# INTEGRATING SIMULATION AND BUSINESS INTELLIGENCE ANALYSES FOR TACTICAL AND STRATEGIC DECISIONS IN TRANSPORTATION SYSTEMS

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## ABSTRACT

Transportation planners, analysts and decision-makers usually make use of simulation tools in order to accurately predict the performance of new practices and policies before their implementation. Additionally, most of them, recently introduced new auxiliary Business Intelligence decision support tools in order to transform their available huge amount of real operating data into timely and accurate information for their decisions.

Although both of those types of automated decision support are valuable, very few attempts were already made by researchers to integrate them into a unified tool.

This paper proposes a conceptual framework for a decision support system that integrates both of these technologies, simulation and Business Intelligence, in order to enhance the overall practical interest for its usage by taking advantage of the foreseen synergy of the integration.

The paper discusses the potential interest of the proposed integration, and identifies a set of questions that can then be answered with effectiveness and more efficiently than before.

**KEYWORDS: Business intelligence. What-if simulation. Integrated decision support system.**

**L & T – Logística e Transportes**

## 1. Introduction

The design and planning of transportation systems are usually very difficult tasks due to the intrinsic high complexity of the interactions between the numerous stakeholders and physical elements involved. This is the main reason why simulation tools are widely used in such tasks, since they allow mimicking the functioning of the systems, testing and evaluating the performance of different plans, prior to their actual execution. Nowadays, evaluation of different alternative solutions is worthy to identify the option(s) that are economic, social and environmental sustainable. In most cases, traditional analytical methods are unable to fully address these issues.

Business intelligence (BI) tools comprise a set of analytical, statistical and artificial intelligence techniques along with sophisticated graphical technologies that enable decision makers to transform their available (huge amount) of data into timely and accurate information for their decisions.

Simulation tools and BI tools can be viewed therefore as complementary tools for decision making support. However, only a few attempts to make use of effective OR technologies (e.g. simulation) along with BI capabilities of historical data analysis has been reported in the literature (Sabbour *et al.*, 2012). This paper intends to do so, i.e. to propose a conceptual framework for a decision support system (tool) that integrates both of these technologies, simulation and BI, in a similar fashion of the proposal of Sabbour *et al.* ((Sabbour *et al.*, 2012), but focused on a specific field of transportation. Curiously, our approaches were fundamentally developed independently, since the authors of this paper were aware and read the referred work some days before the completion of the document. Additionally, this proposal is based on an extension of another paper of the same authors of this paper, recently submitted and accepted in another conference.

This paper provides a systematization of the performance measures that are relevant to transportation systems, and therefore to be used as the output of the proposed advanced BI tool – section 2. Since BI is a relatively new concept for the OR community, Section 3 introduces such concept, reports some examples of tools that are commercial available, and generally describes their main functionalities. The focus of this work is on the proposal of a comprehensive framework for a what-if simulation based BI decision support system, and this is the matter of Section 4. Section 5 discusses the relevance of this proposal, and Section 6 illustrates some forms of visualization to enhance the effective and efficient use of the data and information available. Finally, Section 7 summarizes the main conclusions of this work along with some suggestions for further developments.

## 2. Performance measurement in transportation systems

The evaluation of the systems performance and all related decision making processes are based on the knowledge and analysis of quantitative and qualitative measures, usually named performance indicators. In this section, we report, in a broader perspective, the set of these indicators that may be relevant in transportation systems.

Performance measurement is a way of monitoring progress towards a result or goal (Sousa *et al.*, 2005; Juran and Godfrey, 1998). It is also a process of gathering information to make well-informed decisions. Performance measures are valuable and provide several useful benefits (TRB, 2006) such as:

- Greater accountability to policy-makers, organization customers and other stakeholders;
- Improved communication of information about the transportation system to customers, political leaders, public and other stakeholders;
- Increased organizational efficiency in keeping agency staff focused on priorities and enabling managers to make decisions and adjustments in programs with greater confidence that their actions will have the desired effect;
- Greater effectiveness in achieving meaningful objectives that have been identified

through long-range planning and policy formulation;

- A better understanding of the impacts of alternative courses of action that performance measures can provide;
- Ongoing improvement of business processes and associated information through feedback.

Traditionally, performance measures have been largely technical in nature. However, today transportation executives and managers must address an increasingly complicated and wide-ranging set of issues regarding the best solutions on balance to transportation problems, the cost-effectiveness of proposed projects and estimated impacts of those projects.

Based on the literature related to performance measurement systems for transportation, there is a large number of measures within the following categories:

- Preservation of assets;
- Mobility and accessibility;
- Operations and maintenance; and
- Safety.

The Transportation Research Board had developed a framework (Figure 1) that transportation organizations should use in order to:

- Identify performance measures that are most useful for asset management: assessing existing performance measures that are in place, identifying gaps, and considering new measures to fill gaps;
- Integrate these performance measures effectively within the organization: engaging stakeholders to ensure buy-in, designing families of measures that can be used at different organizational levels and for different types of decisions, ensuring consistency across measures, identifying needed improvements to data collection and analytic tools, designing communication devices, and documenting measurement and reporting procedures; and
- Set performance targets: establishing both long-term goals and short-to medium-term targets for performance measures.

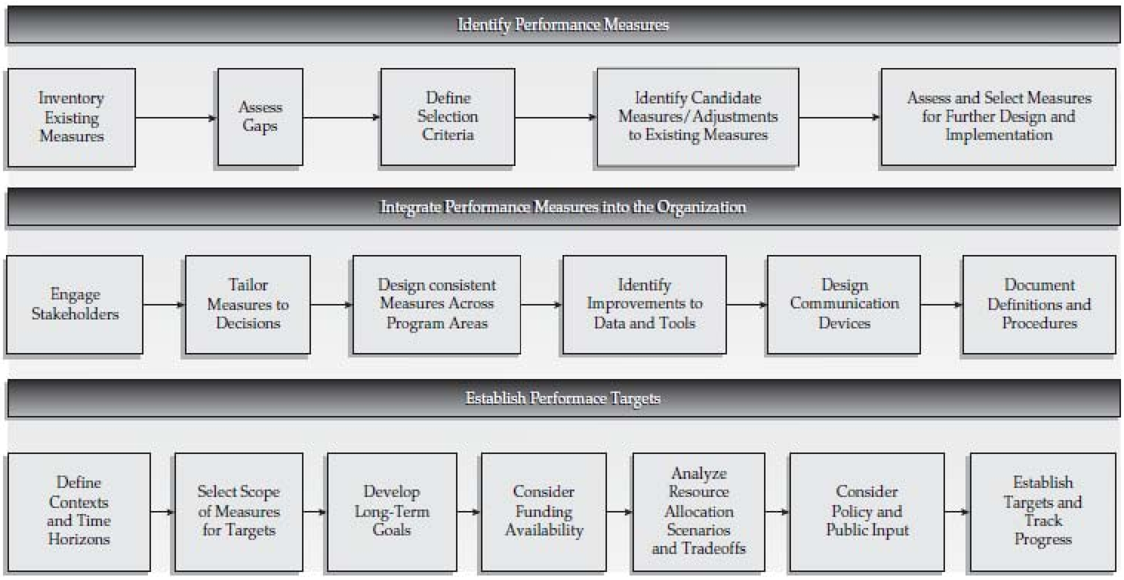


Figure 1: Guidance for performance measures and targets (Source: TRB, 2006).

Rather than a single prescriptive set of measures that might provide a good textbook example (but surely would not be suitable for all companies), the framework is in the form of guidance on the preferred types and forms of measures and the process by which companies should identify and implement them. The framework was developed with the recognition that each company will have a different set of circumstances and needs to consider in selecting and implementing performance measures (TRB, 2006).

One could not define the best set of performance measures for transportation companies, because each company has their own characteristics. However, the TRB suggests a set of "good measures" that if implemented properly, will produce good results. The performance measures categories that have been defined by TRB are the following:

- Preservation – measures the condition of the transportation system and actions to keep the system in a state of good repair.
- Mobility and accessibility – measures the ease of movement of people and goods.
- Operations and maintenance – measures the effectiveness of the transportation system in terms of throughput and travel costs and revenues from a system perspective and maintenance level of service measures focused on the customer experience of the system.
- Safety – measures the quality of transportation service in terms of crashes or incidents that are harmful to people and damaging for freight, vehicles and transportation infrastructure.
- **Economic development – measures direct and indirect impacts of transportation on the economy.**
- **Environmental impacts – measures effects on environment.**
- **Social impacts – measures effects on broader society or on population groups.**
- Security – measures protection of travelers, freight, vehicles and system infrastructure from criminal and terrorist actions.
- Service level – measures the delivery of transportation projects and services to customer.

Nowadays, a particular focus is given to three fundamental broader categories of performance measures (or indicators) – economic, social and environmental. This categorization is obviously related to recent concerns about the sustainability of existing and new projects (e.g. see Dias *et al.*, 2011; Oliveira *et al.*, 2011). In brief, one can say that these three broader categories generally comprise the majority of measures in the larger list in above.

The absence of measurement limits organizations ability to evaluate the changes and therefore precludes systematic improvement. Thus, good performance measures are a necessity for any progressive organization to recognize successful strategies and discard the unsuccessful.

## 3. The actual business intelligence concept

Business Intelligence solutions create learning organizations by enabling companies to follow a virtuous cycle of collecting and analyzing information, devising and acting on plans, and reviewing and refining the results. To support this cycle and gain the insights that BI delivers, organizations need to implement a BI system comprised of data warehousing and analytical environments.

According to Eckerson (2003), smart companies recognize that the systems that support BI solutions are very different from other systems in the company. Well-designed BI systems are adaptive by nature and they continually change to answer new and different business questions. The best way to adapt effectively is to start small and grow organically. Each new increment refines and extends the solution, adjusting to user feedback and new requirements. Additionally, the BI solutions combine data with analytical tools in order to provide information that will support top management strategic decisions (Cody and Kreulen, 2002).

The main goal of a BI solution is to collect data, store the data collected and analyze the data gathered in order to produce knowledge (Santos and Ramos, 2006). Figure 2 show the main components of a BI tool. As part of its data warehousing environment, it takes as input historical data (e.g. operational details) that is then treated in three different phases: data extraction, transformation and cleaning, and transfer and load (ETL). All the relevant information is stored into internal a general-purpose database and then into multi-dimensional (specific-data) cubes, allowing a fast execution of dashboards, analysis and reports which is (ideally) triggered "on-the-fly" by a simple mouse click – this is the analytical environment part of the BI, which is powered by statistical, OR (e.g. forecasting) and artificial intelligence (e.g. data-mining) techniques.

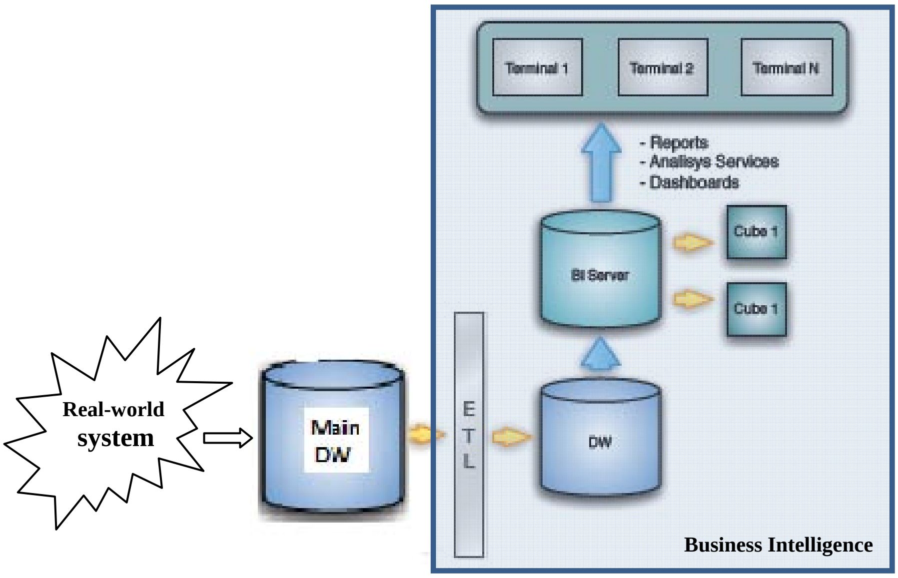


Figure 2: Business intelligent components.

The main features of a BI solution is therefore the creation of reports, the exploration and analysis of data and the creation of dashboards, which provide information on the overall system performance in a simplified form. The use of BI solutions are intended to provide managers and agents responsible for decision making in an organization, timely and accurate critical information about the (overview) performance of the system, so that they can make better decisions to improve such performance.

It is important that organizations understand the key success indicators so they can surmount the challenges associated with every BI project. The successful BI solutions should have the following characteristics (Eckerson 2003):

- Business sponsors highly committed and actively involved in the project;
- Business users and the BI technical team working together closely;
- The BI system viewed as an enterprise resource and given adequate funding and guidance to ensure long-term growth and viability;
- Firms should provide users both static and interactive online views of data;
- The BI team should have prior experience with BI;
- All the company should be committed and involved with the BI solution.

Organizations that have deployed BI solutions cite many tangible and intangible benefits. Although it's difficult to associate a concrete Return on Investment (ROI) resulting from these benefits, most enlightened executives place huge value on having a "single version of the truth", better information for strategic and tactical decision making and more efficient processes (Eckerson, 2003). The most common benefits cited in the literature are the followings:

- Time savings;
- "Single version of truth";
- Better strategic and plans;
- Better tactics and decisions;
- More efficient processes;
- Cost savings;

- Greater customer and supplier satisfaction;
- Greater employee satisfaction;
- Return on Investment;
- New revenues;
- Total cost of ownership;
- Shareholder value.

## 4. Proposed conceptual framework for a simulation-based BI tool

Existing simulation tools aim at strategic or tactical decisions, and rarely are used for operational decision making. In this sense, the key idea of simulation is to execute a model repeatedly, thus allowing the estimation of statistical measures, such as averages and standard deviations but also their confidence intervals. As a result, analysts will foresee the long-run (in most cases, the steady-state) behaviour of the system and its related set of performance measures, allowing then to perform its evaluation, e.g. comparatively against a "competing" scenario for the best in the pool for sustainability.

Perhaps the majority of transportation analysts (e.g., traffic and mobility management bodies and agents, consultants) already use simulation tools. There is available a significant number of commercial solutions, such as EMME2, AIMSUN, DYNASMART, VISUM, DRACULA, etc.

The main problem with such tools is that they are intended to be used by specialists since their outputs are usually very technical and do not integrate some other relevant data analysis (e.g., financial data). Therefore, further analyses are needed in order to reach to very specific and succinct relevant information that can deploy the decision-making. In other words, these tools are devoid of such benefits (processes' wizards, simply clicks and drag-and-drops, and relevant-only information) that characterizes BI tools.

On the other hand, BI tools, as is, are aimed at enabling analysis of historical data only. Therefore, they are not capable of giving accurate anticipations of future trends as new scenarios of functioning are concerned. And, this is the usual shortcoming that decision makers are faced to when using DSS purely based on BI tools. Therefore, it is important to incorporate reliable predictive systems capable of evaluating beforehand the impact of alternative or small changes in strategic or tactical plans. This can be done by integrating what-if analysis by means of simulation whose goal is to inspect the behaviour of a complex system under a given scenario.

In recent years, what-if analysis has been incorporated in BI tools. For example: SAP and SAS dedicated modules, MicroStrategy, Pentaho, QlikView, Powersim Studio, etc. Also, Microsoft has been integrating this technology in spreadsheets and OLAP tools. However, these analyses rely on the application of forecasting models and data-mining techniques on static historical data, thus heavily limiting the capability of performing the evaluation of most scenarios, namely all those that are somewhat different from the existing one.

In order to overcome this shortcoming, we then purpose an integrated approach that fundamentally consists on setting up an interactive loop between a compatible simulation model or tool and a BI tool to support decisions at the strategic and tactical levels (Figure 3).

The cornerstone module of this new integrated model or tool will be the "so-called BI what-if component". The idea for this component is to provide it with properly designed wizards in order to create (new) scenarios that can be simultaneously understood by managers and by the simulator component. As part of the scenario, the simulation model is inputted with all relevant information gathered by the traditional components of the BI (that, in turn, are based on historical data or previously simulated data), e.g. probability distributions of possible events.

In this proposed approach, the BI environment triggers the simulation runs that are necessary to estimate the performance of new scenarios. The simulation model mimics the functioning of the (new) system, and populates its proper data warehouse. This data is extracted by the BI server (if it is correctly "cleaned" already) or by the ETL component, following then the normal analytical processes of the BI. (Note, however, that it will be important to being able to distinguish between real and simulated data and derived information at any moment and at any BI component.)

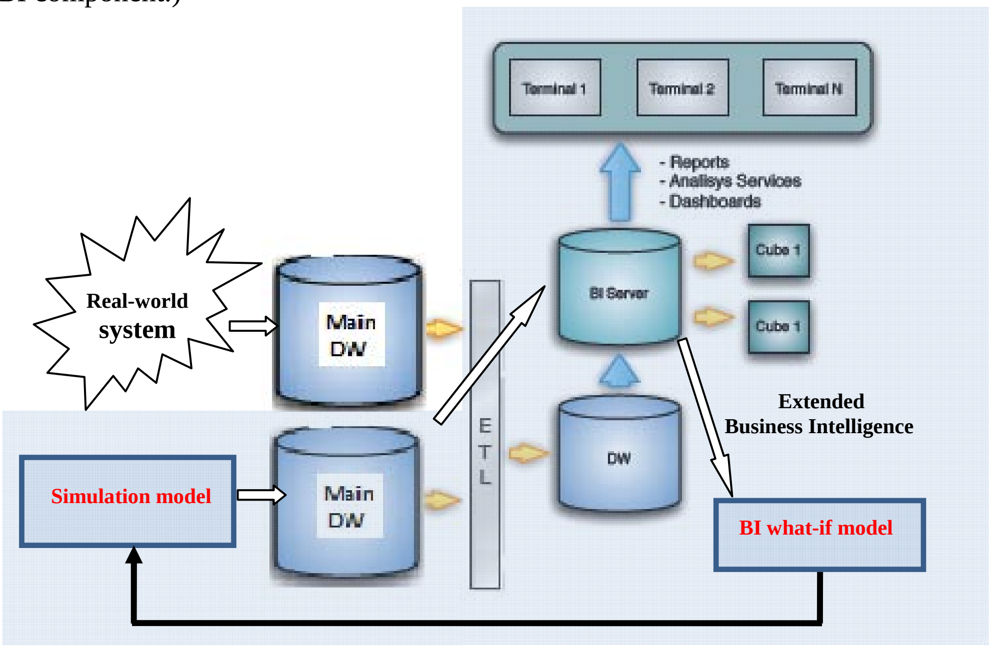


Figure 3: BI simulation-based decision support system.

## 5. Discussion

"Intelligent transportation systems" (ITS) integrate a broad range of IS/IT elements for gathering on-site data and transfer it to the central database(s) of the enterprises or organizations. ITS also integrate the required hardware and software to analyse and manage the information extracted from data.

In general, the amount of data available (e.g. detailed traffic operations events and conditions) is huge, and only a relatively small fraction of that is adequately translated into information that is used by managers. In most cases, this is restricted to the information that is easily obtained by applying traditional query database operations and graphical displays, including standard statistical elements (e.g. historical means and deviations of traffic volumes) in general-purposed tables, graphs and maps. But, in fact, much more information can be potentially gathered from real data: (1) further performance measures can still be obtained by traditional forms; (2) deeper information somehow hidden in the databases that can be highlighted by applying more advanced analytical methods, such as data mining, optimization and simulation, as well as advanced forecasting (e.g. auto-correlative, multi-regressive) and statistical techniques; and, very important, (3) most of all this information can be better highlighted by using alternative, more adequate forms of visualization such as well-designed graphs and maps; also, some information (e.g. spatial-temporal trends) can be exclusively evidenced by specific forms of visualization. It is widely recognized that it is (often) easier to detect a pattern from a "picture" than from a textual or numeric explanation.

From the above, it is obvious that one of the most important problems of ITS is the analysis and management of information. This problem is becoming further relevant due to the permanent increase on the availability of data and their related inexpensive storage and processing power as a result of the widely implementation of modern IS/IT systems.

On the other hand, ITS planners and decision-makers need to foresee the performance of systems (existing or desired to be implemented), and therefore they need to use suitable simulation tools.

At the strategic level, planners are supposed to set up the objective, aim, and the broader strategy and policies of the system. For example, in a recent work on the design and planning of demand-responsive transportation system, Dias *at al.* (2011) report the following set of decisions at this level: How the system should be operating in the long-term in order to be viable and sustainable in the three basic terms: economic, social and environmental? What are the main objectives of its existence? Which type of services must it offer? At what level(s) of flexibility? At what price levels (whether taking account or not potential subsidisation)?

At the tactical level, decisions aim to devise ways to implement the transport system according to the strategy previously defined. This planning stage is crucial for the design of the transport scheme and several authors had identified the most critical decisions. For example, for the case of a demand-responsive transport (e.g., Giannopoulos, 2004; Mulley and Nelson, 2009; Quadrifoglio and Li, 2009):

- What exactly level(s) of flexibility should be adopted, in terms of routes, timetables, frequencies, time-windows (ex, arrivals at stops)?
- What pre-booking mechanisms and rules should be adopted?
- What resources are going to be used (fleet, drivers, informatics, TDC center and staff)?
- What fare structure should be implemented?
- Which level of integration with public transport network (schedule buses/train network, etc.)?

The proposed extended and integrated BI solution can implement most of the performance measures reported before (Section 2), and easily translate them into the form of traditional tables, graphs and reports. This includes making use of simple dashboards. Most of these elements can be easily customized by end users, according to their specific needs and options.

Data visualization can be seen as the process of translating information into a visual form (usually graphs and maps), enabling users (scientists, engineers and managers) to perceive the features of the data available, and, from that point, to help them to make more effective decisions at different levels: strategic, tactical or (even) operational. For example, deciding on the design of service operations strategies or, simply deciding on the realization of a functional regulatory (e.g. corrective) measure to ensure the normal functioning of the system or to minimize the impact of an anomalous event (incident) that has occurred.

## 6. Illustrative examples of extended-BI output

In the following paragraphs three different examples show the importance of adequate visualization patterns according to specific nature of data recorded and information needed.

The examples are related to the design phase of a particular transportation system, before its implementation. In particular, it is related to a passenger demand-responsive transport (DRT) system (see more details in Dias *et al.*, 2011b). No real information exists yet on its functioning, so it is considered as a purely strategic and tactical decision process. In this case, the simulation model component must be used in order to emulate what could happen at any tested real-world scenario, in order to allow the evaluation of different options (essentially, system objectives and rules).

In order to detect peak periods and understand correlation to service delays may be worth using simple line charts of average traffic volumes and delays estimated in the system, as a function of day-time (Figure 4). This should be done by taking into account the average figures for relevant zones or intersections that affects each transport service (or call). Such information (patterns) can be also incorporated into adequate predictive models of time arrivals at stops (e.g. for public panel information).

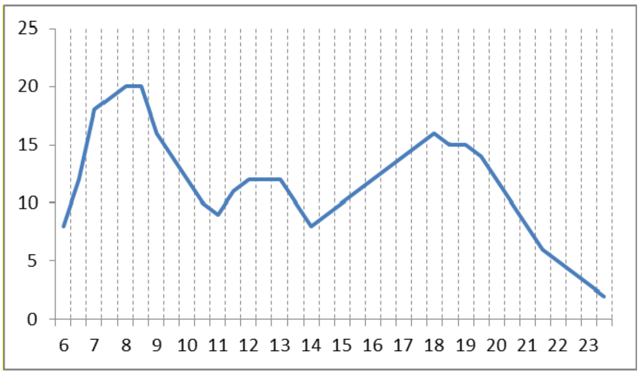


Figure 4: Line chart of the average volume at a given location (e.g. public transport stop or service zone).

In order to perceive and monitor service levels in different directions from a given urban center (e.g. incoming PT services bringing people to work at the morning peak), may be worth using a rose-like diagram (Figure 5). This can be done per service or group of services in each direction (e.g., north, west, south and east bands).

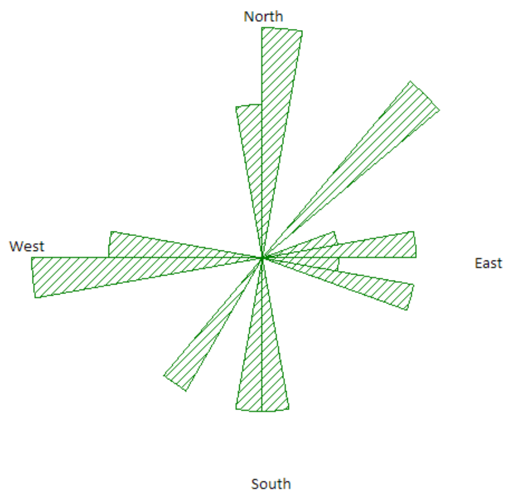


Figure 5: Rose-like graph of frequencies for 12 outbound service calls at the evening peak: each route is represented by a triangle illustrating its direction and relative frequency.

In order to infer the patterns of transit volumes in each direction per time of day (in average), may be worth using clustering analysis, e.g. putting in evidence similar directional service patterns among different time intervals. In these cases, the use of colored "graph-image" may be useful (Figure 6).

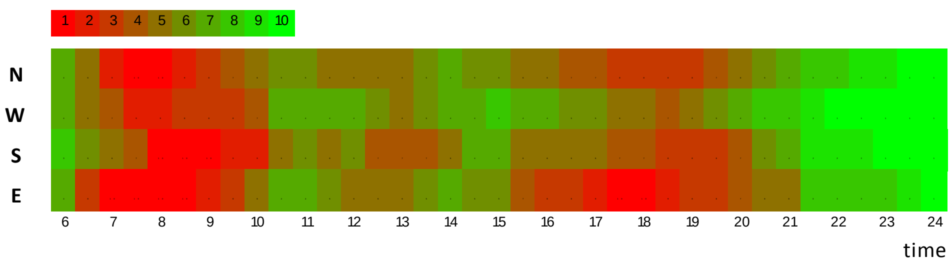


Figure 6: Average inbound and outbound public transit volume by direction and time of day (30 min clusters).

The panels or dashboards are very interesting and useful to the analyst, allowing an overview of the system and discovery interaction between its various elements (e.g. tables, charts, combo box, etc.).

In the case of Figure 7, there is a dashboard in which the user can selects a specific driver for analysing (through the combo box), causing the dashboard display in this table the rows that automatically made conductive, and the sum of distance for each. Then the user can still click on a career, and will automatically be presented with a graph of the distance travelled during the various times of day, for this career.


Figure 7: Dashboard combining table and graph.

## 7. Conclusions

The extended BI solution herein proposed can produce performance enhanced analyses for the transportation operators companies. The reports have two different levels. There are strategic reports that are only used by the companies' top management and there are operational reports to be used by the medium level management.

In this paper we do present a systematization of performance measures to be used for the evaluation of the performance of transportation systems. The model adopted is supported in the framework developed by the Transportation Research Board for transportation companies, which define nine performance measures categories. These performance measures are supposed to be incorporated into simulation and BI transportation models, by properly design their computation model. (Most of the measures, such as averages and standard deviations of a given relevant variable, are easy to implement, but others may not.)

One of the most important problems of ITS is the analysis and management of information gathered either from historical data or simulated data. The simulation-based BI solution herein proposed is funded on a framework that extends commercial available software by explicitly incorporating a "what-if analysis" BI component that easily creates new scenarios (of the functioning of the system) and automatically transmit all needed information (data) to the simulation model as its input.

Real and/or simulated data can be extracted by BI system, and then processed and translated into the form of traditional tables, graphs and reports, and allowing easy customization by end users. Thus, this work promoted the use of general proposed BI tools that, along with the integration of advanced analytical techniques and prospective what-if simulation, support the inference of both strategic and operational performance measures helping decision makers in the transportation sector in monitoring and manage their working system, in designing new strategic and tactical improvements, and even in designing new sustainable systems by accurately predicting their performance and related economic, social and environmental impacts.

Currently, the authors are devising a specific integrated simulation-based BI system for the case of a DRT transport system. Numerical results and validation are expected in the short term.

Public transport services must be monitored by means of dynamic vectorial maps, inter-operating with real-time data gathering devices (e.g. in-vehicle equipment including GPS). This sub-system of the ITS is commonly recognized as being a geographic information system (GIS). Most spatial-temporal patterns will be only detected by displaying the related information on the map, so this sub-system constitutes a must-be in a BI for transportation systems. As part of the research work carried out, it was possible to integrate a GIS web-service (*googlemaps*) in the actual version of the BI application. Further work consists on establishing its integration with alternative, yet functionally richer, GIS software in order to enhance the usefulness of the overall decision support tool.

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