URBALIS Evolution: Controlling the Performance

AUTHOR NAME 1, AUTHOR NAME 2
Affliation Line 1
Affliation Line 2
Affliation Line 3

ABSTRACT

The demand for urban and suburban transport is changing very rapidly in response to the sustainable development stakes of big cities and urban agglomerations. In this context, the public transport authorities are asking for bigger and better transportation capacities and a higher level of performance. The goal is to achieve high level of performance that must be accompanied by a high level of safety and maximum comfort for the passengers. This paper identifies the improvements of the URBALIS piloting system from ALSTOM Transport. First, the requirements were established based on a thorough analysis of the performance needs of urban transport systems. Since the performance needs are quite significant, two steps were needed to control the performance level and to guarantee the performance that was achievable and observable on site in commercial operation: process management and follow up of performance. This paper also reports the performance of the simulator X-DrivE that has been developed 1) to support the management, 2) to execute the performance follow-up process and 3) to validate all the improvements of the URBALIS piloting system. The performances achieved with the simulator on site conformed to the studies carried out in the factory with different application domains such as: train, metro and trams, heavy or light metros, steep slopes. We have observed that the time taken to fine-tune the URBALIS piloting system has been reduced by a factor of three with the engagement of X-DrivE. Furthermore, this paper discusses how the works in the factory and the use of endurance tests (robustness) have contributed to the time efficiency as well as of system fine-tuning. In this paper, ALSTOM Transport has shown how different steps as well as the representative simulator X-DrivE have allowed us to concentrate our efforts on the great project of the future: the optimisation of energy consumption.

Keywords: Urban transport, railways, automatic metro, automatic piloting, assistance in piloting, simulation, performance, ATC, ATO, CBTC.

I. INTRODUCTION

Public transport systems reflect the policy and the durable development of megapolises and megalopolises. The transport authorities of these big cities wish to have at their disposal public transport systems that are safe, reliable, and comfortable and that provides a high level of performance. Besides, the energy problem, one of the essential components of sustainable development, becomes a major preoccupation of the operators.The needs of operational performance of a system of transport are expressed by the transport authorities or the operators in the specifications and tenders.

A system of automatic piloting, or a system of assistance to piloting, allows the operator to respond to certain performance requirements. Within the framework of the URBALIS products, ALSTOM Transport has developed an automatic piloting system and an aid to piloting by taking account of the future and present expectations of transport authorities and operators. In order to do this, the signalization teams of ALSTOM Transport have considered as a reference, the system of automatic piloting of the metros of Santiago Line 1 and the Hong-Kong Lantau Railroad, started in 1996 and 1998 respectively.

In examining the needs of the performance of transport systems to be begun in the years 2000, and then basing oneself on the tendencies expressed by the operators, a new system of automatic piloting for the URBALIS product has been defined. Its design has been thought out with a concern for mounting accountability, such that the project can easily benefit, if required, from the latest innovations and improvements.

After a brief description of the URBALIS product, a first part describes the need to control performance. The second part deals with the different stages which have led to the design of a new system of automatic piloting.

The third part of this document describes the organization put in place, as well as the skills solicited, in order to achieve the expected level of performance. A process of management and follow-up of the performance has thus been defined. This process begins with the tender phase. At each stage of the project, specific skills are required. This process constitutes a key element in the implementation of the methods and techniques which end up in the performance of the public transport system.

In order to support process management as well as performance follow-up and in order to validate the technical choices of the automatic piloting solutions, a tool has been developed.

This tool is used from the tender phase itself and is subsequently used until the entry into service, with a view to verify and validate the performance of the system of transport. This tool can be used to identify a change in the performance workable by the system of transport and to anticipate, if need be, the necessary modifications with a view to furnish to the operator, a solution which is adequate for the operator's expectations.

X-DrivE Simulator, described in the fourth part, is the simulator designed and developed within the framework of the URBALIS projects. This tool allows the reproduction of the dynamic behavior of the trains and to put in place the automatic piloting system. X-DrivE Simulator can also simulate the performance of a transport system, for example, the dynamic intervals between trains and the time taken by a single trip.

Examples of projects and applications are cited in the last part of this document in order to illustrate the management of the performance within the range of URBALIS products.

II. URBALIS: A BRIEF DESCRIPTION

URBALIS is an Automatic Train Control (or ATC) system that protects trains. . It is made up of two sub-systems: the ATC Sol (disembarked) and the ATC Bord (embarked on the train). There exists several modes of transmission between the ATC Sol and the ATC Bord, such as: transmission by the rails or transmission by the radio waves. In the transmissions by radio, URBALIS uses a technique of transmission by guide waves, a technique which allows a reliable and performing solution in all types of tunnels. URBALIS is a CBTC (Communication Based Train Control) solution.

The ATC Sol guarantees the authorizations of the movement of trains in safety. One function consists in locating the trains on the network and creating a protective zone around these trains. A second function consists in sending authorizations of movement to the trains. These authorizations must be established and transmitted safely in order to eliminate all risk of accident.

The ATC Bord is made up of two components: a security component called the ATP (Automatic Train Protection) and a functional component, called the ATO (Automatic Train Operation). The ATP verifies permanently the safety context of the train (doors closed outside of the passenger exchange zones), the validity of the authorizations of movement of the train and ensures that the train is driven by respecting the rules of safety. Among the rules, the ATP verifies that the train will be able to stop upstream from the security points (restrictive signals, other trains).

Once a safety condition is no longer validated or respected, the ATP applies an emergency brake until the train comes to a complete stop. The ATO manages the running of the train, as well as the automatic piloting system and assistance to the piloting of the driver. In this paper, both the automatic piloting system, and an assistance system to piloting are described. The automatic piloting system allows the driving of the train by sticking to the guidelines of security as close as possible without sacrificing the comfort of the passenger and a high level of performance. The assistance system displays to the driver the speed guidelines which allow the former to stick to the trip time of the train. URBALIS evolution also has a mixed piloting mode in which the automatic piloting system can take or leave the responsibility of driving the train to the driver.

2.1 Context and needs of performance control

Until the middle of the 90s, the automatic piloting systems were installed on the lines whose railway signalisation (signals + speed guidelines) was defined for achieving a higher level of performance as desired by the transport operator. Their design was limited to simple automation and an elementary system of controls. An example of ATO for such a type of project is the one in Santiago, Chile (Line 1), installed on a metro with rubber tires.

The last installation of this type of piloting system was carried out in Hong Kong (in collaboration with the airport and the centre of Hong Kong) in 1998. This line is a suburban link, with an interval between trains of 2 two minutes. The presence of elevator doors has imposed precision stopping in the station of 35 cms in order to allow an optimum passenger exchange.

Since the years 2000s, the level of performance required for an urban transport system has not stopped growing. The intervals between trains diminish. The keeping to the schedule and, therefore, the trip time, is a very strong requirement. The multiplication of projects with elevator doors means that the stopping position of trains should be very precise. This demand concerns also the types of diversified material: metros on rubber wheels, metros with iron wheels, suburban trains, power by catenary systems or third rail, tramway with or without power through the ground (APS).

Certain requirements are specific to operators. For example, operators want the power to compensate for certain failures like the temporary loss of breaking capacity of the train. In the event such an incident happens and the train is in the terminal phase of stopping at a station, it is possible that the train would stop beyond what is tolerated around the nominal stopping point declared by the signals. The opening of the doors is not possible and a repositioning of the train is necessary. URBALIS Evolution allows this maneuver in automatic mode, something which limits the disturbance of the operation.

Certain operators express at times the wish to use a piloting system URBALIS in support of driver or of an existing embarked piloting system. The system of piloting URBALIS is used in the critical zones from the point of view of performance.

The requirements expressed above are contractual and are often accompanied by heavy financial penalties when they are not met. The operators are also more and more vigilant about the consumption of energy and it is necessary to propose a solution to this issue.

ALSTOM Transport has therefore defined and conceived a new system of automatic piloting by prioritizing different achievable performances in a strict order of priority: the performances

1. Optimize the driving of the train within safety limits
2. Control the performance of stopping at a station
3. Controlling the time taken between stations
4. Control the intervals between trains
5. Optimize driving such that energy is conserved.

In effect, the controlling of the trip time, for example, cannot be achieved if the system of automatic piloting is not sanctioned by the safety system and if the stopping at the station is correct. If one or the other two conditions is not respected, it is clear that it is difficult to guarantee a trip time with accuracy.

The same thing is true for the controlling of energy consumption, which is a stake for the future. A driving of the train in terms of optimized energy consumption can be implemented efficiently only if all the other performances are achieved and controlled.

The kinematic measure (displacement, speed, acceleration) is done through a sensor called odometer, installed on an axle. When this sensor is installed on a free axle, there is no traction or braking effort on this axle: consequently, without blockage slipping of the wheel, an accurate kinematic measure is easy to obtain. Nevertheless, the existence of free axles reduces the braking and traction capacities of the rolling stock and creates disparities in the distribution of efforts along the train. The railway transport operators therefore require more and more the installation of an odometer on non-free axle so that the train can distribute the orders of traction and braking on all the axles. The system of automatic piloting URBALIS drives the train by trying to anticipate and avoid blockages and slipping of the wheel, so that a kinematic measure is the most reliable possible.

The kinematic measure being rendered reliable, it was necessary to develop a system which guaranteed the driving of the train without the safety system unleashing a sanction. An algorithm of the estimate of time before the sanction has been developed. The system of automatic piloting drives the train by taking into account a time margin with respect to the estimated moment of letting loose of the emergency braking.

In order to guarantee the stoppages in the station, with a great degree of accuracy, a system of prediction of the reactions of the train, as well as a predictive order have been put in place.

Once the piloting is controlled, the objective was to be able to decrease the trip time. In order to do this, the margin of time before the sanction by the safety system must be reduced to a value that is as close as possible to the reaction time of the train. This approach was rendered possible thanks to the utilization of a quick and robust order.

In order to facilitate the installation of the robust order, all the piloting requirements emanating from various functional requirements (for example, stoppages at stations, speed limits, safety stoppage points) are dealt with in a homogeneous manner.

In order to be able to implement these piloting principles in the microprocessors offering limited resources, methods and techniques of applied mathematics, notably optimum research, have been utilized so that the load of calculation can be reduced.

The time of load of calculation of the piloting sytem has in this way been reduced by 30%.

Through its properties and the performance obtained, the robust order has on the one hand replaced the predictive order and on the other has allowed the easy decorrelation of notions of deceleration and breaking. For example, on a gradient it is possible to obtain a deceleration without breaking, be it in lightly tractioning or in not giving any order, and this within a very short reaction time.

Beginning with the control of the driving of a train, a new objective of performance has been targeted : guaranteeing the trip time with an accuracy of the arrival time of less than three seconds. A module has been developed in order to control this performance.

In the middle of the years 2000s (?), communication by network between the train and the automatic piloting system embarked, of the type CAN ou MVB, was developed. This communication allows designs in which the orders of traction and of braking are entirely dissociated, authorizing even the simultaneity of orders. Thus, the starting and the stoppages on steep slopes have been able to be managed integrally, by the automatic piloting embarked (in a similar manner to the "taking off on a hill" of an automobile driver: traction but all the while maintaining the break).

The communication by network has also authorized the development of piloting strategies depending on the condition of the train, in case of damage. The piloting system adapts itself to the context of the number of elements of propulsion and breaking, in service.

2.2 Evolution of urbalis automatic piloting system

The initial version of the URBALIS piloting system allowed a performance control when it is autonomous. A functionality was added to it: Sharing of train driving with another system or even with the driver. Within the framework of renovation, it was possible to conserve the whole or part of an existing system and to utilize the URBALIS piloting system only in critical zones where there was a need for improved performances.

At this stage of the design, the criteria of performance directly and easily measurable, when carrying out the embarked system of automatic piloting, can be controlled. It is therefore possible to bring to bear all the evolution of techniques and methods which will lead to the optimization of energy consumption.

The following synoptic summarises the changes made to the URBALIS automatic piloting system in order to respond to the three first priorities of performance control. The main deadlines of application are mentioned in order to situate the contribution of these improvements.

Table 1

Year	Events
1998	Reference projects: Santiago of Chile and Hong Kong
	• Advanced odometers in order to measure the kinematics on a non-free axle • Estimate of time remaining before the sanction by the ATP • Serving to a fixed time of the ATP sanction • Automatic repositioning in station.
2003	Singapore: North East Line
	• Digital optimization: load of calculation reduced by 30% • Simplification of the piloting automation thanks to the definition of properties by piloting requirements: safety, performance, functional • Installation of a robust order • New piloting module of the train in order to respect the arrival time given
2007	Urbalis 200: Shanghai L3 et L4, Delhi Rail and Metro Corridor, Santiago of Chile L4, Daegu L2 and Incheon (Korea)
	• Separated and combined order of the traction and breaking • Advanced management of departure (taking off) • Transmission of the orders by network • Strategy of piloting depending on the state of availability of the train • First version of the new module of piloting that is energy efficient.
2008	Urbalis 300: Lausanne (M2), Singapore Circle Line Urbalis Evolution: Beijing line 2 and Airport Link
	• URBALIS system of piloting in support of another system or of the driver
2009 2010	Sao Paulo, Milan line 1, Shanghai line 10, Dubai (tramway with APS)
	• Optimization of energy consumption
2011	

It is important to note that any improvement of URBALIS piloting (Urbalis 200, 300 or Evolution) is directly transposable to the other URBALIS piloting systems.

III. MANAGEMENT AND PERFORMANCE FOLLOW UP PROCESS

The preceding section described the technical evolution which has allowed the control of the first three performance needs. In order to proceed to the deployment of the technical solution, management and performance follow up process has been defined and installed since the beginning of the 2000s. This entire process is initiated from the tender phase and is applied until the entry into service of the line of public transport. At each stage of the project, the process requires specific competencies and tasks.

The process unfolds like a cycle in V, the first phase of descent of the cycle corresponding to the response to the tender as well as to the specification, the design and the installation of the system. At the end of the first phase, the regulating of the piloting system is carried out in the factory. The second phase, that is, the rise of the cycle, begins from the very first tests of the piloting system on site and is pursued until the verification of all performances after the entry into service.

From the very tender phase, specialists in railway signalling and automation analyse the profile of the transport line, the performances of the rolling stock used as well as the performances asked for. They verify whether the performance asked for meets the performance actually achieved. If a performance is not achievable two types of pressures can be expressed:

- The first towards the external systems at URBALIS, for example, the performances of the train or the speed profile of the line
- The second towards the specification and design teams

These pressures allow the system of piloting URBALIS to respond to the performances asked for.

During the entire phase of specification and design, the performances are regularly verified, particularly at each evolution or demand for change in the features of the rolling stock or of the carriageway profile or of speed. Studies are carried out in order to be able to respond at any moment to the requirements of the operator as far as performance is concerned.

The team specialized in automation studies the performances of the rolling stock (train or trams) in order to prepare tests which will allow the development of the piloting system. Meetings are organized between the teams and the equipment suppliers of the rolling stock.

Once the installation is over and the rolling stock (train or tram) is available, the tests – that are previously defined - are carried out on site or on a trial track. The recording of the tests are sent to the factory for an indepth analysis on a simulator. The first stage consists of verifying the behavior of the simulated models conforms to the behavior of the train on site.Then the setting and the parametering of the piloting system URBALIS are finalized. These settings are put through endurance texts or tests of robustness and of dispersion in order to verify the performances of the piloting in terms of driving. This verification done, settings are provided to the simulation project teams in order to verify the performances in terms of the time taken by the trip and the intervals between trains.

In order to control the trip time and the dynamic intervals between trains, a module of simulation of the movements of the trains has been developed. The objects of the railway signalization, such as the signals, the itineraries and the planning of the missions of the trains have been encapsulated in a way as to be able to respond to all types of situations and simulate the dynamic behavior of the network.

X-DrivE simulates thus the piloting system URBALIS on the representative data of the transport system.

The results obtained with X-DrivE are accurate :

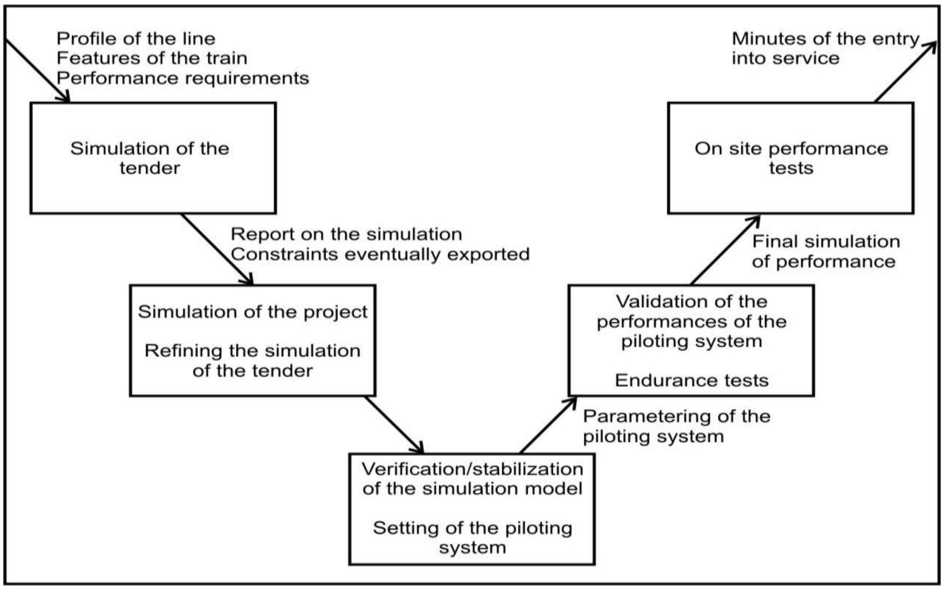

Figure 1

Once the simulation phase was over, a follow up phase of the performance on site was launched. At the end of this phase, a report of the test and of the validation of the performance was written. This report can be integrated to the minutes when the piloting system was entered into the service of the entry into service. The diagram below describes from the macroscopic point of view the cycle put all the different activities there were in place.

IV. THE X-DrivE SIMULATOR

For buttressing the evolution of the URBALIS piloting system as well as for the management and follow up of the performance process, the X-DrivE (eXtended Driving Environment Simulator) has been developed.

The optimization of the driving of the train and the control over the performance of stopping at a station have been obtained thanks to an adequate modelizing of the behavior of the train and to a precise simulation of the piloting system. In order to do this, X-DrivE integrates a design and validation module of the embarked ATO. Thus, each evolution of the system of piloting URBALIS has been integrated in the simulator X-DrivE for the purpose of technical feasibility and validation of the on board software.

- Stopping position simulated with an error margin of maximum 3 cm
- shortest trip times between two stations simulated with accuracy of 1 second.
- Trip times in the lowest hourly traffic simulated to an accuracy of 3 seconds
- Dynamic interval between trains simulated to an accuracy of 3 seconds.

In terms of energy consumption, X-DrivE does not simulate the energy consumption of a transport line. However, on the other hand, the economical piloting module provides representative results of the variation in the consumption of energy, in other words, the simulator permits one to put a figure on the gains in energy consumption and to define thus the most economical method of piloting.

X-DrivE sustains therefore, with a great deal of reliability, the design of the URBALIS piloting system and the process of management and follow up of the performance and this from the stage of the tender until the verification of performances on site, by regularly refining the hypotheses of calculation and simulation.

V. APPLICATIONS

Examples have been provided, below, in order to bring out the control of performances obtained thanks to the simulator X-DrivE and to the process of managing the performance.

5.1 Controlling the accuracy of the stop

In the process of the management of performance, tests of endurance or robustness are scheduled. A utility of endurance tests has been integrated to X-DrivE with the aim of estimating the performance achievable on site. The endurance test can only be launched if the simulation models give results that are close to the observations and measurements effected on the rolling stock. In the opposite case, one must sharpen and/or modify the mathematical models of simulation.

inuous curve shows the accuracy of the notes taken by the operator.

One remarks that the measurements on site conform to the simulation under X-DrivE: in both cases, we obtain a rate of success of 99% of stoppages within the tolerance of plus/minus 30 cm around the nominal position of stopping. The opening of the doors being authorized if, and only if, the accuracy of the stoppage is within the interval of plus/minus 50 cm, the simulation allowed the anticipation of the performance of stopping at the station.

This example shows the control of the performance of stopping thanks to the process of deployment of URBALIS solutions.

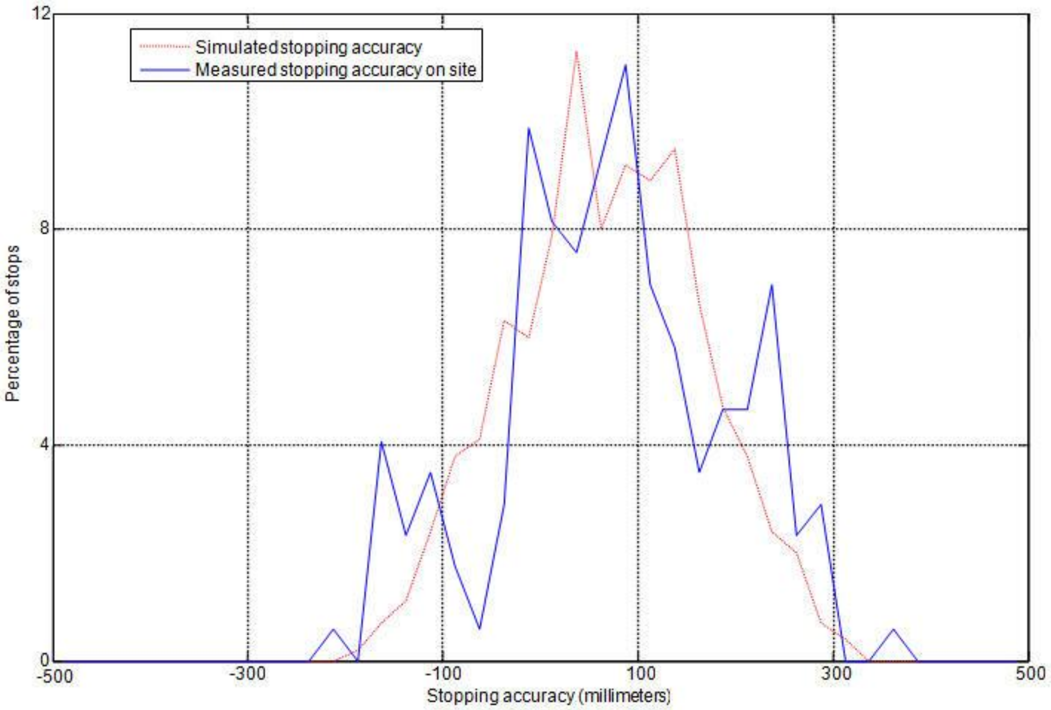

Figure 2

When the endurance test provides results that are in conformity with the expectations of an operator, the process carries on. In the opposite case, new settings or evolutions in the piloting system take place.

The Figure 2 shows the dispersion of the accuracy of stopping between the simulation and the measurements on site for the project in Incheon IIAR (Korea). These tests took place when the system of transport was accepted by the client. 12 trains out of 14 (total number of trains) were circulated for this test for hundreds of hours.

On the axis of abscissas, the accuracy of stopping is reported. In ordinates, the percentage of stops is noted for a given value of accuracy. The dotted curve shows the result of the simulation under X-DrivE and the cont-

5.2 Repositioning the train

The URBALIS systems 300 and Evolution possess a function of repositioning at the station. Thus, when an external event, for example a loss of tension in the station or a temporary incapacitation of the braking system of the train, does not allow the train to guarantee an accurate stoppage, the repositioning function is launched. By driving both the traction and the braking, the automatic piloting system can control movements between 10cm and 6m.

This function allows the recovery of certain damaged cases and increases thus the availability of the system.
It is actually in service on the projects in Singapore (North East Line and Circle Line), Lausanne M2 and Beijing Airport Link.

5.3 Controlling the trip time

For the purpose of planning a train or tram mission, one must know the trip time between two stations as well as the possible interval between two trains. With X-DrivE, the automatic piloting system was simulated in the context of operation. This took into account the speed profile, the track and the itinerary outline. possible to simulate a trip time larger than the minimum time between two stations and permit therefore a gaining of energy. On the Incheon project (URBALIS 200), the speed profiles simulated were compared to the speed of the trains measured really on site.

Figure 3 shows that the simulated speed profile is very close to the speed profile measures on site, represented by the continuous line, and is very close to the simulated profile in a nominal case.

When it is possible, the URBALIS piloting systems allow the compensation of certain disturbances in order to guarantee an arrival time at the destination that conforms to the planning. In the example below, the departure of the train is delayed (gap of the continuous curve). The URBALIS system of automatic piloting will establish a piloting profile in order to catch up with the delay and arrive at the planned time (curve superimposed on arrival). In this example, the train goes a little faster to make up the for the delay in departure.

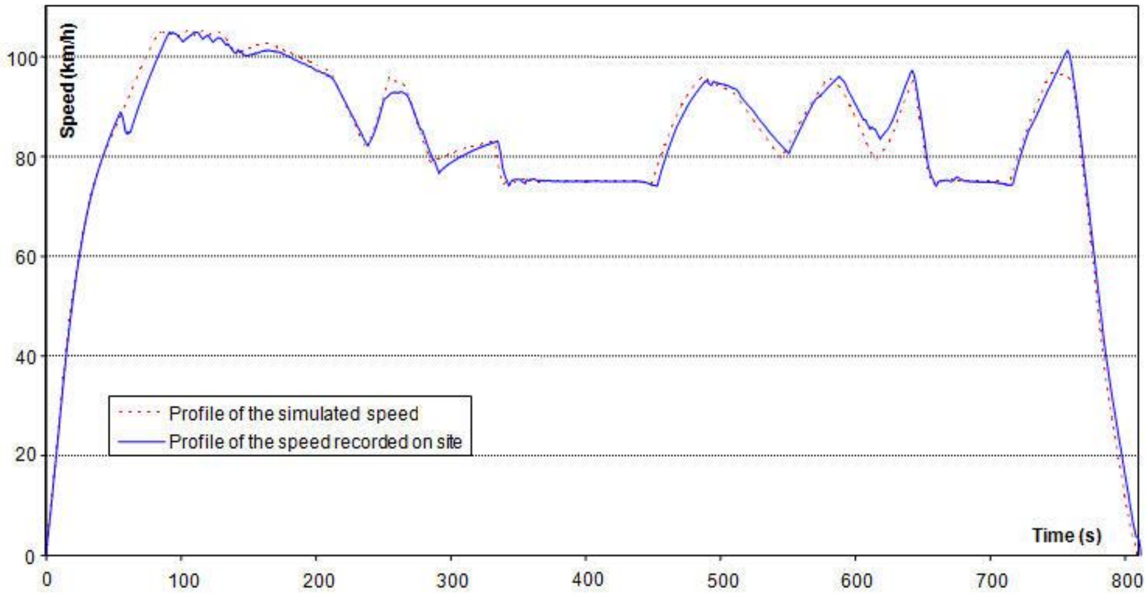

Figure 3

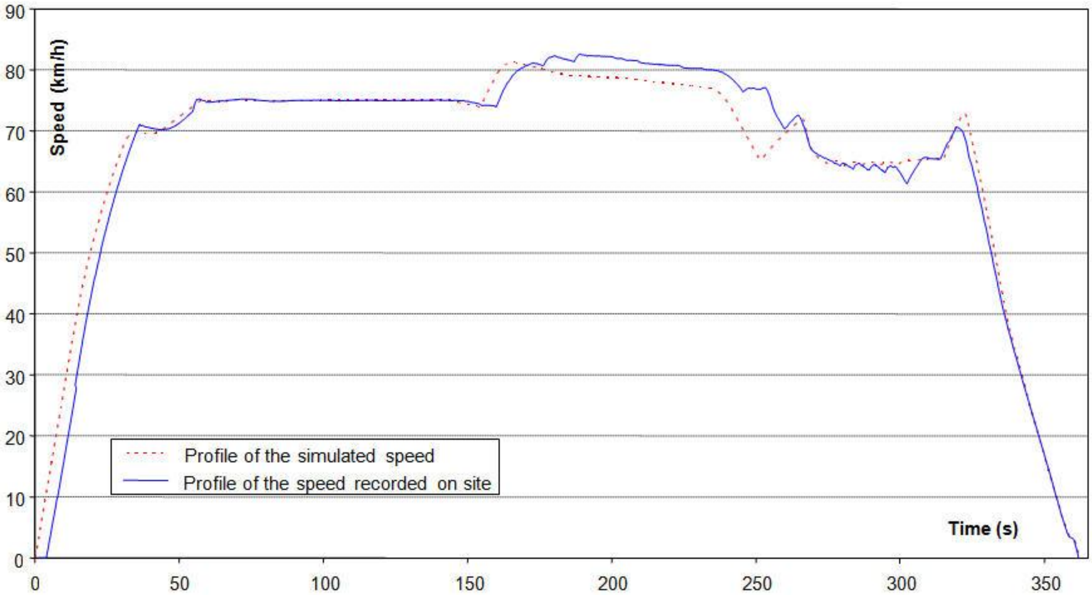

Figure 4

This control over the trip time allows the planning of trains that is accurate.

The following curve (Figure 5) shows the noting down of operations. The curves that are continuous describe the expectations in terms of trip times. The blocks represent the occupations of the trains on the track. When the continuous line is horizontal, the train is stopping at a station.

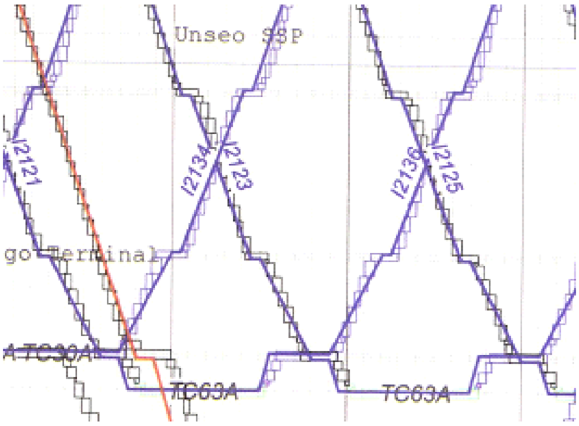

Figure 5

On this graph one notes that the planning is strictly respected.

This control over the trip times, in addition to the control over piloting, allows the deepening of the methods of piloting, particularly the methods of piloting that favor energy efficiency.

5.4 The Lausanne metro

The Lausanne metro is an automatic metro which possesses the particularity of an operation on slopes that can attain 12%, including the station. On the outline of the Lausanne metro, you cannot find two stations with identical slopes. They are all different, going from 0% to 12%. The photo (Figure 6) below provides a glimpse of the station called “Lausanne Gare (CFF)” at 12% slope.


Figure 6. Passengers wait for the shuttle at CFF.

Figure 7. The shuttle stops at CFF.

The system of automatic piloting on this URBALIS 300 project must be very robust. This is because of the requirements of all levels of traction and breaking that are used for stopping the train. Thus, the stoppage at the central station (Figure 7), on a slope of 12%, is done in the traction phase. As the system of automatic piloting drives separately the traction and the breaking, it is necessary to anticipate the breaking of the train during the traction phase in order to immobilize the train at the platform, maintain it at the station in safety and allow the passengers to get off and get on.

In the direction of the getting off, it is suitable to first release the brakes before applying a traction effort.

On this project, it was necessary to take into account subjective aspects such as comfort. The emergency brakes, on this project with steep slopes, attains very high values, approximately three times stronger than on a project with gentle slopes (less than 3%). Thus, the piloting must be neither too violent nor too soft in the stopping and taking off stages.

5.5 The Milan Metro

URBALIS Evolution was chosen by the operator for renovating the signalisation system on line 1. The ATC Bord sub-system will equip new and modern trains as well as the traditional trains of the actuel fleet. For the latter, an automation of stopping already exists and is in operation. It consists of piloting the braking of the train in station from a signal positioned at the entrance to the station. The system is released when the train passes over the signal within a range of speeds which is well-defined. Outside this range, the braking in station is not guaranteed by the existing automation. The driver has the responsibility of driving the train up until the signal which can be a delicate affaire. The piloting by the driver must be accurate otherwise the system does not guarantee the order of stopping at the station and the driver must then assume this task.

For this renovation, the system of stopping at the station is not replaced. On the other hand, the automatic piloting system of URBALIS will be used in a manner such that the piloting of the train reaches the signal of braking at the station. The speed of the train while passing the signal at the entrance of the station is thus guaranteed.

In this application, the control of the piloting URBALIS is combined with the existing automated system of stopping at the station which already gives satisfaction to the client.

5.6 The Dubai tram lines

The Dubai tram system will be equipped with an URBALIS Evolution system of signalization. The stations are air-conditioned and the platforms are equipped with elevator doors. Accordingly, the accuracy of stopping at a station must be great and guaranteed with an accuracy less than 20 cm. In order to do this, the driver is substituted by the system of automatic piloting URBALIS when the tram approaches a stopping position or upon entry into the station, in order to achieve the desired performance.

In this project, the URBALIS system of piloting takes over from the driver when he feels that a station is potentially dangerous from the point of view of security.

5.7 Other significant references

The major URBALIS references are given hereafter.

Singapore North East Line (U300): It's an integral automatic piloting system, depot and commercial line, put in service in 2003. It is a heavy metro (train 140m long) on iron wheels.

Singapore Circle Line (U300): It's a system of automatic piloting, depot and commercial line, put into service in 2003. It is the longest automatic metro on iron wheels: about 40 km.

Beijing Line 2 (URBALIS Evolution): It's the first renovation with the URBALIS Evolution system. The studies in the factory have allowed the renovation to be completed within two years without interrupting the operation of the line.

VI. CONCLUSION

The improvements of the URBALIS piloting system have been identified after analysis of the evolution of the performance needs of the urban transport systems.

The performance needs being bigger and bigger, process management and performance follow-up has been put in place in order to control the performance level and guarantee the performances achievable and observable on site in commercial operation.

The simulator X-DrivE has been developed with the aim of supporting the process management and performance follow- up and to validate all the improvements of the URBALIS system of piloting.

The application domains are varied and the performances obtained on site conform to the studies done in the factory: train, metro and trams, heavy or light metros, and steep slopes.

Moreover, thanks to the process of management of the performance and to the simulator X-DrivE, the time taken by the refining of the URBALIS system of piloting has been reduced by a factor of three.

The work in the factory and the use of endurance tests (robustness) have contributed to this gaining of time of carrying out and of refining the system.

The organisation put in place, the process of managing the performance, as well as the representative simulator X-DrivE, allow us, at present, to concentrate our efforts on the great project of the future: the optimisation of energy consumption.