SUPPLY CHAIN PERFORMANCE MEASUREMENT SYSTEM BASED ON SCORECARDS AND WEB PORTALS

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ABSTRACT

Successful supply chain management becomes essential for the ultimate success of corporations. Companies today seek an effective performance measurement (PM) system to maximize the bottom line. Unfortunately, performance measurement in the supply-chain field has not kept pace with today's world of interdependent business relationships. What companies need is a new PM system that unifies different business elements, concepts, technologies and tools. In this paper, the architecture of such a pervasive PM system is introduced. The main system elements such as process model, metrics and data warehouse are described. Finally, a specialized PM web portal which enables proactive performance monitoring and fosters the improvement and optimization is presented.

Key Words: Performance Measurement, Scorecards, Key Performance Indicators, Portals, Supply Chain.

1. Introduction

Supply chains are growing increasingly complex, from linear arrangements to synchronized, multi-echelon, outward-facing networks of distributed servers. There is much more information that needs to be monitored than there was just a few years ago. Most companies lack the tools that can quickly shift through and present data coming from supply chain partners and systems.

The overall performance of the supply chain significantly affects the financial health of all member companies. Therefore, an effective supply chain performance measurement process should be able to directly address performance areas that create sustainable profitability and financial strength.

In order to accomplish this requirement, the performance measurement process will need to provide a reliable indication of the contribution of supply chain operations to the areas like growth, cost minimization, working capital efficiency and fixed asset utilization

A robust and scalable performance management system is the platform for improvement. It must be exception-based and allow users to prevent problems, resolve issues, capture knowledge, and sustain improvements. The system must be able to handle an increasing number of users and amounts of information (due to expanded products, members of the supply chain, geography, and time). While it must be personalized and easy to use, it must also ensure high levels of security and privacy.

Supply chain PM cycle is not just for the supply chain, but for all aspects of the enterprise as well as for the extended supply chain. Ultimately, by managing the performance of myriad processes across enterprise boundaries, companies will have achieved the vision of Enterprise Performance Management (EPM) [1].

In supply chain, large volumes of raw transactional data are generated by each process and stored. The challenge for many companies lies in determining what information is necessary to drive improvements and efficiencies at each process in the supply chain, and designing an information management environment to turn the raw data into meaningful metrics and key performance indicators (KPI). Key performance indicators are measurements that directly relate to key business requirements.

KPI come in various forms from simple reporting measurements to very complex, cross correlated analytic results.

Information from supply chain management (SCM) processes must be collected, measured, analyzed and continuously monitored. This requires integration of data coming out of ERP, SCM and all other systems supporting these business processes. Data from transactional systems should be summarized into the Data Warehouse (DW), which should be able to scale to large sizes and be continually updated.

A well designed and integrated PM framework increases the capability of business intelligence (BI) systems to provide accurate insights for effective supply chain decision making. BI is evolving from traditional BI to *pervasive* BI (PBI), which empowers everyone in the organization, at all levels, with analytics, alerts and feedback mechanisms. On the benefits side, PBI promises to [2]:

- More effectively leverage the strengths of the whole supply chain by giving every employee the power to contribute to and enhance key performance indicators (KPIs) that have been set by management.
- Increase sustainable competitive advantage by helping every employee to make the right decisions at the right time in step with company and customer objectives.
- Improve operational efficiency by uncovering new best practices and driving those practices from the bottom up as well as the top down.

2. Background Research and Literature Review

Business performance management [3] describes the methods, metrics, processes and systems used in organizations to translate strategies into plans, monitor execution, and provide insight to improve financial and operational performance. It represents the strategic, integrated evolution of business intelligence to support the management process.

The importance of performance measurement in the context of SCM cannot be overstated. Timely and accurate assessment of overall system and individual system component performance is paramount. An effective performance measurement system provides the basis to understand the system, influences behavior throughout the system, and provides information regarding the results of system efforts to supply chain members and outside stakeholders. In effect, performance measurement is the glue that holds the complex value-creating system together, directing strategic formulation as well as playing a major role in monitoring the implementation of that strategy. In addition, research findings suggest that measuring supply chain performance in and of itself leads to improvements in overall performance [4]. Despite its importance, supply chain performance often was measured in oversimplified and sometimes counterproductive (cost-reduction-based) terms [5]. Lack of an appropriate performance measurement system has been cited as a major obstacle to effective supply chain management [6].

Traditionally, companies have tracked performance based largely on financial accounting principles. Financial accounting measures are certainly important in assessing whether or not operational changes are improving the financial health of an enterprise, but insufficient to measure supply chain performance for the following reasons [7]:

- The measures tend to be historically oriented and not focused on providing a forward-looking perspective.
- The measures do not relate to important strategic, non-financial performance.
- The measures do not directly tie to operational effectiveness and efficiency.
- Most performance measurement systems are functionally focused.

Until few years ago, there were several reasons why most companies did not implement supply chain performance measurement systems [8]:

1. No clear established approach or set of measures was available.
2. Software vendor products offered only a limited range of supply chain metrics.
3. Companies were too busy with other more important initiatives.

The traditional approaches to monitoring performance had been metrics projects and balanced scorecards. In metrics projects, functional organizations and workgroups established and tracked metrics that were considered most relevant for measuring performance. Unfortunately, there were a number of limitations with metrics projects:

- By focusing on functional metrics, they ended up driving locally optimized “silo” behavior at the expense of the overall company.

- It was time consuming to compile and analyze information, so visibility often came too late to make a difference. In addition, they only provided information on limited history, not insight into the future.
- Metric tracking was manual, so numbers were often calculated incorrectly or inconsistently over time.
- Many times, workers didn't know what to do with the data. It wasn't always clear what constituted poor performance, when to act, or how to act. Or else, people were so distracted and confused by the measuring process itself that they didn't act.
- Although selected metrics were called key performance indicators (KPIs), there was no feedback or validation to ensure that organizations were actually measuring the most relevant business drivers.
- Experienced managers learned how to "game" or "tinker with" the metrics to make themselves look good.

In an attempt to overcome some of these limitations, many companies have initiated balanced scorecard (BSC) projects. Based on the methodology of Robert Kaplan and David Norton [9], these organizations created a balanced set of metrics representing financials, customers, internal business processes and innovation. The goal was to enable better decision-making by providing managers with a broader perspective of both tangible and intangible assets. Although conceptually compelling, most balanced scorecards were implemented as static management dashboards, unable to drive action or performance improvement because [10]:

- These dashboards are usually driven out of finance organizations, therefore are typically highly weighted by financial information. Much of the important non-financial data and qualitative information is not captured or synthesized.
- Information is often manually aggregated from operational data sources and is prone to errors and significant delays.
- Infrequent sourcing of information allows people to play tricks operationally to improve the numbers. Who hasn't heard of the manager who shipped orders early or incomplete to reduce inventory levels?
- Where there is data integration, it is often "hard-wired" and difficult to modify over time as strategies and objectives change. Static systems – which encourage the improvement of specific metrics, not necessarily overall business performance – become self-perpetuating due to the fact that those managers successful under the old systems do not want to introduce new ones.
- Executive-level systems are often disconnected from tactics and operations. Because the metrics are high level and presented without regard to their implicit interdependencies, managers are uncertain what action to take to improve overall performance.
- Dashboards do not track decisions and their effectiveness over time so it is difficult for organizations to improve by learning from experience. Moreover, there is no mechanism to embed business rules to help improve the decision-making and problem resolution process itself.
- There is little or no support for collaborative processes across organizations, up and down the chain of command.

The Balanced Scorecard has been successfully implemented at hundreds of companies, however, many companies still need a practical measurement system that will enable them to improve profitability. As Kaplan and Norton state in [11], the execution of the measurement system is more important than the measurement system itself. Accordingly, fewer than 10 percent of the strategies outlined on the Business Scorecard were successfully implemented. This implies that the measurement strategy must be simplified for a successful execution. 80 percent of enterprises that fail to integrate the balanced scorecard into PM methods and tools will drop the balanced scorecard and return to a less organized and less effective set of metrics [12]. There is a need to establish dynamic supply chain performance measurement systems to effectively manage supply chain operations and meet financial and nonfinancial business objectives. In the following sections, we present a comprehensive supply chain PM model and its realization through a specialized PM web portal that is an integral part of the overall BI model.

3. Architecture of PM System

A robust infrastructure is crucial to realize the benefits of various PM initiatives. Figure 1 shows how main components fit together to create an environment to support PM solution.

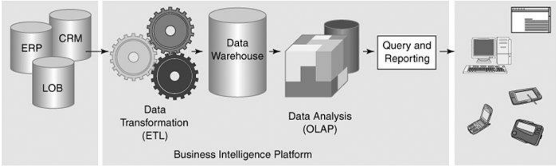


Figure 1. PM Platform Architecture

The proposed PM model unifies people, processes, methodologies and tools into a single business solution. PM model is developed in such a way to seamlessly integrate within overall BI and collaboration platform [13].
The architecture of the PM model is presented in Figure 2.

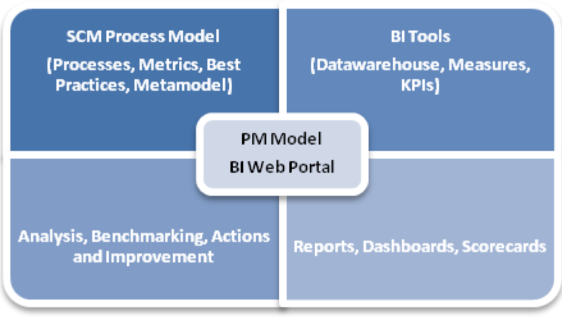


Figure 2. Architecture of the PM Model

The starting point is the SCM process model which provides a library of the supply chain specific set of processes, relationships, metrics and best practices. The developed SCM metamodel enables flexible modelling and creation of different supply chain configurations (models). These models are the basis for the construction of DW metadata (measures, dimensions, KPI). The data warehouse approach, allows the single version of the truth because of the integrated and consolidated data repository. Server-based definition of KPIs offers centralized metadata management and enables creation of various front-end PM and analytical applications. We have designed a specialized PM web portal with an adequate set of elements (reports, dashboards and scorecards). The web portal also integrates collaboration and analytical services, and enables users to take actions.

3.1 Supply Chain Metrics

A standardized supply chain process model provides significant benefits. Standardized models provide companies' maps toward business process engineering, establish benchmarking for performance comparison and uncover best business practices for gaining competitive advantage. By standardizing supply chain operations and metrics for managing such operations, companies can not only compare their results against others, but they are also able to gain visibility of operations over a supply chain that may cross corporate borders. Partners in a supply chain can communicate more unambiguously and can collaboratively measure, manage, and control their processes.
The SCM process model contains the standard name for each process element, the notation for the process element, standard definition for the process element, performance attributes that are associated with the process element, metrics that are associated with the performance attributes, and best practices that are associated with the process.
All process metrics are an aspect of a performance attribute. The performance attributes for any given process are characterized as either customer-facing (reliability, responsiveness and flexibility) or internal-facing (cost and assets) metrics. A SCM scorecard with all the top-level attributes defined by the SCM process model is provided in Table 1.
These top level metrics are the calculations by which an implementing organization can measure how successful they are in achieving their desired positioning within the competitive market space. Lower level calculations (level 2 metrics) are generally associated with a narrower subset of processes. For example, Delivery Performance is calculated as the total number of products delivered on time and in full based on a commit date. Additionally, even lower level metrics (diagnostics) are used to diagnose variations in performance against plan. For example, an organization may wish to examine the correlation between the request date and commit date.
Based on the SCM process model, we have created the SCM Metamodel [14] (Figure 3), which enables creation of any supply chain configuration and is the basis for further modelling. The Metamodel is normalized and contains all SCM elements such as processes, metrics, best practices, inputs and outputs. It also incorporates business logic through relationships, cardinality, and constrains.
The Metamodel is extended with additional entities to support supply network modelling. That way, processes, metrics and best practices can be related to the specific node and tier in the supply network. With this Metamodel, processes at different levels can be modelled thus providing more detailed view of supply chain processes and metrics.

Table 1. SCM Scorecard with Top Level Metrics

	Performance Attributes				
Top Level Metrics	Customer-Facing			Internal-Facing	
	Reliability	Responsiveness	Flexibility	Cost	Assets
Perfect Order Fulfillment	x				
Order Fulfillment Cycle Time		x			
Upside Supply Chain Flexibility			x		
Upside Supply Chain Adaptability			x		
Downside Supply Chain Adaptability			x		
Supply Chain Management Cost				x	
Cost of Goods Sold				x	
Cash-To-Cash Cycle Time					x
Return on Supply Chain Fixed Assets					x
Return on Working Capital					x

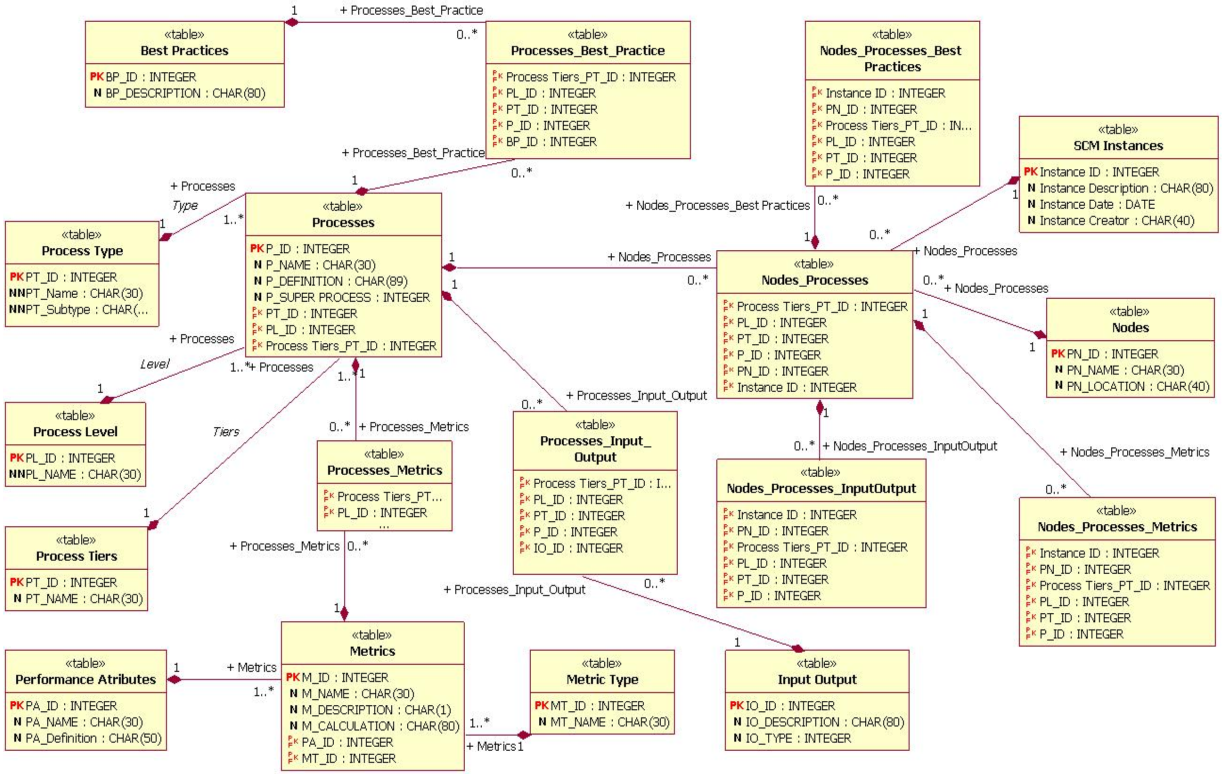


Figure 3. SCM Metamodel

3.2 PM Data Warehouse

A user who wants to retrieve information directly from a data source, such as an Enterprise Resource Planning (ERP) database, faces several significant challenges:

- The contents of such data sources are frequently very hard to understand, being designed with systems and developers instead of users in mind.
- Information of interest to the user is typically distributed among multiple heterogeneous data sources.
- Whereas many data sources are oriented toward holding large quantities of transaction level detail, frequently the

queries that support business decision-making involve summary, aggregated information.
- Business rules are generally not encapsulated in the data sources. Users are left to make their own interpretation of the data.

In order to overcome these problems, we constructed the Unified Dimensional Model (UDM) (Figure 3) [15]. The role of a UDM is to provide a bridge between the user and the data sources. A UDM is constructed over one or more physical data sources. The user issues queries against the UDM using a variety of client tools.

UDM allow creation of one data source view (DSV) for use by the system. The data source view is an abstraction layer that is used to extend the objects (relational tables and views) that are exposed by the data source to a collection of objects from which OLAP (On-Line Analytical Processing) server objects are created.

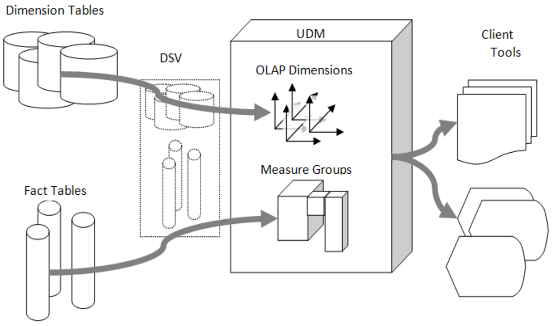


Figure 3. Unified Dimensional Model

Within the data source view we included all of the relational views that were used to create dimensions, hierarchies, and attributes. Data source views have two important roles:

First, they are a layer of abstraction between the objects that are used by OLAP Server and the data source. This allows creation of objects such as named queries and computed columns, which could be created in the data source itself (for example, in relational views). This is important because OLAP designers might not have the rights necessary to make metadata changes in the supply chain partner's source system.

Data source views allow you to create relationships between tables and views that are not physically located in the database or that are impossible because they are between databases.

Additionally data source views allow you to cache the metadata about the data sources so that you can develop cubes without having a connection to the source data systems.

UDM also enables the creation of hierarchies. Although the consolidation of all the attributes of an entity into a dimension greatly simplifies the model for the user, there are additional relationships between the attributes that a simple list cannot express. For example, product category, subcategory and stock keeping unit, define one of the hierarchies in which products can be organized.

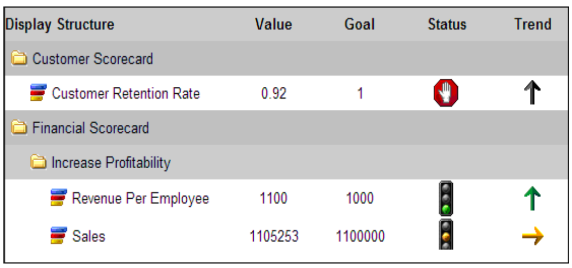
The model can also provide translations of data. An attribute can map to different elements in the data source, and provide the translations for those elements in different languages, which is very beneficial in the supply chain context.

Real-world supply chain models might include tens of measures and dimensions, with each dimension including tens or hundreds of attributes. The UDM also provides special views, called perspectives. A UDM can have many perspectives, each one presenting only a specific subset of the model (measures, dimensions, attributes, and so on) that is relevant to a particular group of users.

Companies often define key performance indicators, which are important metrics used to measure the health of the business. The UDM allows such KPIs to be defined, enabling a much more understandable grouping and presentation of data. Key performance indicator is a collection of calculations that are associated with a measure group in a cube that are used to evaluate business success. Typically, these calculations are a combination of Multidimensional Expressions (MDX) expressions or calculated members. KPIs also have additional metadata that provides information about how client applications should display the results of the KPI's calculations.

Table 2 lists common KPI elements and their definitions.

The use of OLAP-based KPIs allows client tools to present related measures in a way that is much more readily understood by the user. The Figure 4 shows an example of how three KPIs, organized into display folders, might be displayed by a client tool.



Display Structure	Value	Goal	Status	Trend
Customer Scorecard				
Customer Retention Rate	0.92	1		
Financial Scorecard				
Increase Profitability				
Revenue Per Employee	1100	1000		
Sales	1105253	1100000		

Figure 4. OLAP KPI

Table 2. OLAP KPI Structure

Term	Definition
Goal	An MDX numeric expression that returns the target value of the KPI.
Value	An MDX numeric expression that returns the actual value of the KPI.
Status	An MDX expression that represents the state of the KPI at a specified point in time. The status MDX expression should return a normalized value between -1 and 1.
Trend	An MDX expression that evaluates the value of the KPI over time. The trend can be any time-based criterion that makes sense in a specific business context.
Status indicator	A visual element that provides a quick indication of the status for a KPI. The display of the element is determined by the value of the status MDX expression.
Trend indicator	A visual element that provides a quick indication of the trend for a KPI. The display of the element is determined by the value of the trend MDX expression.
Display Folder	The folder in which the KPI will appear to the user when browsing the cube.
Parent KPI	A reference to an existing KPI that uses the value of the child KPI as part of the KPI's computation.
Current time member	An MDX expression that returns the member that identifies the temporal context of the KPI.
Weight	An MDX numeric expression that assigns a relative importance to a KPI. If the KPI is assigned to a parent KPI, the weight is used to proportionally adjust the results of the KPI value when calculating the value of the parent KPI.

4. PM Portal

In order to overcome the shortcomings of the existing BI and PM client tools we have designed a specialized web portal that enables supply chain users to monitor business processes, collaborate and take actions [16]. Portal represents the single point of access to all relevant information in a personalized and secured manner. Its composite and service-oriented architecture enables inclusion of different PM components and tools (KPIs, dashboards, scorecards, reports, etc.). PM elements can be personalized and adjusted, and information can be filtered just by using a web browser. PM elements can be defined within the portal and also embedded form the external source (OLAP, another application, spreadsheets) via web services. This information is presented through different special web parts. The portal itself can be a provider (via web services or RSS) to other applications.

Figure 5 shows the specialized SCM Scorecard for the global supply chain performance management. It is constructed based on top of the OLAP KPIs, which are again based on the SCM process model and metrics. KPI are created by SCM segments (plan, source, make, deliver and return) as hierarchies, so it is possible to perform drill-down analysis and track performance against defined goals.

The portal also supports the concept of strategy maps provide a hierarchical view of the KPI measures across levels of the organization by presenting relationships, priorities and perspectives. Figure 6 illustrates a PM web page with two web parts.

The first web part renders balanced scorecard with relevant KPIs, and the other web part shows an automatically generated strategy map related to the balanced scorecard. Each element on the map is highlighted with appropriate color. This enables visual performance tracking in relation to predefined strategy.

Modular architecture of the portal enables creation of various PM mashups tailored to specific business needs. Web parts, pages and also the complete portals can be saved as templates and reused many times with minimum effort.

Dashboard page can display numerous metrics and views business on a single screen. Portal supports quick deployment of dashboards assembled from web parts. Each web part can contain a particular view or metric, and users can customize their individual dashboards to display the views that are most meaningful to them, such as those with the metrics they need to monitor on a daily basis.

Additionally, portal supports events and automatic alerting. Users can subscribe to specific documents or keywords and categories, to be notified when metrics are updated or new intelligence becomes available. They can also use other features, such as planning, enterprise search, subscription, and routing functions, to work with team members on a single item (i.e. scorecard, KPI, etc.), and to automate collaborative performance management processes. Portal also provides fine-grained authentication and authorization.

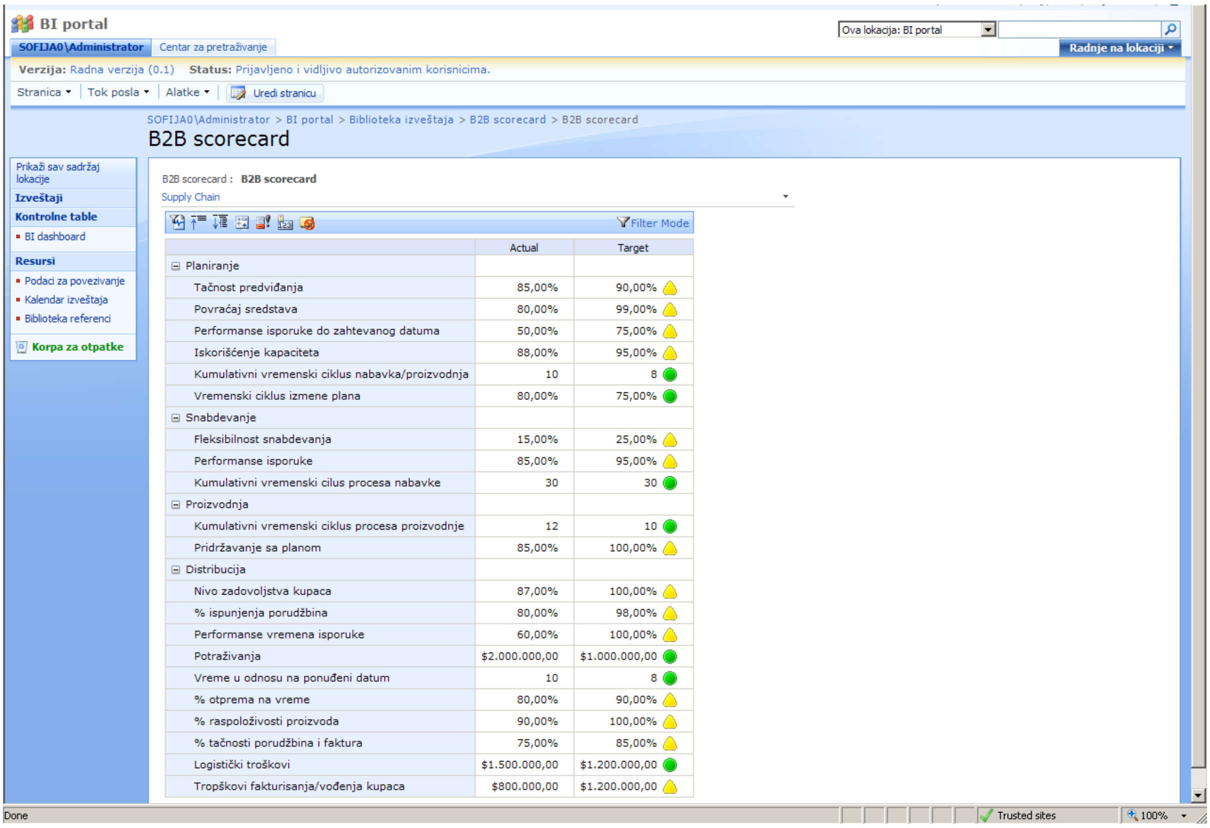
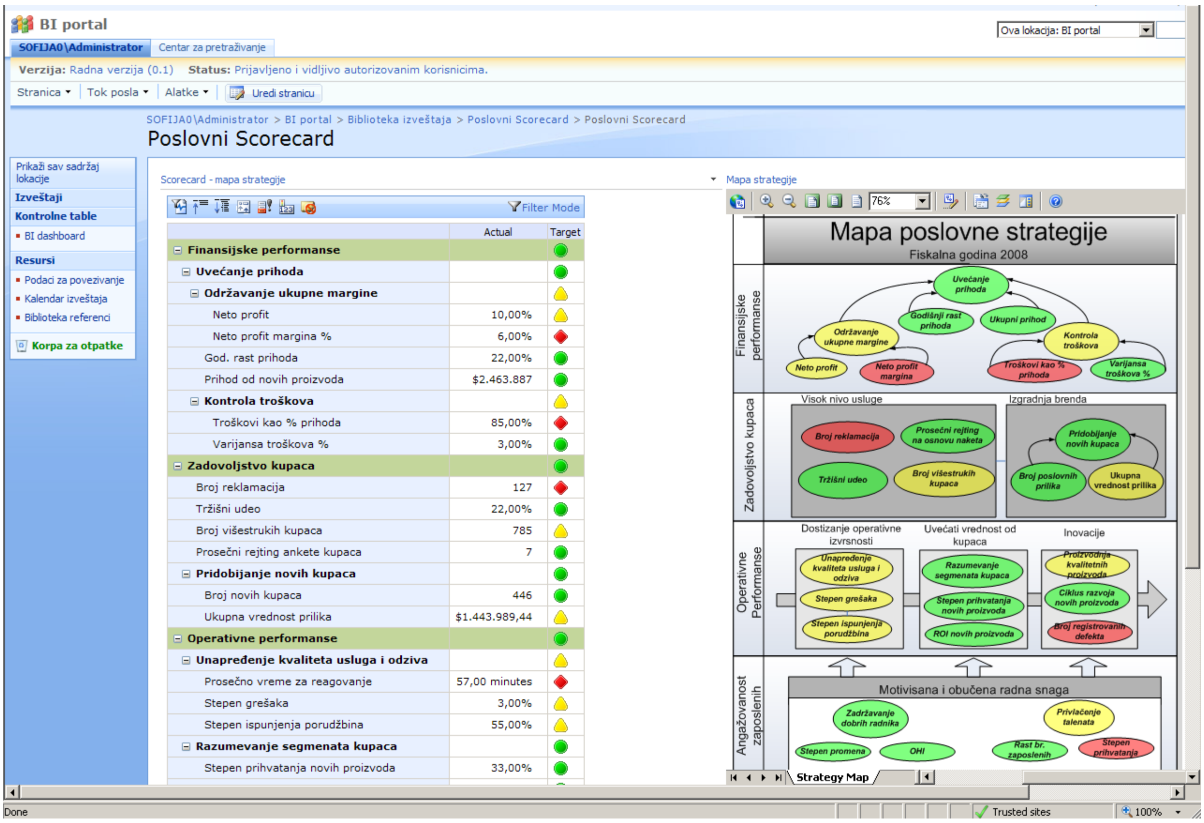


Figure 5. Supply Chain Scorecard



Slika 6. PM Scorecard and Strategy Map

5. Conclusion

Supply chain performance measurement is vital for a company in order to survive in today's competitive business environment. Supply chain performance measurement should be a business-critical process, driven by metrics and supported by business intelligence. With increasing competition and changing market forces, tapping into this critical asset is essential in sustaining competitive advantage in the global space.

PM model presented in this paper fuses all relevant elements such as people, business processes, metrics, KPIs and tools into a single comprehensive system. The underlying architecture supports the complete cycle of BI/PM processes like ETL, DW, OLAP and reporting. The unified data model helps to establish a single version of the truth on supply chain performance, which is quantifiable and understood by all entities in the supply chain.

Specialized PM web portal offers the following benefits:

- Real-time supply chain monitoring and alerting.
- Flexibility, personalization and customization.
- Integration with existing transactional, BI and collaboration systems
- Built-in knowledge and best practices through predefined web parts and templates.

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