BUSINESS INTELLIGENCE FOR TRANSPORTATION AND INFRASTRUCTURE SYSTEMS

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1. ABSTRACT

This study illustrates the advantage of using a business intelligence (BI) approach for the analysis and processing of transportation and infrastructure data. As a case study, a data warehouse, interactive dashboards including maps, and advanced analytics were created for data from the Pavement Management System (PMS) of the Nevada Department of Transportation (NDOT). The combination of all these capabilities in one single platform enables to maximize the value of the available data.

2. INTRODUCTION

The traditional approach to manage and use transportation and infrastructure data involves disconnected silos of information of various types. This approach is inefficient, expensive, and precludes a holistic analysis and use of the data. It takes significant time to obtain and process data to prepare reports and insights required by various data users including engineering, planning, design, construction, operations, and management. In addition, replication of data and the corresponding processing is typically performed by various groups. Often times there are major inconsistencies across the silos of data that complicate their integration. In addition, advance analytics and the use of state-of-the-art methodologies are precluded because the required data is not available in the correct schema/format and context. To address all this problems, this study is developing a data warehouse, a business intelligence (BI) collection of reports and dashboards, and advance analytics for various data systems of the Nevada Department of Transportation (NDOT). The development includes integration of data and tools to provide state-of-the-art solutions and capabilities to NDOT. As an example, the Pavement Management System (PMS) has limited ability to answer administrative questions and provide business solutions due to lack of connectivity with other key NDOT's data sources. A potential mechanism to integrate data across various disconnected silos is through their spatial and temporal characteristics. Once the data is integrated and structured, a BI approach is used for analysis and forecasting. BI facilitates data-driven decision-making for a large range of cases such as investment, prioritization of projects, and strategic planning. The reports generated in BI are interactive, visually attractive, easy to use, easily exportable, and the users can easily build new reports. The combination of all these capabilities in one single platform enables to maximize the value of the available data.

3. PAVEMENT MANAGEMENT SYSTEM

Highway engineers and managers Pavement Management System (PMS) to make informed decisions for maintaining and improving pavement conditions in a cost-effective manner. The PMS accommodates data such as pavement condition and traffic information, required for engineering analyses that are made during decision making process. Such analyses are data driven processes, which are heavily dependent on the quality and accuracy of the data.

The Nevada Department of Transportation (NDOT) developed its PMS in July 1980. Over the years, the PMS has been improved in terms of data collection and storage. In addition, it has been updated to address the federal requirements for the Highway Performance Monitoring System (HPMS) and state requirements for the State Highway Preservation report per the Nevada Revised Statutes (NRS).

The current PMS has limited interaction with other relevant systems including road network, traffic information system, safety management system, and maintenance management system. In addition, existing practices using PMS have limited ability to answer administrative questions and provide business solutions. As these systems have spatial and temporal data characteristics, they can be integrated into an Enterprise Data Warehouse for BI.

This paper focuses on providing a concept for the implementation of BI for the PMS for the NDOT. The BI framework creates an environment to perform various analytical evaluations of pavement improvement projects to maintain roadway network in adequate condition by utilizing the available funds.

4. OVERVIEW OF NDOT PAVEMENT MANAGEMENT SYSTEM

The PMS of the NDOT consists of the following three major components:

1. Data collection system, which includes a set of standard guidelines for collecting pavement condition data such as roughness and distresses.
2. PMS application database, which stores the pavement condition data as well as other relevant information such as historical and current contract data, maintenance data, cost data, traffic data, and environmental data.
3. Analytical methods to evaluate repair or preservation strategies.

The PMS includes information required to recommend strategies for cost-effective repairs and maintenance within allowable budget. NDOT has developed its own rating system to calculate Point Rating Index (PRI) value. The PRI includes a numeric scale that corresponds to condition cues and descriptions and is used to rank the condition of pavement segments based on different distresses. Each pavement segment is rated and a corresponding repair strategy is recommended. The repair strategies vary from preventive maintenance to major rehabilitation. The PRI and associated repair categories are used to determine the overall condition of the roadway network (*1*).

5. BUSINESS INTELLIGENCE FRAMEWORK

The BI framework provides a learning environment by enabling agencies to follow a virtuous cycle of collecting and analyzing information, devising and active on plans, and reviewing and refining the results (*2*). In this study, Oracle Business Intelligence Enterprise Edition (OBIEE) is used to create the BI framework for the PMS. The following sections provide details about the BI for the PMS.

4.1 Data Warehouse Design and Implementation with Oracle Data Integrator

The data required for BI is pulled from the source database using an Extract-Transform-Load (ETL) process through Oracle Data Integrator (ODI) and is used to create a data warehouse for OBIEE. The data warehouse design follows a star schema, which is created by dimensional modeling.

The PMS database includes various data elements such as location information, contract related information, various tests data, environmental data, contract geometry and associated information. The geometry from these tables are used in Oracle MapViewer to create Oracle maps in OBIEE. In addition, tables outside the PMS are used to complement the data warehouse and to improve the consistency in the interface. There is an external table for date and another table that is used to integrate documents related to pavements.

The data for the PMS are integrated into the data warehouse using six interfaces and two procedures. The procedures of the PMS are responsible for creating database objects and creating data for a lookup table. These interfaces and procedures create a star schema that consists of five tables. Figure 1 shows an overview of the physical star schema. The star schema for the PMS consists of a single fact table. The data for both the fact table and the dimension table is extracted from a source table.

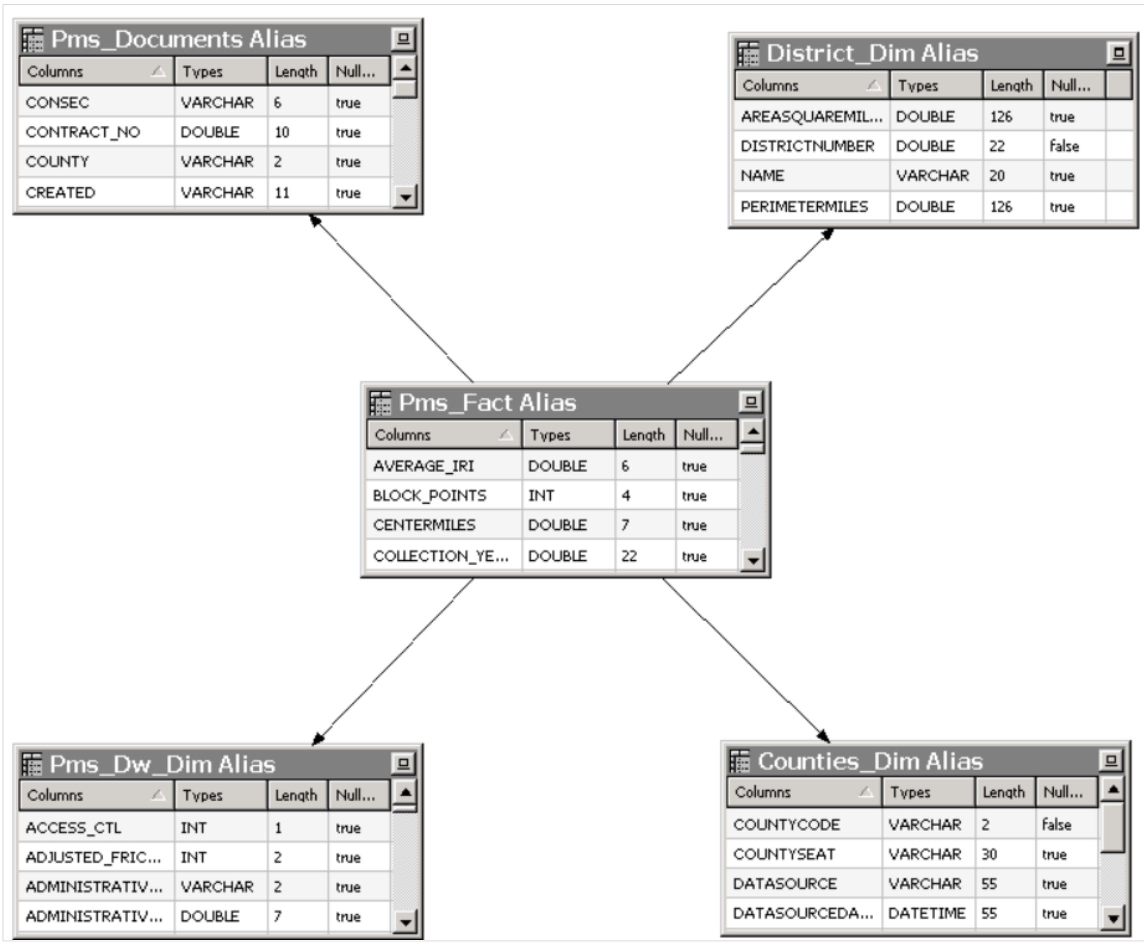


Figure 1 Overview of the physical star schema.

4.2 RPD Repository Design and Implementation

After constructing the data warehouse using ODI, the metadata layer is created. The metadata layer is defined by the RPD file. This file provides instructions to OBIEE to interact with the various tables already created. The RPD file created for PMS consists of three layers: physical, business model and mapping, and presentation layer as shown in Figure 2.

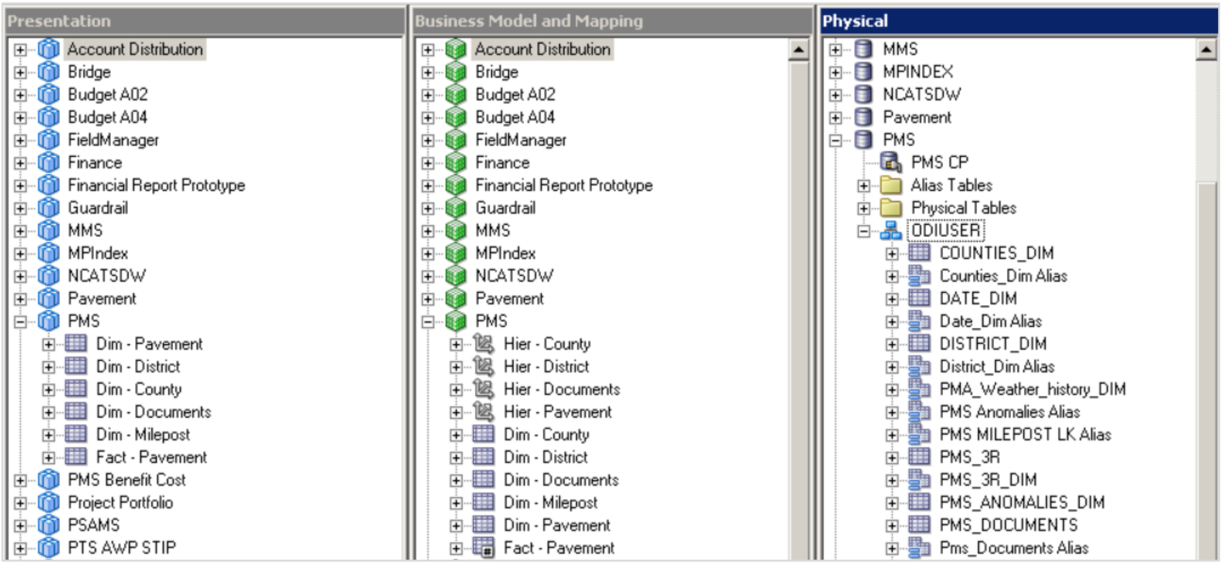


Figure 2 Three layers of RPD associated with PMS.

The physical layer connects OBIEE to the schema, 'ODIUSER', which is the target schema of the ODI operations. The physical layer consists of the tables that are part of the data warehouse diagram. After adding all tables to the physical layer of the RPD, they need to be joined in the physical layer. This allows OBIEE to know what interactions are possible among tables to create joins between the business model and mapping layer. The business model and mapping layer facilitates further refinement of joins to reflect the business logic of the subject area. Additionally, the layer can be used to refine naming conventions, program hierarchical logic into the OBIEE metadata as well as create other logical columns that are defined as functions of other columns. The presentation layer consists of items that are displayed to the user. Viewing rights and other security features on a table or a column basis can be established at this level. This layer of the RPD also consists of aliases of previous names for columns.

4.3 Dashboards and User Interface

Various analyses are created based on the current business rules. In addition, few dashboard prompts are designed, which help pavement engineers and managers to query the data required for their analysis. The results of the analyses are presented in dashboards by combining different views including title, table, graph, map, and narrative. User can customized the results just by drag-and-drop process. Moreover, the dashboard has capability to drill down from higher level information to detailed information. The reports thus created are interactive, attractive, and easy to export in any format.

The dashboard designed for PMS is shown in Figure 3. The dashboard consists of seven pages: (i) Summary (ii) IRI (iii) PSI (iv) Cracking/Distress (v) Contract (vi) Corrective Actions, and (vii) System Data. All pages except, 'Summary' and 'Corrective Actions', consist of other dashboards, which can be accessed using the links provided in the left panel of each dashboard page.

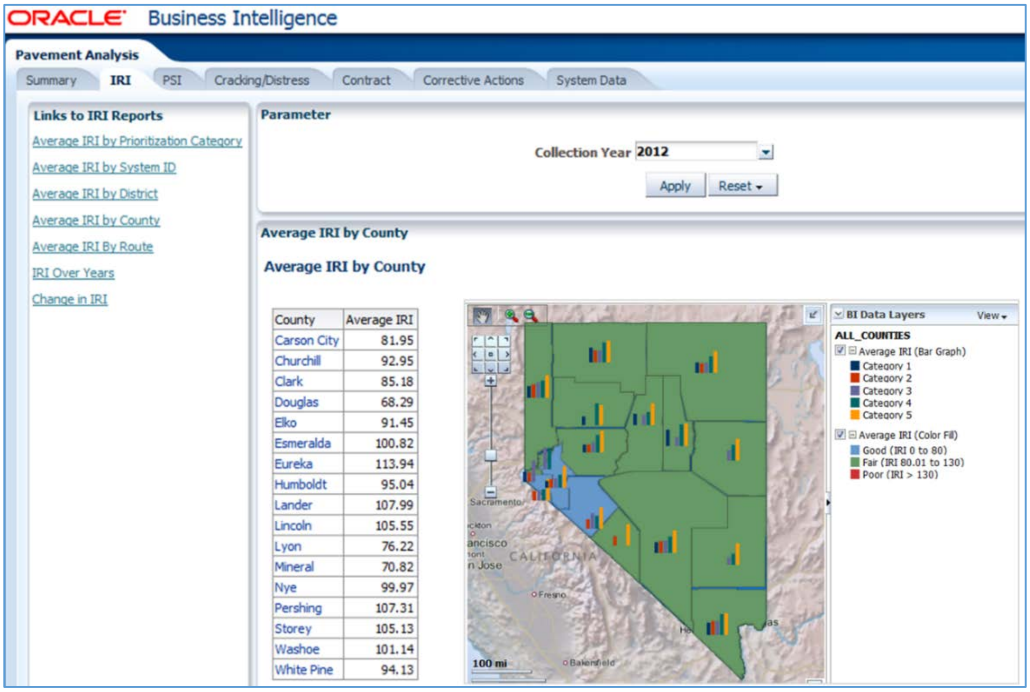
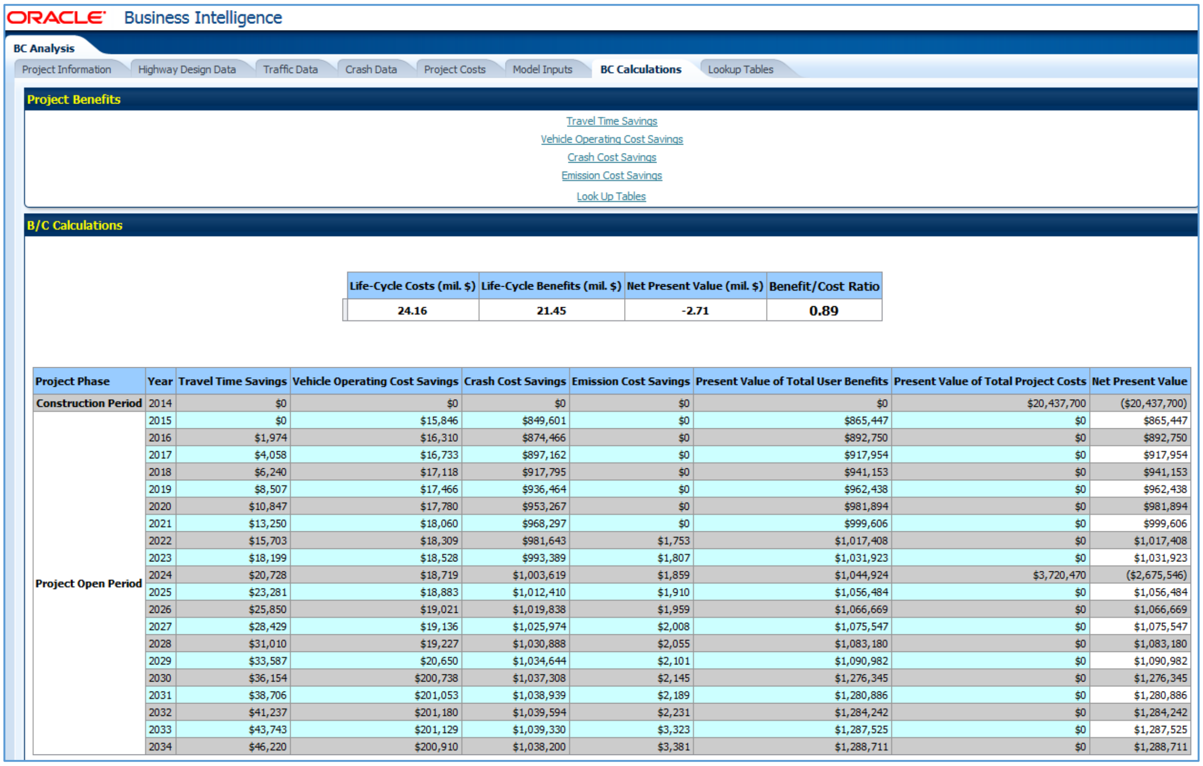


Figure 3 Dashboard designed for the PMS.

6. BENEFIT-COST ANALYSIS TOOL

A benefit-cost analysis (BCA) tool was developed in BI environment using the Oracle R enterprise. Pavement engineers can use the BCA tool to analyze the prospective pavement improvement projects to select the most cost effective alternatives. The tool uses the methodology of the existing Cal-B/C tool and Nevada specific data. The tool consists of eight tabs. The first four tabs are designed to provide project specific data. The tabs, model inputs and BC calculations, provide the results obtained from the BCA tool. The last tab, lookup tables, includes all other general data required to perform the benefit-cost analysis, which remains constant for all projects. Figure 4 illustrates one of the tabs.



Life-Cycle Costs (mil. $)	Life-Cycle Benefits (mil. $)	Net Present Value (mil. $)	Benefit/Cost Ratio
24.16	21.45	-2.71	0.89

Project Phase	Year	Travel Time Savings	Vehicle Operating Cost Savings	Crash Cost Savings	Emission Cost Savings	Present Value of Total User Benefits	Present Value of Total Project Costs	Net Present Value
Construction Period	2014	$0	$0	$0	$0	$0	$20,437,700	($20,437,700)
Project Open Period	2015	$0	$15,846	$849,601	$0	$865,447	$0	$865,447
	2016	$1,974	$16,310	$874,466	$0	$892,750	$0	$892,750
	2017	$4,058	$16,733	$897,162	$0	$917,954	$0	$917,954
	2018	$6,240	$17,118	$917,795	$0	$941,153	$0	$941,153
	2019	$8,507	$17,466	$936,464	$0	$962,438	$0	$962,438
	2020	$10,847	$17,780	$953,267	$0	$981,894	$0	$981,894
	2021	$13,250	$18,060	$968,297	$0	$999,606	$0	$999,606
	2022	$15,703	$18,309	$981,643	$1,753	$1,017,408	$0	$1,017,408
	2023	$18,199	$18,528	$993,389	$1,807	$1,031,923	$0	$1,031,923
	2024	$20,728	$18,719	$1,003,619	$1,859	$1,044,924	$3,720,470	($2,675,546)
	2025	$23,281	$18,883	$1,012,410	$1,910	$1,056,484	$0	$1,056,484
	2026	$25,850	$19,021	$1,019,838	$1,959	$1,066,669	$0	$1,066,669
	2027	$28,429	$19,136	$1,025,974	$2,008	$1,075,547	$0	$1,075,547
	2028	$31,010	$19,227	$1,030,888	$2,055	$1,083,180	$0	$1,083,180
	2029	$33,587	$20,650	$1,034,644	$2,101	$1,090,982	$0	$1,090,982
	2030	$36,154	$200,738	$1,037,308	$2,145	$1,276,345	$0	$1,276,345
	2031	$38,706	$201,053	$1,038,939	$2,189	$1,280,886	$0	$1,280,886
	2032	$41,237	$201,180	$1,039,594	$2,231	$1,284,242	$0	$1,284,242
	2033	$43,743	$201,129	$1,039,330	$3,323	$1,287,525	$0	$1,287,525
	2034	$46,220	$200,910	$1,038,200	$3,381	$1,288,711	$0	$1,288,711

Figure 4 Benefit-cost analysis tool in BI framework.

7. CONCLUSION

This paper describes the development of Business Intelligence for the PMS of the NDOT. Varieties of dashboards are designed, which assists pavement engineers and managers to fully understand the pavement condition in the entire state. In addition, a BCA tool is develop, which can be used to analyze the prospective pavement improvement projects to select the most cost effective ones. The reports developed in the form of dashboard can be used to make decision regarding the future pavement repair strategies. Further work consists of integration of other NDOT systems to enhance the usefulness of strategic decision support system.

8. REFERENCES

1. Nevada Department of Transportation. (2011). *NDOT Pavement Management System Overview*. Carson City, Nevada.
2. Sampaio, P., Pareira, G., Carvalho, M. S., Telhada, J., Paisana, A., Paixao, P., and Fonseca, A. *A Business Intelligence Solution for Public Transportation Sector*. European Concurrent Engineering Conference, 2011, Pages 27-32. *http://hdl.handle.net/1822/15243*.