XTP Planner: Time and Service Planner Module for an Operational Management Platform of a Public Transport Operator

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Abstract — This work aims to analyze, define and fit into the operational procedures all phases associated with the planning process of a public passenger transport operator, which allows the generation of schedules and services for vehicles and drivers of a passenger transport company to satisfy the needs of a previously agreed service. In the scope of this work, this problem will be seen in a global way, analyzing all stages of the planning process, including parameterization, preparation, production of analysis indicators and generation of results for different operational scenarios. This work was developed in a business environment and it’s a requirement that this module, "XTP Planner", must integrated, in the form of a prototype, with the XTraN Passenger platform - a product for managing the passenger transport operation that TECMIC; SA develops and sells.

Keywords: Passengers, Planning, Schedules, Vehicles, Drivers.

I. INTRODUCTION

Nowadays it is the high degree of complexity of today’s public transportation network that enables the daily commuting of tens of millions of people living in the metropolises of the world. In this work we introduce a new process that we intend to take a step forward in this typology of systems by being able to aggregate in a simple module, integrated in an operational management platform of public passenger transport, the ability to plan and generate in an optimized way:

• The schedules of public transportation lines: basically in the way they are presented to the public and that support all the operational activity), according to the specifications and objectives and criteria defined for the exploration scenario that guarantee the quality of the service rendered to the public and / or agreed with the supervisory bodies;

• The Services to be allocated to buses (or other type of vehicles); ensuring that the trips to be carried out in order to comply with the respective schedules are covered in the most efficient way possible, paying attention to the means available, their characteristics and the criteria to define their operability;

• The Services to be allocated to drivers - a similar situation, but from the point of view of the service to be fulfilled by the human resources, the daily work shifts of the drivers, taking into account criteria of cost optimization, but also a set of labor rules, not only imposed by the applicable legislation, but also those agreed with the workers;

Each of these modules must have an autonomous operation, each of which in itself represents an added value to the XTraN Passenger platform. All entities involved in the process of generating results should contain a broad set of attributes (physical, cost, and use) in order to allow a high dynamism in the definition of the operating environment (scenario) that characterizes the reality of an operator's operation of the public transport service. The ability to replan, in response to new operating conditions, is an important and differentiating factor of this solution, taking full advantage of the full integration with the operational management platform.

Rather than focusing on the algorithm associated with optimization models, this work aims to analyze all stages of the process: pre-planning (parameterization), planning, generating results (planning proposals) for different scenarios, generation of metrics / metrics evaluation of results and operationalization of a new planning.

We developed a prototype that covers the following macro tasks of: 1) Specify all stages of planning; 2) Specification of the extension of the XTraN Passenger platform [1] and all the necessary attributes to characterize the scenarios and means; 3) Calibration and parameterization of the means involved in the operation; 4) Construction of planning scenarios (reality and objectives for the operation in a given period); 5) Calibration and parameterization of planning scenarios; 6) Calibration and parameterization of the public transport offer - service to be offered to passengers; 7) Integration into the optimization module (RtP) [2] Generation of planning solutions; 8) Generation of the structure of a planning: schedules (service to be made available to the public), vehicle and driver services (construction of the services to be assigned to vehicles and drivers); 9) Analysis and evaluation of results; and 10) Activation of a plan - fitting into the operation (operational planning);

Briefly, as entries for the XTP Planner module, we have: 1) Extension and sharing of the XTraN Passenger data model, which defines the entire transport network; 2) Data and indicators resulting from the operation (eg, actual statistics regarding travel times); 3) The attributes that characterize the means available for the operation; 4) The attributes that characterize the operating scenarios, namely the definition of the service to be provided to passengers; and 5) The weights, calibration and quantities that will mark and define the requirements of the planning solution that we intend to obtain. As outputs: 1) Generation of the schedules of the lines (definition of the public schedules) and daily services for allocation to vehicles and drivers; and 2) Production of Indicators for analysis and evaluation of results.

II. RELATED SYSTEMS

The following is a sampling of the main solutions for passenger transport planning, resulting from the analysis made using information available on the Internet:
GIST – OPT. The GIST system, developed by the company OPT (Optimization and Transportation Planning, SA) is a modular decision support system at the planning level, whose objective is to assist the operational planning of transport companies, in the scheduling process and resources of their daily operations [3]. It allows the management of basic information on the transport network, the lines and the journeys to be made - although it contains the basic data sufficient to support the main planning process, does not contain the details of the routes to be made and the respective partial times per point of stop and route variant (operated by sync points). It also allows to generate, manually or automatically, the schedules of vehicles and drivers, including the daily scaling of these, through algorithms optimizers and heuristics. Although it is a very mature and complete tool that has good results, it is a very heavy tool in terms of parameterization and does not have the capacity to be fed back by the operation data.

Hastus – Spin. Giro's Hastus software is an integrated solution that provides flexible modules for transport planning, scheduling, operations, passenger information. This system provides the necessary tools to create schedules for vehicles and operators efficiently, through the use of optimization algorithms [4]. The solution, although extremely advanced and complete, does not have the ability to integrate directly with vehicle tracking systems or passenger count data. At the planning level, it presents considerable execution times, being a little agile tool for generating new versions of planning. In addition, this is a costly solution and, as such, with an application restricted to large companies only.

Trapeze. Trapeze is a leading international company in intelligent transport system solutions. Trapeze solutions automate many tasks associated with the planning, management, delivery and measurement of transport services, linking the data between internal and external applications [5]. The range of Trapeze solutions applies to public and school transports, freight trains and other sectors, that is, it is not very focused on public transport. Trapeze's integrated approach offers a business solution linking backoffice to operations and information centers. Although complete, it has similar limitations to previous ones: data feedback and replanning capability.

Wplex is a pioneer in the development and delivery of systems for the operational management of urban and air transportation in Brazil. Its solutions are divided by the areas of public transport, air transport and rail transport. The Wplex solution for public transport has tools for scheduling fleet and crew events, real-time fleet and crew monitoring, and tools for automatically informing passengers [6]. Of all the analyzed solutions is the one that is most equated, in conceptual terms, to the approximation used in this work.

In conclusion, we can say that the market offers a wide variety of solutions for the management and planning of passenger transport networks. As noted, these have a wide variety of features and functionalities. However, despite the breadth and sophistication they present, there are still some gaps, mainly in the integration of "real" data from the exploration and in the fact that they involve a great effort and considerable complexity in the parameterization, they are usually platforms of high cost, more comprehensive use that are tailored for a specific sector.

III. REQUIREMENTS OF XTRAN PASSENGER PLANNER

In view of the defined objectives, it is intended that this module (XTP Planner) is fully integrated with the XTraN Passenger platform, which, as already mentioned, is a management product of the passenger transport operation that TECMIC develops and markets. With the introduction of this new module, we intend to combine in one tool, integrated into an operational management platform for public passenger transport, the ability to plan and generate in an optimized way: 1) The schedules of public transportation lines: basically in the way they are presented to the public and that support all the operational activity according to the specifications, objectives and criteria defined for the exploration scenario, so as to guarantee the quality of the service provided to the public. and / or agreed with the supervisory bodies; 2) The Services to be allocated to vehicles; ensuring that the trips to be carried out in order to comply with the respective schedules are covered in the most efficient way possible, paying attention to the means available, their characteristics and the criteria to define their operability; and 3) The Services to be allocated to drivers - a similar situation, but from the point of view of the service to be met by the human resources, the daily work shifts of drivers, taking into account not only cost optimization criteria, but also a set of labor rules , not only imposed by the applicable legislation, but also those agreed with the workers;

Each of these modules should operate autonomously, each of which in itself will be of added value to the XTraN Passenger platform. All entities involved in the planning process should contain a wide range of attributes (physical, cost, and use) in order to allow a high dynamism in the definition of the operating environment (scenario) that characterizes the operating reality operator of the public transport service. The ability to replan, in response to new operating conditions, is an important and differentiating factor of this solution, taking full advantage of the full integration with the operational management platform.

This work aims to analyze all phases of the process: pre-planning (parameterization), definition of operating scenarios, generation of results (planning proposals) for different scenarios, generation of indicators / metrics for results evaluation and operationalization of a new planning. It should be noted that this work does not focus on the results generation model, in this specific case the "constraint programming", this component (which we will call the RpP module) was embedded and adapted from a previous work,
for which inputs were defined and outputs according to what is specified in this work. The use of this optimization component corresponds to a possible approach, which we consider valid and adequate for the objective in question, however, in terms of the final product, this is not yet a closed question and will be subsequently decided.

The scope of this work is constituted by the specification of all phases of the planning and construction of a prototype that covers the following macro-tasks: 1) Identification and specification of all stages of planning; 2) Specification of the extension of the XTraN Passenger platform and all the necessary attributes to characterize the scenarios and means; 3) Calibration and parameterization of the means involved in the operation; 4) Construction of planning scenarios (reality and objectives for the operation in a given period); 5) Calibration and parameterization of planning scenarios; 6) Calibration and parameterization of the public transport offer - service to be offered to passengers; 7) Optimization module (RtP) for generation of planning solutions; 8) Generation of the structure of a planning: schedules (service to be made available to the public), vehicle and driver services (construction of the services to be assigned to vehicles and drivers); 9) Analysis and evaluation of results; and 10) Activation of a plan - fitting into operation (operational planning).

Briefly, as inputs to the XTP Planner module, we have: 1) Extension and sharing of the XTraN Passenger data model, which defines the entire transport network; 2) Data and indicators resulting from the operation (eg actual statistics on travel times, passenger count data); and 3) The means (vehicles and drivers) available for the operation;

Secondly, the XTraN Passenger Mobile app is part of an ecosystem and not a standalone product. It does have access to broader and lower level functionality than any of its “competitors”. This partnership with Tecmic - the company which engineered the buses’ onboard devices - provided the opportunity to improve the available Restful API, re-engineering small parts of the architecture improving overall performance and functionality of the application.

IV PLANNING PROCESS - XTP PLANNER MODULE

We intend to provide the users of the platform - operators of a control center of a passenger transport operator, a new planning tool with the ability to optimally plan: the schedules of the lines, the structuring of the services and their schedules, as well how to support the assignment of vehicles and drivers to their services.

Timetable: the concept of timetable is very easy to explain to any public transport user, they are tables containing the starting times of each vehicle in each of the terminals (typically two terminals, one for each direction of movement), organized per line and are usually divided into separate versions for each type of day and time of year.

Service: represents the vision of each vehicle (service of vehicle sometimes called "plate") or of each driver (driver service sometimes called "board"). Defines what a vehicle or a driver has to do over a day, that is, lists a set of trips, ordered chronologically that a certain means has to perform, being that: 1) A service may have different versions for each season; 2) Within the same service, we may have trips of one or more lines; 3) The service may not be continuous, that is, we may have one or more intervals between trips where the vehicle or the driver leaves the service.

Drivers (Services) working periods have the following concepts: 1) Block: A set of consecutive journeys (between each start and end of service) of a driver service, a service may have several blocks during the day, ie the vehicle or the driver can enter (enter) and exit (end) the several times during its execution. The intervals between blocks are called pauses; 2) Step: represents, for a driver service, what the block represents for the vehicle service, ie a consecutive period of work;

In a service, each trip represents an execution of a route referring to a certain line, in a certain direction, starting at a certain time and with an origin and destination - this is because a trip can correspond to the execution of a single segment of the route and not to the entire route.

Depending on the time, day type and time of year, the XTraN Passenger platform estimates and makes available to the planning module the standard travel time of a particular trip.

- A trip, even if on the same line, can execute a different route, ie the line may contain route variants (eg a different route on a certain type day);
- A trip can be programmed to be partially executed, where, on time, the origin and destination may not correspond to the route ends;

Phase 1 - Parameterization (F1) - The first phase, of parameterization, is generic and transversal to any scenario, it is where we define a set of parameters that do not have specifically to do with the intended planning solution, but with the reality of operation and the definition of the means that public transport operator has available - are definitions shared by the various planning scenarios, their adjustment does not depend directly on the defined scenarios (times, times, regularities, etc.). Example of these are for global parameters: 1) Prefix service name - defines the prefix to use in the name of the services and start time of the day Start time of a work day; 2) for service - Maximum blocks of a service; Minimum pause time Pause; Minimum and Maximum time to arrival at stop and travel start time; 3) for drivers - Driver's Day Period; Driver's Nighttime; Driver's Turn (Minimum and Maximum); Driver Break (Minimum
and Maximum); Maximum Driver Stages; Min. Long Driver Break Parameters Relative to the Type of Means (Vehicles and Drivers) are: 1) Parameters related to availability and autonomy; 2) Parameters related to maintenance; 3) Parameters related to the place where it "rests" (collection station); 4) Parameters related to its cost; and 5) Parameters related to working / rest time. These parameters were defined by transportation operator Parameters related with driver types settings: 1) driver name; 2) cost hour cost of each hour of work; 3) short night time short of every night in hour work; 4) cost extra time cost of each extra hour of work; 5) maximum turn duration maximum daily working time; 6) daily step change maximum number of steps you can take each day; 7) max. duration of the phase maximum duration of a consecutive period of work; 8) max. time after step max work time after finishing each step; 9) max. extra hours per day maximum time that you can work more per day; 10) min. rest between stages minimum rest time between stages; and 11) min. break between shifts min. rest time between shifts Parameters related with vehicle are: 1) vehicle type name; 2) daily cost daily cost of the vehicle even when not doing service; 3) cost per km cost of vehicle per km; 4) lines where this type of vehicle can operate; 4) max. work per day maximum operating time per day (outside the garage); and 5) maximum time between maintenance maximum time between two maintenances, ie after maintenance, the vehicle has a maximum time to perform other maintenance. A collection or depot station is a parking place where the vehicles remain during the time they are not in service, where they are maintained and cleaned.

Phase 2 - Scenario Definition (F2): we define and prepare the scenario. Each scenario is defined within a season (basic concept of the platform) and contains the objectives we want to fulfill, both in terms of the passengers' offer - regularity and punctuality of the lines, and in the calibration, in degree and / or value, of preferences (or, if you want, constraints) that will serve as input to the generation of the planning solution. In the definition of the scenario, we will calibrate variables that define a particular situation and a set of objectives that the operator intends for the planning solution that will generate. The scenario contains: 1) The requirements for defining the punctuality and regularity of the lines - this is the approach chosen, so that it is easier to arrive at the schedules based on the needs of the passengers; 2) The amounts of the means involved (by type); 3) A set of global parameters (transversal to all means) that define the solution in the most general aspects / objectives; 4) A set of fundamental criteria and weights to calibrate the solution generation algorithm, such as: the Criterion to penalize line changes (important to prevent a vehicle from "jumping" between lines, because even if it is more cost-efficient it may not make sense in terms of managing the operation); 5) Criterion to penalize stopping or non-use times (park); 6) the Criteria for Penalizing Empty Travel; 7) Criterion to penalize overtime or night time. The key idea of a scenario is to allow the operator to idealize the schedules that you want to create for a given time. This concept brings together a particular problem and its solution or solutions. Planning involved also the number of trips that are intended to be made in a given period, building a set of trips (service) that each vehicle can perform in the normal process of going back and forth. Often this process even has a complex "algorithm" behind it, but it is an approximation where the result will be much more oriented and conditioned by the characteristics of the vehicles or drivers generating plans where there is a greater "linearity" and simplicity of use resources at the expense of optimizing available resources. Therefore, the operator will define what he wants, in terms of supply, for each line: Regularity - Intervals (time bands) that define different demand requirements, such as: 1) The desired frequency (s) of departure for each line terminal, within each time slot; 2) Each terminal (beginning of each of the traffic directions) has, according to the time of day, very different needs in terms of number of passengers; 3) Always identify "reinforcements" in certain sections of the line; and 4) we create a new specific time slot for a segment that corresponds to the execution of part of the complete route of the line (shortened trips). Punctuality - Identify fixed times for trips where, regardless of the stipulated frequencies, we want a vehicle to fulfill a particular trip (extra regularity trips). This parameterization can be made in the perspective of the departure (start time of the trip), in the perspective of arrival (arrival time at the end stop of a trip) or with the identification of points of connection (or synchronism) - in this case we will identify the need to pass at a certain point (stop the route) at a given time. This restriction, which can generate extra trips, is mainly used to synchronize trips in order to allow connections between lines (minimize transshipment times) or even to connect to other external operators (for example a ferry boat that we know beforehand which was to leave many passengers at a certain time); Parameter Setting Function for the Punctuality and Regularity of Lines - The functions offered seek to help the operator in a process that is not always fast and may even become repetitive. The frequency definition allows the operator to automate part of the creation process as it only needs to define the regularity of departures for the various periods that define the search during the day. We can go from a very complex situation, with several periods and frequencies, to a single "super" line - a single frequency that encompasses the operation of the day (eg, from 04:00 to 03:00 the next day with departures every 10 minutes). It is still possible to define the regularity of departures in minutes or in total of departures in the defined period, however, the use of one suggests the automatic updating of the other. As already mentioned, sometimes there may be a need to reinforce only part of the route with more trips, hence it is always possible to define the start stop of the trip and the destination, and by default the route is defined by the line, variant and the direction of the working day that is being parameterized.
In addition to the frequencies, the operator can parameterize in a very simple way the extra trips, setting a time of departure or arrival, or the identification of the synchronization points, in this case, at the level of the user interface, an equivalent signaling (but distinct) to a trip, but that may not result in the need to introduce yet another trip. Viewing / Monitoring a Scenario - Scenarios are written so that the operator can return to the scene at will, however, it is not possible to guarantee that some lines will remain valid in case of deep changes - this aspect is validated. After creating or opening an existing scenario the operator has access to all existing rows. By choosing a line / variant, we can visualize its frequencies, extra trips and sync points. A widely used form of representation in this public transport reality - the travel diagram - was chosen.

As shown in Figure 2, we represent a day (type) of exploration where, for each line, we represent all predicted trips, identifying: 1) the desired Start Time; 2) the origin and destination of each trip; and 3) Estimation of the duration of each trip - the operator also has the list of stops on the y-axis and the time-space on the x-axis, if the user moves with the mouse at the points of travel, the stop-over time is indicated. This information is, at this stage, defined as an objective of the planning solution that we intend, when executing RtP solutions generator module, we will obtain a solution of schedules "adjusted" to all the parameters defined for the scenario and for the use of available resources.

![Figure 2 – Screen shot of visualization scenario](image)

Scenario Preparation - Goal Setting and Calibration. After parameterizing the scenario to the level of punctuality and regularity of the lines, we must carry out the "calibration" of the planning solution. These configurations can have a significant impact on the results generated, both in the amount of media to be considered in the solution and in the calibration of weights and restrictions to be considered.

In this phase we will essentially define:

"Scope" of the Solution: Although we are usually planning for the whole universe of the operation, the planning solution may have a narrower scope, that is, we can only plan for one type of day or we may want to plan for a restricted group of lines. Usually this type of partial solution only happens in an operational reality where the operator does not intend to "mix" means between the several lines, in the background we are talking about an operator that has a group of means allocated a specific set of lines - in this case we will have solutions with a degradation of the optimization of the means (considering the global reality of the operation) but, eventually, with an easier management to perform from an operational point of view.

Sometimes this situation occurs in state or municipal companies where it is often assumed that each vehicle does not change lines during a service, potentially this type of solution tends to benefit the regularities of the operation (less tendency to deviate from the plan) and, on the other hand to degrade the level of use of resources throughout the day;

Model Result: This is a particularly relevant aspect in this approach, since it will allow planning to be done as a reference, very useful for replanning, which is one of the concerns and differentiating factors of this work.

Remember, in each solution we will get the three results for the scenario defined:

- Schedules - Definition of public timetables;
- Services for Cars - Daily services for the vehicles;
- Services for Drivers - Daily services for drivers;

For each of these solution components, the solution generating module, starting from the attribute base and scenario definition, will be responsible for generating each of the solution portions (although they are generated in sequence, they are not naturally independent). The goal is to reach a final result with these three components, each of them has value in itself. For this reason, the module has been prepared to generate results at several levels:

- Only with schedules;
- With the daily schedules and services for the vehicles;
- Starting from fixed hours ("lock" this component) and generate only the daily services;
- Total, with daily schedules and services for vehicles and drivers;

This aspect of generating results from a base (solution already elaborated) is fundamental to carry out a new planning (replanning) without changing the schedules already made available to the public, so we will have the possibility to start from Fixed Schedules ("lock" this component already generated), ie not considering the objectives for the frequencies, have already been reflected in the model solution, and generate a new solution for daily services of vehicles and drivers.

Amount of Means: here we define the amount of means (vehicles and drivers) that we will use in planning, by default the module presents all means defined in the system, but there is always the possibility of only using a percentage of the existing means. This aspect must always be taken into account in order to try to leave a reserve to overcome the normal failures and difficulties of the operation - faults, exchanges, reinforcements, etc.;

It should be noted that the solution generator module (RtP) will always try to provide a solution, even if this solution cannot meet all the requirements and constraints defined, for example, we may have a solution that, for defined requirements, has to use more vehicles or drivers than stipulated as maximum objective.

Solution Calibration: As shown in Figure 3, we will give the operator the ability to calibrate some constraints that, together with all of the attributes already described, try to shape the intended planning solution. This type of calibration always has a subjective component or, if we want,
a sometimes non-linear relationship with the results, it is therefore difficult to quantify these values, which is why they are presented in a slide bar format giving the operator to refine the conjugation of the various weights according to the experience that is acquiring, the most relevant "weights" are:

- Penalize Line Changes: it is the degree of freedom with which we allow the vehicle to change lines within the same service. As already mentioned, when this change is allowed to happen in a more dynamic way, we will potentially be able to optimize the occupation of the means to the objectives of the operation, on the contrary, if we restrict this dynamism we will benefit the regularity of the operation (less tendency to deviate from the plane);
- Penalize the Distances traveled in Empty Travel: in practice, we mean the attempt to use means that are close to the beginning (first trip) terminals of each service. This situation is of particular interest when the media belong to separate collection stations and, even with some availability advantage, may be at a disadvantage because they are further from the start terminal. When we have several stations, this calibration may tend to limit the use of media in areas distant from its collection station;
- Preference for Minimizing the Number of Vehicles Used: give priority to reducing the number of vehicles to be used, even if less than the vehicles indicated as available for planning (input). Of course, we will always try to reduce the means to be used, here it is a question of giving preference to this aspect, to the detriment of fulfilling other objectives (eg total cost of the solution or total distance covered);

Often in order to "make feasible" a solution we will arrive at a result that does not meet all the defined restrictions, in particular with respect to the working restrictions of the drivers that are more "difficult" to fulfill in full. The following calibrations attempt to identify the degree of default (possible) for the aspects that are typically decisive, particularly in terms of driver services and the number of means to be used:

- Penalize Long Pauses: interval (rest) between stages;
- Penalize Waiting Times in Terminus: valid for both types of service, we are talking about time between trips during the execution of a service block;
- Penalize Number of Driving Steps: exceed the maximum number of steps of a driver during his daily service;
- Night Driving Excess Time penalty: the night sometimes requires the generation of more services (even if smaller);
- Penalty for the Use of Extra Hours: it must be analyzed in detail because, as a general rule, it is thought that drivers are more "difficult" to fulfill in full. The experience that is acquiring, the most relevant "weights" are:

Phase 3 - Generation of the Planning Solution (F3). We generate the planning solution - a result (optimal or suboptimal) containing, in a structured form and for each type day of the season in question: 1) Schedules; 2) Vehicle Services; and 3) Driver Services. They are outputs of the planning solutions optimizer module (RtP module):

As a result we have a hypothesis of a planning solution, which contains, in a structured way and for each type day (of the time in question): 1) Schedules - Definition of public timetables, based on all trips made, for all lines, for each type day; 2) Vehicle Services - Daily services to allocate vehicles, based on all trips made, grouped by service (and respective blocks), for all lines, for each type day; 3) Driver Services - Daily services to allocate drivers based on all trips made, grouped by service (and respective stages), for all lines, for each type day.

Phase 4 - Result Analysis - Planning Solution (F4):

In the fourth phase, which is detailed in section 4.7, we will analyze the result obtained (output of the RtP module that corresponds to a possible solution to the intended planning), indicators are available that will aid in the evaluation of each result and thus give decision support, to be taken by the operator, in order to move towards the activation of a particular planning solution.

A solution can be activated or simply recorded for further analysis and decision.

Phase 5 - Activation of a Planning (F5):

In the fifth step, which is detailed in section 4.8, it is where we will activate a planning, after choosing a certain result (the solution we want for the planning) we will operationalize a planning from a certain date in the calendar;
Phase 6 - Allocation of Services to the Media (Operational Planning) (F6), where we will allocate the vehicles and driver to their respective services for each calendar day - let's allocate half a x to the service and.

V TESTING

Another of the distinguishing aspects of this work is how we will characterize and evaluate each result and help the operator in the decision process. For this evaluation, in order to move towards the activation of a particular planning solution, a simple output with the structure of the schedules and of all the services is not in itself a clear indicator to support a decision with such a great impact on the activity of a public transport operator. Thus, a set of indicators was identified to assist in decision making, including the ability to compare two distinct outcomes (from the same scenario or even from another defined scenario).

In order to carry out the first tests we chose the company Coesa, an operator from the city of Rio de Janeiro, which uses the XTraN Passenger platform successfully and organized to participate in the test. This company, small in size for the Brazilian reality, has about 200 buses that serve about 20 lines, urban and semi-urban. This configuration of lines is ideal for conducting this type of test, since it mixes a typically urban reality (Niterói - Center of Rio de Janeiro) with a semi urban one, which runs longer journeys from the western part of the state of Rio de Janeiro. Typically, these urban lines have high frequencies of departure, with no major differences throughout the day (very high and constant demand); on the contrary, semi-urban lines have a much smaller number of journeys, concentrated at morning rush hour and afternoon.

From the point of view of the planning and the management of the operation, this company presents an organization already with some degree of maturity, this having with reference other companies of the sector that operate in the same reality and geography, in particular: 1) Have a team dealing with planning and other operational management team; 2) For planning have two elements that deal with the generation of the plan for the time and the allocation of resources to services - a task that is done weekly; 3) For the operation, there are six operators that are organized in shifts and whose function is the daily control of the operation, the importation of the services for each season (including adjustments made during the same) and weekly import of service allocation vehicles and drivers;

In terms of planning, this company regards it as the base on which the operation is based, that is, the control of the operation is carried out with the objective of enforcing the defined plan, both in terms of schedules, in terms of services and respective allocations to vehicles and drivers. This is a situation that already shows some evolution in terms of its organization, which does not always happen, especially in this South American reality - often the operation tends and focus almost 100% on the aspects of regularity taking into account the momentary demand that exists in each line / location.

Looking at the planning process, as it currently exists in this company, it is processed as follows: 1) Before the beginning of each season, the schedules and services associated with the vehicles are generated using the WPlex tool [7]. This generation is based on the objectives of regularity for each line and, in relation to vehicle services, tends to maximize the time each vehicle can be in operation (outside the collection station); 2) Generation of services for drivers is done almost manually, in particular, vehicle services are exported and worked on a spreadsheet where they are divided in order to fit in the shifts of drivers who, typically, have three type structures: dawn - morning, morning - afternoon and evening - night; 3) The three key planning structures (schedules, vehicle services and drivers) are formatted in GTFS (common format for public transport schedules and associated geographic information) and made available in a file in order to be imported by XTraN Passenger; 4) the Associate to each process of importing new schedules and service, is always the identification of the date of entry into force of the plan in question; 5) The import task is a procedure that involves a large set of validations - the base data must be coherent (between the two systems) and the time and service structure must be completely correct. Of course, this is a point of failure that always represents a risk factor to consider when putting a new planning or a new version of planning into "exploitation"; 6) With regard to the allocation of services to vehicles and drivers, the mechanism is used to weekly associate each vehicle service to a specific vehicle, and the same operation is performed for the driver services;

Typically, two scenarios with different characteristics and motivations:

Case 1: COESA Brazil company base (urban reality); used all Urban Lines (32); Regular Scenario - Frequency of uniform matches throughout the day: 1800 games (trips); Operation: Standard time variation over 6 slots
Case 2: COESA Brazil company base (semi-urban reality); Used all Semi-urban lines (7); Irregular scenario - Frequency of departures with three frequency variations (with two peak hours: 7-10h and 17-19: 30h) throughout the day: 361 departures (trips); Operation: Standard time variation over 6 slots.

In the following table we present the indicators related to the results obtained for the two test scenarios, for each of the scenarios we have three results, obtained from several combinations of three fundamental "weights" that "calibrate" the constraints of each scenario: 1) preference for Decreasing Distances Traveled in Empty Travel; 2) preference for Minimizing the Number of Vehicles Used; and 3) preference Minimize Line Changes.
Table 1 - Total Cost and Indicators Vehicle Services

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<thead>
<tr>
<th>Indicator</th>
<th>Case 1 (run time ~ 11 min)</th>
<th>Case 2 (run time ~ 7 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preference for Decreasing Distances Traveled in Empty Travel</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Preference for Minimizing the Number of Vehicles Used</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Preference Minimize Line Changes</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total cost</td>
<td>175.652 €</td>
<td>35.517,4 €</td>
</tr>
<tr>
<td>Total Vehicles (of services)</td>
<td>168</td>
<td>35.515,9 €</td>
</tr>
<tr>
<td>Total Line Changes During Service</td>
<td>999</td>
<td>12543,9 €</td>
</tr>
<tr>
<td>Total Distance Traveled (km)</td>
<td>59410,8</td>
<td>12546,3</td>
</tr>
<tr>
<td>Average Time of a Vehicle Service (hh: mm)</td>
<td>12:37</td>
<td>07:40</td>
</tr>
<tr>
<td>Average Waiting Time for Vehicle Service (hh: mm)</td>
<td>07:50</td>
<td>01:30</td>
</tr>
<tr>
<td>Average Distance per Empty Service (km)</td>
<td>67,85</td>
<td>57,02</td>
</tr>
<tr>
<td>Average Number of Blocks per Service</td>
<td>1,185</td>
<td>1,410</td>
</tr>
<tr>
<td>Total Stages</td>
<td>2309</td>
<td>53 [30, 130]</td>
</tr>
<tr>
<td>Average time (min)</td>
<td>01:23</td>
<td>01:05</td>
</tr>
<tr>
<td>Average Distance (km)</td>
<td>51,50</td>
<td>51,33</td>
</tr>
<tr>
<td>Total Stages</td>
<td>2309</td>
<td>53 [30, 130]</td>
</tr>
<tr>
<td>Average time (min)</td>
<td>01:23</td>
<td>01:05</td>
</tr>
<tr>
<td>Average Distance (km)</td>
<td>51,50</td>
<td>51,33</td>
</tr>
<tr>
<td>Total Services (No. of drivers)</td>
<td>510</td>
<td>423 [177, 540]</td>
</tr>
<tr>
<td>Total Stages</td>
<td>2309</td>
<td>53 [30, 130]</td>
</tr>
<tr>
<td>Average time (min)</td>
<td>01:23</td>
<td>01:05</td>
</tr>
<tr>
<td>Average Distance (km)</td>
<td>51,50</td>
<td>51,33</td>
</tr>
<tr>
<td>Total Stages</td>
<td>2309</td>
<td>53 [30, 130]</td>
</tr>
<tr>
<td>Average time (min)</td>
<td>01:23</td>
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</tr>
<tr>
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<tr>
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<td>1,185</td>
<td>1,410</td>
</tr>
<tr>
<td>Total Stages</td>
<td>2309</td>
<td>53 [30, 130]</td>
</tr>
<tr>
<td>Average time (min)</td>
<td>01:23</td>
<td>01:05</td>
</tr>
<tr>
<td>Average Distance (km)</td>
<td>51,50</td>
<td>51,33</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indicator</th>
<th>N.º</th>
<th>Average time (min)</th>
<th>Average Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twists</td>
<td>2309</td>
<td>51 [30, 130]</td>
<td>51,33</td>
</tr>
<tr>
<td>Blocks</td>
<td>2309</td>
<td>51 [30, 130]</td>
<td>51,33</td>
</tr>
</tbody>
</table>

The experience of use is a key factor to gain sensitivity in the adjustment of the parameters, however, it is possible to verify that, normally, the cheapest solution, that uses less vehicles and travels less distance, is obtained with the combination of the preferences to be minimized the number of vehicles and the distances traveled on empty, giving total freedom of line changes during the service. Normally this type of solution implies greater difficulty in regulating the lines during the operation and less capacity to deal with deviations, less "slack" in the chain of trips. Looking at the perspective of the Driver Services, now focusing on Case 1, we have the following result:

Table 2 - Result Case 1 - Driver Services Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>N.º</th>
<th>Average time (min)</th>
<th>Average Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Services (No. of drivers)</td>
<td>510</td>
<td>423 [177, 540]</td>
<td>149 [53, 213]</td>
</tr>
<tr>
<td>Total Blocks</td>
<td>2309</td>
<td>53 [30, 130]</td>
<td>32 [22, 49]</td>
</tr>
</tbody>
</table>

The driver display mode, shown in Figure 5, is similar, with a particularity that seeks to help the operator to perceive the intersection between vehicles and drivers, i.e. for each driver's service the vehicle services identified are identified will serve. This issue is particularly interesting for the dispatch work functions of those who distribute the vehicles to the drivers who present themselves every day to the service.
VI CONCLUSIONS

In a global way, we can say that the full integration of this process with the operation brings many advantages, since the planning and control teams of the operation share concepts (network, calendar, parameters associated with the means, definition of the scenarios) and tools, both have a clear sense of what is relevant to the planning and, consequently, to the operation. Sharing the same system and concepts brings a common vision of the problem and fosters integrated work. If this is done by different tools, the vision is not integrated and does not foster the replanning tasks that are an essential tool for improving the better use of resources. In addition, the lack of export, validation and import procedures minimizes the risk of failures and expedites the start-up of new planning solutions.

Summarizing other important aspects, resulting from the experience of using and analyzing the indicators obtained for each planning solution: 1) The parameterization functions, in particular the setting of scenarios and their calibrations, have proved to be user-friendly and intuitive. The feedback obtained from the users goes in the sense of having a correct perception of what each parameter represents and how important it is to planning - there is a clear notion of what are the parameters that characterize the means and of what goals or constraints we want for a given plan. In this respect, the variables associated with the maximum and minimum durations of the various "key" periods (blocks, steps, pauses, time in terms, etc.) were critically analyzed by those who often do not have the notion of relevance accepted range for these values has in the planning process; 2) Although they are a time-consuming operation, the parameterizations present help and re-use functions that meet the expectations of the operators, in particular all the functions of copying and reusing parameters and settings at the scenario level - this aspect speeds up and promotes replanning actions; 3) The generation of new planning solutions (replanning) proved to be a simpler task based on previous user experiences. The possibility of defining a scenario and, based on the same definition, calibrating and obtaining solutions that can be analyzed and compared, represents a gain for users who can thus make more informed and sustained decisions; 4) In this respect, the indicators presented and, fundamentally, the comparative analyzes were another positive aspect in terms of user feedback - usually the planning tools generate solutions that are difficult to analyze and interpret. The indicator tables, associated with each solution, as well as the analysis metrics (eg, restrictions violations) were a very important element in terms of the user experience; 5) Based on the analysis of the indicators produced for each solution, it was possible to conclude that, in particular, vehicle schedules and services were well structured: - The schedules reflect well the parameters and the objectives of punctuality and regularity defined in the scenario - both in terms of number of journeys by hourly range and in terms of spacing between them, fulfilling a maximum adjustment margin (in this case were considered 4 minutes of maximum adjustment). In this aspect, it will be important in the future to give the user a way to compare or qualify, for each line, the regularity defined in the scenario with the result obtained, in this test, this analysis was made by analysis of some sample lines;

- Vehicle services reflect and respond well to adjustments in parameterizations. The combination of the weights of the three most relevant "preferences" ("Decrease Distances traveled in Empty Travel", "Minimize the Number of Vehicles Used" and "Minimize Line Changes") allows the generation of new results in which it is visible, for analysis of the indicators, the reflection of these weights in the obtained result;

- The structure of services, particularly of vehicles, is uniform, with blocks and breaks of reasonable duration, with few cases where the duration of the blocks is close to the minimum or maximum - this can be proved by analyzing the indicators. At the level of vehicle services, the time is well spent, in a uniform way, exploring well the autonomy of operation of the vehicles and the times of permanence in the station.

REFERENCES