Data Analytics and Reporting in Toll Management and Supervision System – Case study Bosnia and Herzegovina

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Abstract

Toll Management and Supervision System (TMSS) is responsible for centralized collection and processing of data originating from both internal and external systems (all underlying Tolling system layers – lane/plaza, and external partner systems like ERP, banking systems, POS etc.). Processing of this data enables generation of wide scope of reports and data analytics which are used for overall system monitoring and management of system functionalities and key business performance indicators in both on-line and off-line operational regime. Data analytics and reporting are essential for effective decision making on all management levels (operational, tactical and strategic). In fact, managers and line-of-business users are anticipating the system through these reports and information visualizations, while most of other system functionalities are mere support services for technical system functioning and operation. In this paper we will present Reporting and Analytics module of TMSS implemented at highway segment “Jošanica – Kakanj” on corridor A-1 in Bosnia and Herzegovina. Data analytics is based on modern data warehousing (DWH) architecture which provides optimal performances in near real-time processing of statistical and historical information of large data volumes. Reporting is based on optimized DWH data structures, enabling generation of pre-defined (standardized) as well as ad-hoc (dynamic) reports and data visualizations implemented on latest Oracle Business Intelligence technology platform.

Keywords: Pay Toll System, Data Processing, Data warehouse, Business Intelligence, Analytics and Reporting

1. Introduction

Toll Management and Supervision System (TMSS) is the central system of toll collection, in which all the data on operations of lower hierarchical levels are collected. After data analysis there is a set of reports, based on which it is possible to monitor and manage the system operations both online and offline, as well as to control the performance of all system functions. Data processing and the set of reports are the basis for making various decisions on all levels of management: operational, tactical and strategical. This paper
describes Analytics and reporting as a special module of TMSS. Analytics is based on the Data Warehouse (DWH) architecture which provides optimal performances in near real-time for the statistical and historical analysis of large amounts of data. Reporting is based on optimized data structures, enabling generation of pre-defined (standardized) as well as ad-hoc dynamic reports using the modern Business Intelligence (BI) technology.

The TMSS is designed for the highway section Jošanica – Kakanj on the corridor A-1 in Bosnia and Herzegovina. This section is 37 km long and has six toll stations with 30 toll lanes. The TMSS is applied from 14 June 2012 and there is a plan to expand it to other sections of highways in Bosnia and Herzegovina (Mihajlo Pupin Institute, 2012).

The paper includes six sections. The section 2 describes the context of the DWH, and the section 3 describes the BI technology, both applied while designing the TMSS. The section 4 is a brief description of the Toll Management and Supervision System. The section 5 of the paper is a description of the Analytics and Reporting module and a review of reports which are available on the system operations. The section 6 shows the Reporting and Analytics as support in decision making at various management levels. The section 7 consists of final considerations.

2. Data warehouse

Data Warehouse (DWH) is a database technology that allows entry, storage and processing of heterogeneous data from different sources in order to provide a quality basis for reporting and analytics to end users. From a system point of view, the DWH corresponds to the organizational scheme of the business system, from the level of the source data to the level of decision making. From the technological point of view, the DWH is a set of layers that provide receiving, transforming, processing, and on-line analytical processing (OLAP) of data. The DWH systems provide storage and processing of large amounts of data from integrated heterogeneous sources in optimized multi-dimensional data patterns. Multidimensional data patterns correspond to the nature of human thinking and reasoning, and consist of facts, measures and dimensions (Golfarelli, 2009). The facts are the main factors in the decision making process, and the measures represent a quantification of facts expressed in a particular dimension.

Some of the reasons for designing the DWH systems are (Stewart, 2008):

- Integration of data with business functions and processes in order to obtain a complete picture of individual parts or the whole business system.
- The possibility of simultaneous execution of large queries and reports, and routine operations of business users with other system functions.
- Reorganization of data in order to perform queries and reports more quickly.
- Assurance of quality through strict checking of data entry – data consistency and integrity.
Development of the DWH systems is very complex and requires an ad-hoc methodology and the appropriate life cycle. In the literature, the DWH evolution is classified into three different approaches, namely schema evolution, schema versioning and view maintenance (Oueslati and Akaichi, 2010). The DWH system changes are inevitable in practice, because it has to correspond to real business system and its requirements. Today, there are developed quality software tools that enable the DWH system maintenance and a consistent implementation of the changes in all layers.

Inside the TMSS is a developed DWH system whose architecture is shown in Figure 1. The data is collected from various internal and external sources: the database from the lower hierarchical levels, off line data import from the files and data import from external systems (On Board Unit – OBU and Cards Company – CC Providers, Banks, ERP system, Point of Sale – PoS network, etc.). Operational Data Storage (ODS) layer receives and stores all data from internal and external sources. Extraction, Transformation and Loading (ETL) layer performs a check on the consistency of data in accordance with defined rules, establishes relations of data integrity and establishes the data patterns in the DWH. In the Summary layer there is a data aggregation at different levels of detail according to the needs of the analytical layer. Analytical layer consists of a set of data models, which are the basis for generating various reports, as defined in the TMSS. Data marts are defined according to the basic subsystems of a business system and they allow obtaining various business reports. The analytical layer and definition of the reports were developed using the Business Intelligence (BI) tools, and will be described in the next section of the paper.

**Figure 1. Data Warehouse Architecture**
The main advantages of the described DWH system are:

- Possibility to import heterogeneous data from various internal and external systems.
- Consistency and integrity check of data and creation of individual transactions that are stored in the DWH.
- Defining the different levels of aggregation according to the requirements of the business system.
- Good real-time work performance.
- The possibility of extending the system in order to form a base of knowledge and development of Decision Support Systems (DSS).

3. Business Intelligence

Business Intelligence (BI) is a set of methodologies, processes, architectures and technologies that transform raw data into meaningful and useful information and knowledge. This enables better decision-making at an operational, tactical and strategic level and improvement of the performances in the business system (Figure 2). BI provides support in decision making in real time or near real time.
The central part of the BI technology is analytics and reporting, which have obtained new possibilities on the modern Information Technology (IT) platform. BI researches shows that this technology is evolving and companies, based on new trends, can gain a competitive advantage in their respective fields.

The BI system can be viewed from various perspectives. BI systems allow turning data into information and knowledge and thus creating new conditions for decision making in a business system. Decision makers in the business system use the BI analytics to support quality and timely decision-making at all managerial levels. The real value of BI systems is reflected in the additional value generated: better understanding of their own resources, implementation of changes in the business system, opening of new markets, acquiring new customers, etc.

The application of BI in a business system can be (Williams and Williams, 2007):

- Improving the operational functioning of business processes – monitoring, reporting and analytics of the basic business processes, timely response in critical situations, operational and tactical decision-making.
- Improvement of management process in a business system – reporting and analytics as support to management and strategic decision-making, measurement, monitoring, control and planning of business performances, making decisions about increasing profits and / or reduction of costs.

The potential of BI systems is very large, and the business value of BI systems can be a strategic challenge for implementation in all areas. The development of BI system requires understanding the business system, defining a framework for reporting and analytics, as well as linking business requirements with individual BI applications.

In the TMSS a BI system was developed using Oracle BI Publisher (oracle, 2012). The BI system comprises a set of reports, which are grouped according to business processes they relate to and levels at which they are applied. The process of designing a report in Oracle BI Publisher includes the following phases (Figure 3):

1. Design Data Model – The data model includes a description and a structure of the data needed for the report. Data models can be simple (containing one data set) or very complex (containing more data sets, data set definition, parameters). One data model can be applied to the design of one or more reports.
2. Design Layout – Layout is the form and arrangement of data presentation in the report. A layout can contain tabular data, pie charts, diagrams, charts, and other forms of graphic representation.
One report can have one or more layouts. Layouts enable multiple representations of underlying information, suitable for different end-user needs.

3. Report Properties – Basic elements of the report properties are: general, caching, formatting, font mapping and currency format. Properties define the basic elements and parameters of report materialization (generation of output documents).

![Figure 3. Report Design](image_url)

When executing the report, users may specify the format of presentation (materialization). Reports are available in various formats: Interactive, HTML, PDF, RTF, Excel and PowerPoint. Report Design in Oracle BI Publisher requires no manual programming, but it is an interactive process that includes a set of steps in each of the three phases described above (Oracle, 2012).

4. Toll Management and Supervision System – TMSS

The system of toll collection is a complex information system that includes hardware and software components. In organizational terms, the toll system includes three levels: lane level, plaza level and central level. All three levels of the system are in on-line or off-line communication. The central level collects, processes and distributes data allowing continuous monitoring of the toll collection system and receiving reports on all aspects of work. The operation mode and the data processing system at the central level is based on well-defined logical and business rules. Data is collected from the toll lanes, toll stations and from external systems. External systems include: ERP, Banks, POSs, OBU Providers and other external systems.

The Toll Management and Supervision System – TMSS is designed at the central level. In the TMSS all data is stored in the Oracle database, while the internal applications and services are implemented as web-based applications to Oracle Middleware platform, which consists of Oracle WebLogic Application Server and Oracle BI platform for analytical reporting (Oracle, 2012). Access to all data and functions in the system is protected with security mechanisms based on roles, which allow high granularity of access control and review of application, which is supported by the chosen ICT infrastructure platform. The TMSS includes several modules, and each module consists of the components (service-composed architecture – SCA). Each component implements a logical group of functions, which support a major role of an appropriate module (business services). Functions present in the whole system are executed through the integration and coordination of services provided by modules/components. The logical architecture of the
Central system provides a functional connection with the lower hierarchical levels and external systems.

Basic TMSS modules are:
- Internal and external integration
- System Management
- Toll Charging
- Customer Management
- Analytics and Reporting

This paper describes Analytics and Reporting of TMSS and decision making support at all organizational levels of the business system.

5. Analytics and Reporting in TMSS

Analytics and Reporting in TMSS include a set of reports that describe all business segments of toll collection. Based on the reports, it is possible to monitor the system in both on-line and off-line regime, and control the realization of all business functions. Analytics is based on the DWH architecture, which allows optimal performance in near real-time statistical and historical analysis of large amounts of data. Reporting in near real-time depends on the level of granularity (hour, shift, day, period). Reporting is based on the optimized data structures, allowing the generation of standardized ad-hoc and dynamic reports by using the modern BI technology. Using the Oracle BI platform enables users to define new ad-hoc dynamic reports through intuitive web-based applicative modules.

Analytics and Reporting include the following groups of reports:

- **Toll Charging**
  - Financial Report
    - The report on billing and paid passages
    - Total revenue per station
    - Report on free passes
    - Report on payments of collectors
    - Report on surpluses and deficits of collectors
  - Traffic Report
    - Report on overall turnover at stations and on dates
    - Report on the entrance of vehicles on the highway
    - Report on the exit of vehicles from the highway
    - Report on the traffic of vehicles (entrance/exit)
    - Report on the re-categorization of vehicles
    - Traffic images on toll stations
    - Traffic image on entrance stations
- **OBU and CC**
  - Report on sales and amendments for OBU and CC
  - Report on the entrance and exit of vehicles at OBU and CC
  - Report on the passing vehicles at OBU and CC
  - The report by the users of OBU and CC services
- **Financial & Customer Management**
  - Report on clients (OBU and CC)
  - Report on the status of clients' accounts
  - Report on account status of OBU and CC
Synthetic reports
Analytical reports
Overview of unmatched items for booking of the account/client

- System Management
  - Report on the current state of equipment
  - Reports on the import and export of data
  - Reports on the work of the users

All these reports are available in different levels of detail, depending on the set of input parameters: road, station, collector, period, means, client, etc. Analysis of reports provides a complete picture on the functioning of the business system of toll collection and making different decisions regarding:
- The functioning of the toll system,
- Traffic flows on the highway,
- Financial revenues from toll collection,
- Application of OBU and CC in the system,
- Clients and their accounts etc.

6. Analytics and Reporting as support to decision making

The system of decision making in the business system (company) can be schematically represented in the form of a pyramid (Figure 4). The figure shows the organizational levels of decision making, groups of users in the business system, and horizontal and vertical integration of the system. In accordance with the hierarchy, business processes and work organization in the business system (company) there are four organizational levels (Radivojević and Popović, 2009):
- Operational level,
- Tactical level,
- Management level, and
- Strategic level.

Information connectivity of different hierarchical levels in the business system can be viewed in two ways: horizontal and vertical integration. Information flows that go from the lower level are the input data for decision making at a higher level. Information flows that come from the higher-level are management decisions for the lower level. Horizontal integration involves information flows at the same level of decision making, which are shared between different business processes. Horizontal and vertical integration of the TMSS include networking and mutual exchange of information between all segments of the system (modules) at different levels, in order to provide technical and organizational conditions for scalability – the ability to provide in each module the necessary performance required for on-line mode in near real-time.

TMSS's Reporting and Analytics are the basis for making different decisions at all management levels. Essentially, managers and business users see the entire system through a set of reports, while other applicative system functions are provided solely as a service for the operational management of the work in the technical sense.

Figure 4. Managerial and organizational levels
The TMSS generates a large number of reports that can be at different levels of detail and accordingly are meant for different organizational levels:

- Detailed reports on individual events (e.g., the current state of equipment, user activities, cash payments/balances of cashiers, etc.)
- Reports on the daily work of tolling system (e.g., entry and exit passages of vehicles, daily income, report on charges and paid passages, re-categorization, etc.)
- Reports on the system operation in a given period (e.g., number of vehicles, images of the vehicle traffic, toll revenue, sales revenue and additions to OBU and CC, collector surpluses and shortages, the state of customer accounts, OBU and CC, etc.)
- Monthly and annual reports (e.g., total revenue, number of vehicles at stations, the application of OBU and CC, report on customers who have the OBU and CC, review of unmatched items of booking, analytical reports generated by cross-matching of multiple information, etc.)

An example of a report at different business levels of toll collection system, which are obtained using the DWH and BI technology, is shown in Figure 5. All reports generated in the system (shown in Section 5) may be at different levels of detail: for each shift, day, or any defined period. Based on reports defined this way, at each level good decisions can be made relating to individual business processes, group processes, or relationships with external systems (banks, OBU and CC providers, special users, etc.). The decisions made in the business system may be related to:

- The physical configuration of the system (determining the number and type of input and output lanes, definition of shifts),
- Tariff policy (toll pricelists, tariff packages for OBU and CC, lists of exemptions and free passes),
- Stimulation of application of OBU and CC (expansion of the network of sales, bonuses and discounts in paying for selected clients),
- Customer Relationship Management (monitoring of customer accounts, OBU and CC, gray and black lists, the introduction of additional web services), etc.

Figure 5. Reports on the different management levels

Based on a defined set of reports, it is possible to generate the synthetic and analytical reports, which represent a higher level of data abstraction and support to strategic decision making at the highest level of business system. A set of these reports is virtually unlimited and depends on the existing way of functioning of toll collection system at lower levels, the need for business systems and strategic management plans.

7. Conclusion

This paper describes the TMSS and, in particular, the Analytics and Reporting module. The TMSS provides control and monitoring of the toll collection system, obtaining reports and support to management decision making at all
levels of the system. Analytics and Reporting are based on the DWH architecture and the BI technology. The designed set of reports provides users with a complete picture of the functioning of the system. The described central level of the system of toll collection is used on the highway section "Jošanica – Kakanj" of the corridor A-1 in Bosnia and Herzegovina since 14 June 2012. Previous experience of authors in the system deployment and testing period and starting period of system operational usage, shows promising advantages of the new TMSS and Analytics and Reporting modules:

- The modularity of the system and the possibility of extending through new features and reports – the design of new modules with analytical reports aimed at making a strategic level of decision in course of business operation.
- Application of the DWH architecture that allows optimal performance in near real-time for statistical and historical analysis of large amounts of data – quick obtaining of reports (up to 3 sec.) simultaneously with the parallel execution of other system functions.
- Application of modern Oracle BI technology that enables optimized data structures, the generation of standardized and ad-hoc dynamic reports – DWH architecture and BI technology enable the expansion of a set of reports and definition of ad-hoc reports by user.
- The possibility of connecting with external systems, and export of reports in various formats – import of data from banks and OBU and CC providers and export of reports in the ERP of the business operator.

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References


