worse service at the same cost. With headway fluctuations, the average waiting time (one half of the headway for identical headways) increases with a magnifying factor that is always greater than one (depends on the square of the headway variation coefficient). That’s why is very important to control the bus headways when we change from “schedule management” to “frequency management”. This was not the case of Lleida and the apps ad the VMS still show some information problems in the sense that they give “old” forecastings for the expected bus time at any bus stop and the users get mad because “the bus came early” and they miss the bus and have to wait for the next one, getting late to their appointment.

We now present the state of the art in bus design and operation, including our research at BarcelonaTech and the results obtained in Lleida. Finally we present some interesting learnings from the implementation and we derive some conclusions.

3. STATE OF THE ART

3.1 Uurban bus network design

Transit system design is a complex problem that involves three main stages: strategic, tactical and operational. In this paper we focus on the first tasks of the problem, where we define network topology, lines, stops and service frequencies for Lleida’s bus network. Many models have been developed to obtain optimal solutions for these different tasks. These models are grouped into discrete or analytical.

The first group is based on graph theory. These models allow us to work with real mobility patterns through O/D matrix and to adapt transit routes to the urban street network. In contrast, the problem discretization implies to manage a great volume of data (not always available) that constitutes a NP-hard problem. The main differences between discrete models are their objective function, the route construction criteria and the solving methodology. However, the most common criterion is to connect directly (without transfers) the greatest number of trips. The resultant networks are complex and each line that composes it works independently with regard to the others without a clear network operation. An extensive review of these models can be found in Guihaire and Hao (2008).

Analytical models based on continuous approaches, on the other hand, offer a simple tool to define design guidelines of transit network with regard to its physical and temporal variables. Its main advantage is an aggregated treatment of the data, more easy to compile, and as a consequence, to solve the optimization problem. However, these models present a high homogeneity degree of supply and demand. Objective function, decision variables and network structure are the factors that distinguish the different models developed. We emphasize one of the last models developed, the hybrid model. This consists in a hub and spoke scheme in the periphery of the city and in a mesh structure in the central area, which is defined for a grid street pattern in Daganzo (2010) and Estrada et al. (2011) and it is adapted to a radial/circular pattern in Badia et al. (2014). These hybrid schemes propose a clear network structure, which looks for adapting to the urban street pattern, and transferring is an essential step of the transport chain.

3.2 KPI and Balanced Scorecard

Kaplan and Norton (1996) introduced the concept of Balanced Scorecard (BSC) which is founded in a set of objectives aligned with strategic lines and four perspectives (financial, customer, process and organization) inside the organization to achieve the strategic goals and improve the performance. This framework is a powerful tool which allows the organization to align all actors with the strategy and allows the organization to evaluate the evolution of overall process. This evaluation is based in a set of key performance indicators (KPI) which accomplish the requirements: specific, measurable, achievable, relevant and timely. Furthermore, this KPI are going to be strategic if they are going to be part of BSC, however they are going to be operational if they are going to be part of the dashboard which is the equivalent concept of BSC when the main process to be analyzed is inside of operational field.

Particularly, in the case of urban bus service in Lleida the main strategic objective is to improve the performance of the network and it could exist a set of strategic KPI to analyze the achievement of this objective, but in the specific operational point of view is mandatory to build a dashboard which supports the planners in the process of design of new network. This matter will be described in section 4.

3.3 Change implementation

We take into consideration the 8-step process for leading change proposed by Kotter (1995). This model is well known by managers in organizations and is the most powerful source to understand the relevance of creating a vision and aligning the organization. The steps are listed below:

1. Establishing a Sense of Urgency. Help others see the need for change and they will be convinced of the importance of acting immediately.
2. Creating the Guiding Coalition. Assemble a group with enough power to lead the change effort, and encourage the group to work as a team.
3. Developing a Change Vision. Create a vision to help direct the change effort, and develop strategies for achieving that vision.
4. Communicating the Vision for Buy-in. Make sure as many as possible understand and accept the vision and the strategy.
5. Empowering Broad-based Action. Remove obstacles to change, change systems or structures that seriously undermine the vision, and encourage risk-taking and nontraditional ideas, activities, and actions.
6. Generating Short-term Wins. Plan for achievements that can easily be made visible, follow-through with those achievements and recognize and reward employees who were involved.
7. Never Letting Up. Use increased credibility to change systems, structures, and policies that don't fit the vision, also hire, promote, and develop employees who can implement the vision, and finally reinvigorate the process with new projects, themes, and change agents.
8. Incorporating Changes into the Culture. Articulate the connections between the new behaviors and organizational success, and develop the means to ensure leadership development and succession.

4. METHODOLOGY

The methodology used to design the Lleida’s bus network is composed by three phases: transit network guidelines for Lleida (conceptual and analytical approach), analysis of current network and definition of dashboard for design and, finally, design of the network for implementation.

The first phase, the conceptual and analytical approach, is composed by two steps. First, we look for the guidelines to define the physical network and an initial approximation of average frequency. Second, service frequencies are adjusted to allocate the limited resources to each line in function to their estimated demands.

To face the first step we use the model presented by Badia et al. (2014). As it has already been commented, a new approach wants to be implemented in Lleida’s bus network. This should present a clear structure by means of its adaptation to urban street pattern. The Lleida's pattern is generally radial-circular, the same in which Badia et al. (2014) base the development of their model. With this model we obtain the optimal theoretical layout for Lleida, i.e., the number of lines that compose the system and its line and stop spacings.

This design will have to be adapted to the real layout of streets. The model also allows us to know resources that agency has to invest in an optimal scenario as a result of the trade-off between user and agency costs.

Once physical variables are fixed, service frequencies are adjusted. The O-D matrix of the city and number of passengers carried by each line of the old bus network give us the possibility to estimate users of the new lines. New headways are calculated in function of these loads.

The second phase is the adaption to an implementable network. This task consists in taking the idealized network and adapts it to real streets and stop location. The evaluation of the implementable network is calculated with a dashboard defined specifically for this project. The same dashboard is used to evaluate the current network and it constitutes the tool that planners could use to compare different version of networks.

The third phase is an iterative method of scenarios evaluation. For this purpose a software application was developed ad hoc for this project which lets planners to evaluate different scenarios semi-automatically. It is an advantage regarding current solutions that requires a lot of information and costly models.

4.1 Transit network guidelines for Lleida

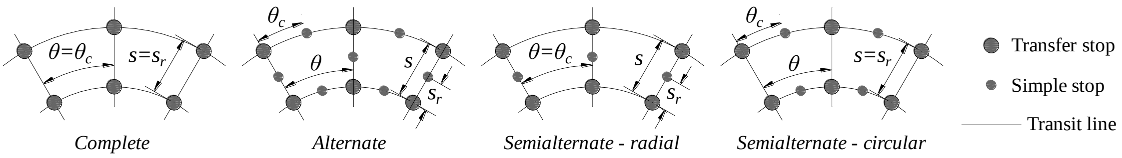
The first step to apply Badia et al.'s model (2014) is the definition of its input parameters for Lleida. These parameters, summarized in Table 1, take into account characteristics of the city, transport technology, users, demand and unit agency costs. It is important to highlight those related with the time perception. Among the different times that users invest in the transit system, walking and transferring are penalized. A relevant percentage of Lleida's users are senior people and all of them are used to a high spatial coverage, where stop spacings are short. For these reasons, we consider that the access time is poorly perceived with regard to the other times and it is penalized by a weight of 2. Moreover, we also penalize transfers by means of δ parameter, which is equivalent to kilometers that a user walks in a transfer. Users in Lleida have usually worked with direct trips and the new network approach implies an important change in their behavior. The value of δ considered is 0.15 km, which is equal to a time of 3 minutes per transfer, and moreover, this time is penalized by a weight of 3. In contrast, waiting time has a less negative perception since current headways are generally high (when headways are longer than 15-20 min, people "memorize" the bus passing "schedule" at their stop and they drop by about 5 min before), therefore, it is not penalized.

Transit demand in Lleida is low, only 3,500 pax/h, and presents small peaks during the day, considering a ratio between rush hour (Λ) and average hourly (λ) demands of 1.5. We assume that this demand presents a decreasing curve with regard to city center, where the number of trips is high than peripheral neighborhoods. We assume a linear decreasing curve where at city center its value is maximum and at the city boundary is null. The city size is approximated by an average radius of 2.5 km, although in some parts of the city, low density neighborhoods or industrial areas are situated further away, and in others areas the city development is smaller. The transport technology parameters for a conventional bus mode and the value of time are the same as in Badia et al (2014).

Input parameter	Description	Units	Value
Λ	Demand at rush hour	pax/rh	5250
λ	Average hourly demand	pax/h	3500
R	City radius	km	2.5
μ	Value of time	€/h	15
δ	Walking transfer penalty	km	0.15
v_{FFS}	Free flow speed	km/h	25
w	Walking speed	km/h	3
τ	Dwell time	s	30
τ'	Boarding time	s	3
C	Vehicle capacity	pax/veh	80
SF	Occupancy safety factor	-	1.2
$€_L$	Infrastructure unit cost	€/km-h	18
$€_V$	Operative unit cost	€/veh-km	0.85
$€_M$	Fleet unit cost	€/veh-h	35
w_A	Access time weight	-	2
w_W	Waiting time weight	-	1
w_t	Transferring time weight	-	3

Table 1. Input parameters of network design model for Lleida's bus system.

The decision variables of the model are six: line and stop spacings of radial and circular lines (θ, s_r, s and θ_c respectively), portion of central area size α and central headway H. Line and stop spacings maintain an integer relationship, the values of which have been restricted in this study. We propose the same configurations such as Estrada et al (2010): complete when all stops are transfer points ($s_r/s= \theta_c/\theta=1$), alternate when there is a simple stop between each pair of transfer points ($s_r/s= \theta_c/\theta=2$), and semialternate that can be radial when in radial lines there are both simple and transfer stops and in circular lines only transfer stops ($s_r/s=2$ and $\theta_c/\theta=1$) or vice versa that is circular ($s_r/s=1$ and $\theta_c/\theta=2$). This decision avoids moving away transfer points too much from users.



Complete *Alternate* *Semialternate - radial* *Semialternate - circular*

Fig. 1 - Four network configurations studied for Lleida's bus system.

The last step is the minimization of the objective function (1), where both user and agency costs are included. In this way, we obtain the optimal values of the decision variables that define the optimal network configuration. Among agency costs, infrastructure (L), fleet (M) and kilometers traveled (V) are considered. As user costs, we evaluate all the time that users waste along the whole transport chain: access (A), waiting (W), in-vehicle (T) and transferring ($\delta\ e_T/w$, where e_T is the average number of transfers per trip). This objective function is subject to some constraints like possible values of the decision variables (1a) or vehicle occupancy (O) (1b). In the case of Lleida, we have to include others related to a limited number of resources, maximum fleet and vehicle-kilometers traveled. The new network cannot need more vehicles than the previous network, M_{max}=32 vehicles. Also, it has to reduce around 20% the current vehicle kilometers traveled, V_{max}=460 veh-km/h.

$$min\{Z = C_A + C_U = [€_L L + €_V V + €_M M]/\lambda\mu + [w_A A + w_W W + T + w_t(\delta/w)e_T]\} \tag{1}$$

$$s.t.\quad s > 0;\ \theta > 0;\ s/R \leq \alpha \leq 1;\ s_r/s = 1\ or\ 2;\ \theta_c/\theta = 1\ or\ 2 \tag{2}$$

$$O \leq C;\ M \leq M_{max};\ V \leq V_{max} \tag{3}$$

In Table 2, the bus network characteristics are summarized for Lleida. The optimal configuration is an alternate, where are introduced simple stops in all lines. In the current scenario, with limited resources, transit network uses all available vehicles to serve around five lines with an average central headway of 8.8 minutes. Transit system operates at full capacity and users support the great part of the system costs. It is estimated that the total system cost achieves 45.28 min/p-h, that is the same as 11.32 €/p-h.

Variable	Optimal transit network
α	0.62
H (min)	8.8
θ (º)	48
θ_c (º)	24
s (m)	1080
s_r (m)	540
Z *[a] (min/p-h)	45.28 (31.53)
C_U/C_A *[a]	16.97 (11.51)
# lines	5.19
# radial lines	3.75
# circular lines	1.44
L (km)	38.82
V (veh-km/h)	446.59
M (veh-h/h)	32.00
A *[a] (min)	20.29 (10.14)
W (min)	8.54
T (min)	8.54
v_{com} (km/h)	13.98
e_t	0.80
0/1/2 transfers (%)	26.91/66.43/6.66
O_{max} (pax/veh) *[b]	79.70 (24.54)

*[a] unweighted costs in parentheses; *[b] maximum occupancy is always in radial lines, in parentheses maximum circular line occupancy.

Table 2. Optimal network characteristics for the constrained and an unconstrained

scenarios.

4.2 Transit network analysis

In this section, current network is going to be analyzed to understand the key points to address the improvements and match them with new design.

First of all, the demand follows a radio-centric pattern. The most important flows of demand exit from the districts to arrive to the center and the OD matrix is very symmetric. This estimation is founded in the data collected by Urban Mobility Plan of Lleida City which holds that 8.4% of movements are by bus and 11% of them are located in peak-hour in the morning. With this data is possible to calibrate a gravitational model which allows planners to estimate accurately all of the relations inside the city. There is a relevant relation between the center of the city and the district where the hospital is located. Also, districts like “Pardinyes”, “Cappont” and “La Bordeta” contribute with high number of passengers to the center. There are other relevant relations between districts with a lot of population and new points which generate demand and movements.

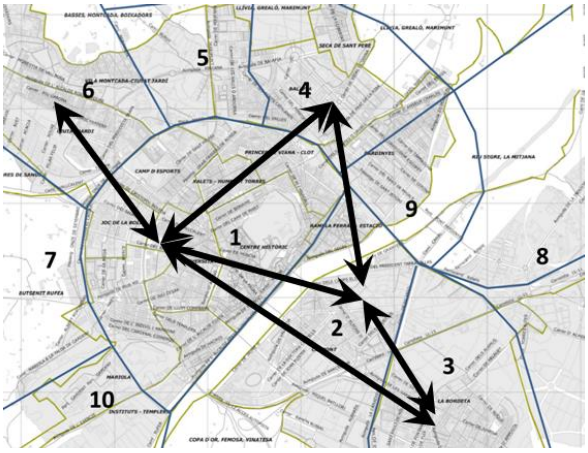


Fig. 2 - Main flows of bus passengers in Lleida.

Second, the performance of current transit network service is provided, partially, by the table 3 which summarizes the main KPI for current bus lines supply. The average commercial speed is high (13.3km/h), taking into consideration the urban development and the low extension of bus lines. Furthermore, the center of the city holds an average speed of 12km/h, this increases until 15km/h when lines arrive to districts behind the center and until 24km/h when lines connects the center with the far districts. Paying attention to these characteristics, Lleida is a suitable city to design a hierarchical transit network.

Third, the demand by line (pax/day; due an agreement of confidentiality, detailed data is not provided in this paper) is aggregated in figure 3 and correlated with supply (km/day and exp/day). These three parameters are KPI for design and the interest they hold is that planners can understand the balance between supply and demand. The set of lines around the center shows a good load factor, particularly the lines L1 and L2 which are two orbitals around the city. Also, the reason of high performance in lines like L5 (“Hospital – La Bordeta”) is that it aligns high demand flow along the supply corridor. However, other set of lines show low performance because they provide high frequency for low level of demand which is far from the center, unbalancing heavily demand and supply. Regarding resources, the number of vehicles in use is 52 and it is the key driver of operational cost.

The local government and the operator desire to redesign the network to correct this unbalances and to cut-off operational cost. To address the new design a dashboard is defined. This consists in the next set of key performance indicators:

1. Total number of resources.
2. Total number of lines.
3. Time window period of service by line.
4. Distribution of peak hours by line.
5. Distribution of resources by line.
6. Distribution of frequencies by line.
7. Cycle time by line.
8. Total kilometers by year.
9. Percentage of reduction of total kilometers by year.
10. Travel time estimation in the transit network (improvement related current scenario).

Line	**Expeditions by day**	**Cycle length (km/exp)**	**Cycle time (min)**	**Commercial speed (km/h)**
L1	87	3.9	20	11.9
L2	85	5.3	29	10.8
L3	49	5.9	32	11.0
L4	16	8.6	44	11.6
L5	68	7.8	36	12.9
L6	39	10.7	39	16.4
L7	57	8.7	38	13.6
L8	46	12.1	47	15.5
L9	51	8.1	45	10.8
L10	65	6.5	31	12.4
L11	17	16.0	39	24.3
L12	23	6.8	30	13.4
L13	26	4.9	26	11.2
L14	11	12.8	50	15.3
LP	11	14.8	60	14.8
L17	31	11.1	48	14.0
L18	26	11.2	52	12.8
L19	3	17.4	35	29.9
BT	2	14.6	63	13.8
	714	**7.9**	**36**	**13.3**

Table 3. Main flows of bus passengers in Lleida.

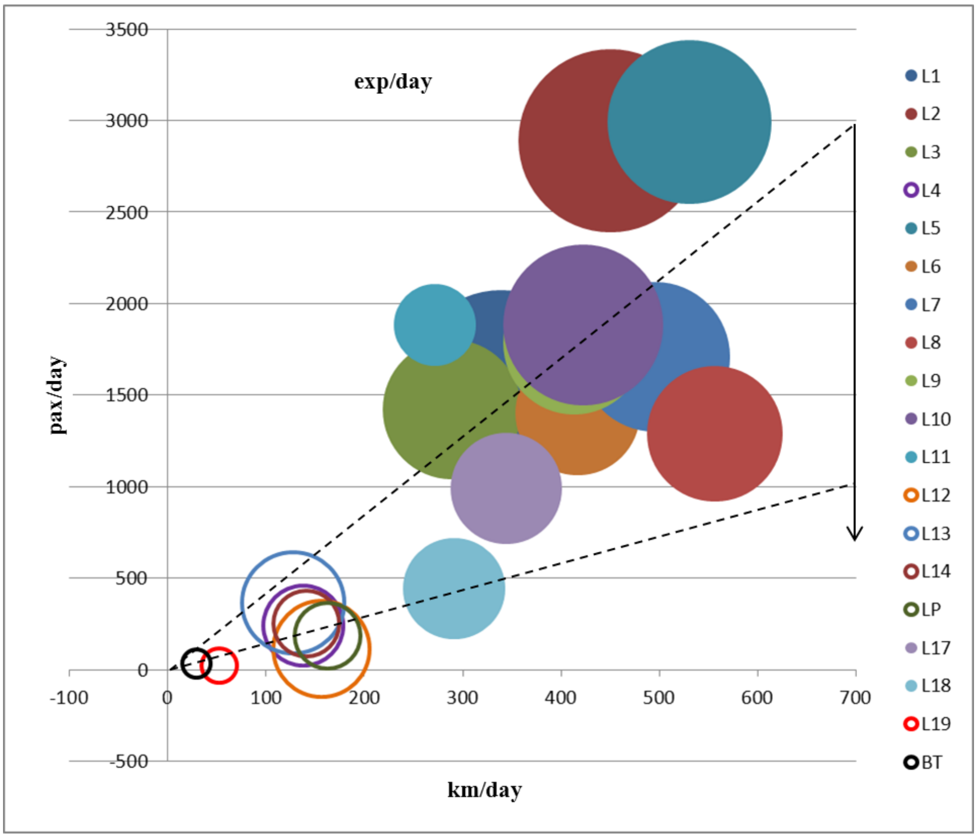
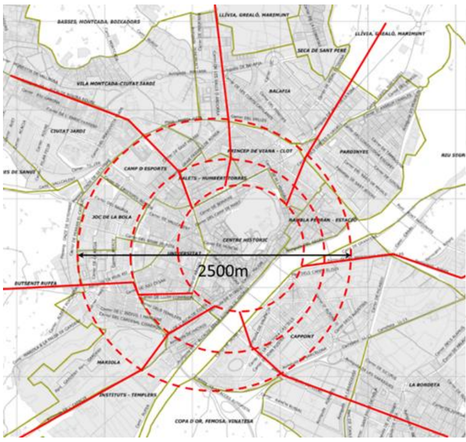


Fig. 3 - Distribution of kilometers, passengers and expeditions by day and line.

4.3 Design of the network for implementation

The initial network structure for design (figure 4a) is an idealization of guidelines and it is based on analytical model. For implementation, the first approach adapts the corridors to the streets and the principal stops are transfer points (figure 4b).

After that, the design process consists on iterations and a collaborative decision making framework between operator, government and team of planners. This process allows the team to achieve the final proposal. Every scenario proposed was evaluated with tailored tool developed ad hoc for this project. This tool evaluates generalized cost of transport.



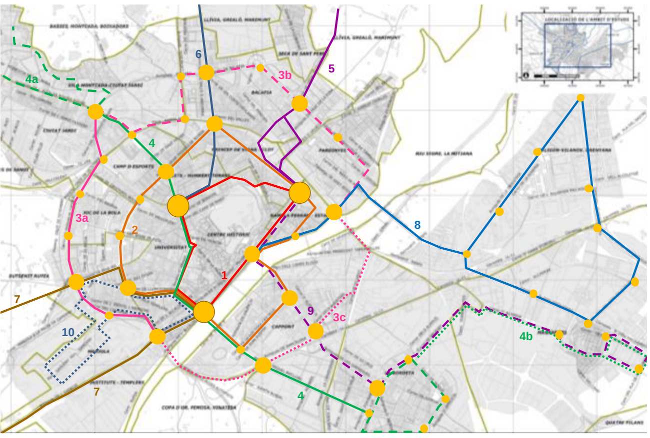


Fig. 4a - Idealized network. **Fig. 4b - First approach of new design.**

5. RESULTS

The transit network design proposed by the planner’s team balances well demand and supply. Also, thecost savings achieves 17% measured in total kilometers by year. In addition, the overall network is more efficient because the travel time was reduced an average of 3.5 minutes (standard deviation of 2.0 minutes). Obviously, there are some pairs for which the travel time increases (nearest points with alternative and suitable modes of transport –bike, walking…-), but there are many pairs with high demand and less travel time than in the base scenario.

The main differences with previous transit network consist on the next key concepts:

1. Elimination of the “district-line” concept (or the “quarter-landlord” ownership of the bus lines). From “direct lines” to mobility centers from each quarter of the city to a bidimensional “network structure”.
2. The elimination of oversupply (redundancy) in the center by lines overlapping.
3. Introduction of the double direction of lines to reduce travel time and increase the perception of network structure.
4. From point-to-point network to hub-and-spoke network. Locating relevant stops to transfer and improving frequency to decrease the cost perception of this transfer.
5. Two time windows (peak and off-peak hour) to contain operational costs and to match better demand and supply.
6. Paying attention to accessibility cost for passengers (maximum walking distance to the stop: 300m).

Table 4 summarizes some of KPIs of design and figure 5 shows the final proposal for implementation.

	L (km)	Peak and off-peak hour		CT (min)	Fleet				Headway				Speed	Total km
		PH	OH		L PH	L OH	Sa	Su	L PH	L OH	Sa	Su	L PH	2013
L1	3.7	6.0	9.0	18	3	2	2	1	6	9	9	18	12.2	134,842

L2	6.0	5.0	11.0	36	4	3	3	2	9	12	12	18	10.0	166,986
L3	6.4	5.0	11.0	36	4	3	3	-	9	12	12	-	10.0	153,531
L4	7.5	13.0	0.0	30	1	1	-	-	30	30	-	-	15.0	49,900
L5	11.9	9.5	6.5	65	5	3	3	3	13	22	22	22	11.0	228,122
L6	14.2	13.0	2.5	60	6	6	3	2	10	10	20	30	14.2	286,304
L7	18.8	13.0	2.0	75	5	5	2	2	15	15	38	38	15.0	408,262
L8	7.3	11.0	4.0	36	3	1	1	2	12	36	36	18	12.2	116,652
L9	12.7	13.0	0.0	60	1	1	1	-	(13 exp/day)				20.0	44,307
L10	20.0	13.0	0.0	45	1	1	-	-	45	45	-	-	16.9	59,236
LCC	10.0	6.0	0.0	60	3	1	-	-	(6 exp/day)				10.0	14,082
														1,662,223

Table 4. KPIs for final network.

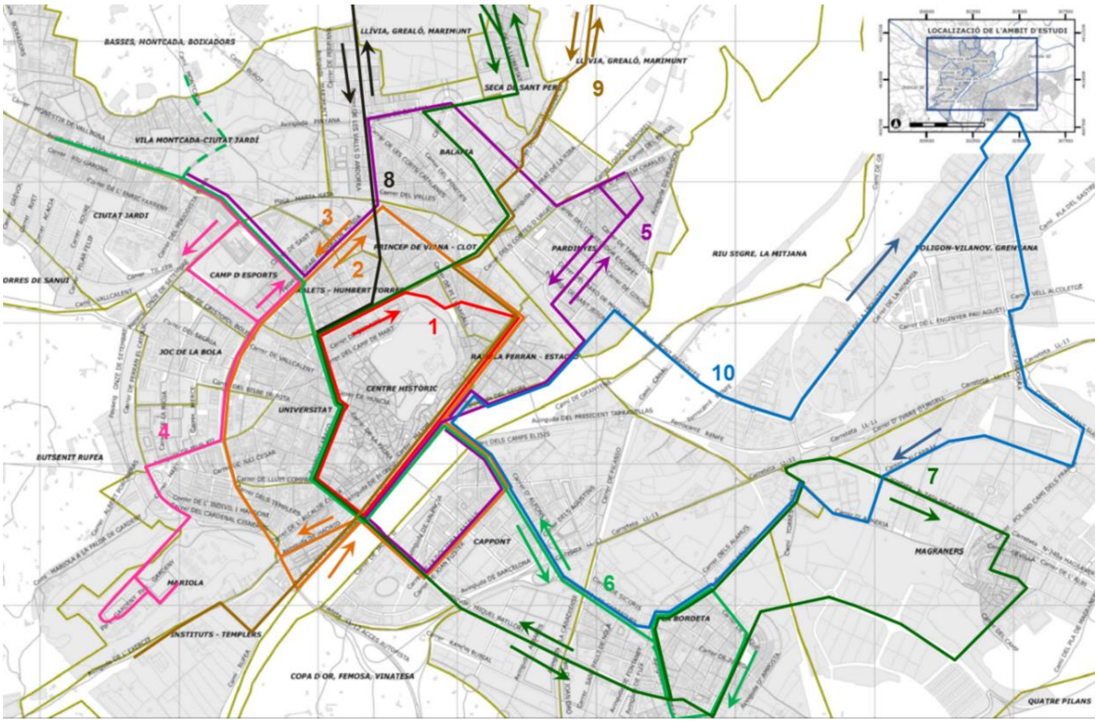


Fig. 5 - Proposal of new transit network.

6. IMPLEMENTATION

The implementation phase has three main areas to pay attention: dialog interaction with principal players or stakeholders in Lleida City (neighbors), organizational and operational change and, finally, communication plan.

First, the dialog interaction let managers and planners to show the network proposal to the districts: the large efforts invested by the transit operator and, especially, by the technical members of the City were crucial. The results of this process are inputs in the design process that allow planners to introduce some changes to improve the nice perception of the solution. Also, this process is very important to generate the coalition to drive the change and to make sense of urgency.

Second, in this phase the operator and the Council change the location of some stops and the information provided in these sites. Also, the fleet and human resources were suited and trained to the new operational procedures. To get the alignment of the overall organization is very important to success in these changes without a transition phase.

Third, in point of view of planners, changing process could be carried out with a transition phase when a lot points in common exist, however the main concept between two network structures in Lleida are different (no-transfer to transfer). For this reason, the migration between networks was planned in a short period of time: disruption change. In this case, the communication plan is a critical activity. The aim is to provide accurate information to people in Lleida to achieve they percept the benefits of the new design since the first moment.

7. CONCLUSIONS

The main conclusions are summarized in this section. First of all, the methodology of network design combining the analytical method and the iterative evaluation with a tailored tool has been very suitable to the characteristics of the project. When the implementation is a requirement a lot of changes are incorporated in the process and is mandatory re-evaluate the performance of the system to accept or resign some demands.

To drive the design process with a dashboard is a powerful tool to not bias the main objectives and the strong requirements. The same dashboard in design phase can constitute part of the dashboard for operational management in service. This set of KPI is the powerful resource to implement an operational strategy. It could be more interesting to include this KPI in private concession agreements.

The new transit network in Lleida balances very well demand and operational expenses. With fewer resources the transit network allows passengers to decrease their travel time. However, customer experience could be a critical factor if the impact of transfers is underestimated or value of time is not accurate. For this purpose is recommended to do a sensitivity analysis.

One of the most critical factors of the transition of networks was not the technical task of design. This one is related to tangible aspects of the network and planners are able to drive requirements easily. Really, the main critical task is to lead the change in the community of stakeholders.

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