Data Mining for Business Intelligence in Distribution Chain Analytics

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Abstract

Manufacturers, wholesalers and retailers in the distribution chain can be seen as Community of Core Knowledge Practitioners (CoCKPs) working together towards making profit, satisfying and meeting the needs of consumers of finished goods or products. Retailers through business transactions deal directly with the end users and are seen to better understand consumer behavior particularly in line with their preference for buying particular products or product combinations. Retail data mining can help discover customer-shopping patterns and trends which can in turn increase the efficiency and profitability of CoCKPs in business. In this paper, a framework to support CoCKPs in acquisition, representation and beneficial use of core knowledge, employing the power of retail data mining, was presented. The framework integrated a Knowledge Based System (KBS) and a Component-Based approach to obtain an effective Knowledge Management System.

Keywords: Business Intelligence, Data Mining, Distribution Chain, Knowledge-based systems, Knowledge Practitioners

1. INTRODUCTION

'Distribution chain' or 'Channel' involves a chain of intermediaries each passing a product down the chain to the next organization, before it finally reaches the consumer or end-user. This chain includes the consumers (end users), wholesalers and producers as elements. Each element have their own specific needs, which the producer in the chain must take into account, particularly that of the all-important end-user. Also producers, wholesalers and retailers in the distribution chain together work towards making profit satisfying and meeting the needs of consumers of finished goods or products.

Manufacturers engage in industrial production in which raw materials are transformed into finished goods on a large scale. Such finished goods are sold to wholesalers who in turn sell them to retailers, who then sell them to end users. In the distribution chain therefore, retailers through business transactions deal directly with the end users and are seen to better understand consumer behavior particularly in line with their preference for buying particular products or product combinations.

Retail, being one of the largest industries by number of businesses and employees has lagged behind other industries in adopting new technologies. Other industries such as financial services, have become very advanced in using intelligent software for financial reporting and consolidation, customer intelligence, risk management, regulatory compliance to mention a few [2].

However, retailers are quickly catching up and beginning to recognize the need for the application of business intelligence to specific areas of their businesses. So also are wholesalers and manufacturers. The competitive game among retailers, among wholesalers and among manufacturers is also increasing. As the industry continues to consolidate, they have begun to realize that using technology to better understand customer behavior, to drive sales and profitability and to reduce operational costs is a necessity for long-time survival.

Business intelligence (BI) provides software tools that are customized for end-business users and they deliver business insights in real-time at the point of a decision. Not only does current BI suffer from the shortage of analysts and experts who are required to configure and run analytical software, it has not been able to transform information quickly into action. Today's BI solutions should go beyond generating reports. If the BI software cannot link back into processes automatically and drive process parameters, the transition from information to action can only be manual and can require long periods after which a specific action would be taken [5].

Retail data mining can help identify customer-buying behaviors, discover customer-shopping patterns and trends, improve the quality of customer services, achieve better customer retention and satisfaction and in general, reduce the cost of business and increase profitability. Retailers are interested in creating data-mining models to know what types of products can be sold together, what the latest product trend is and how to retain profitable customers among others.

2. BACKGROUND INFORMATION

2.1 Knowledge Management

The term knowledge management is often problematic as there is little consensus regarding its definition [7], [6]. A recent study outlined that there is not an accepted single area of discourse within either the academic or popular management literature [17]. Many authors simply avoid the term completely, preferring to focus on specific aspects of the topic such as knowledge, innovation or learning [8]. Furthermore others argue that knowledge management is closely related to concepts such as organizational learning, organizational memory, information sharing, and collaborative work [19].

There is no consensus on the definition of knowledge. Many authors have avoided epistemological debate on the definition of knowledge by comparing knowledge with information and data [11]. A commonly held view is that data is raw numbers and facts, information is processed data and knowledge is authenticated information [11]. Yet, as [11] highlighted, the presumption of hierarchy from data to information to knowledge with each varying along some dimension such as context, usefulness or interpretability is inaccurate.

[11] argued that the effective distinguishing feature between information and knowledge is not found in the content, structure, usefulness or interpretability, but rather *"knowledge is information possessed in the minds of individuals: it is personalized information (which may or may not be new, unique, useful or accurate) related to facts, procedures, concepts, interpretations, ideas, observations, and judgments"*. Thus systems designed to support knowledge in organizations may not appear radically different from other forms of information systems, but will be geared toward enabling users to assign meaning to information and to capture some of their knowledge in information and/or data.

2.2 Knowledge Sharing and Communities of Practice

[10] highlighted that human approaches to knowledge sharing can be slow and are often unconscious. He argued that we must find new innovative ways such as interactive-media rather than rely on "information" to efficiently transfer knowledge. He suggests the open-plan office as one such innovation.

Once knowledge has been captured and codified, it needs to be shared and disseminated throughout the organization. [15] found that people are the most critical conduits of information and knowledge. Knowledge workers typically spend a third of their time looking for information and helping their colleagues do the same. A knowledge worker is five times more likely to turn to another person rather than an impersonal source such as a database or knowledge management systems. Only one of five knowledge workers consistently finds the information needed to do their jobs, and [15] have found that knowledge workers spend more time re-creating existing information they are unaware of than creating original material. All communities share some basic characteristics, regardless of the type of community. [25] identifies these characteristics as joint enterprise, mutual engagement and shared repertoire.

Three-tier architecture allows overcoming the problem of knowledge sharing and knowledge/software maintenance especially when the knowledge involved in the problem to be represented and solved is heterogeneous. It introduces a clear separation between knowledge processing components other components at the application layer [23]. They proposed a framework that can be used in organizations where we can group members in communities (Communities of Core Knowledge Practitioners (CoCKP)) who are able to find innovative solutions to difficult problem problems e.g. in product and process design.

2.3 Business Intelligence (BI)

[16] described BI as a term that encompasses a broad range of analytical software and solutions for gathering, consolidating, analyzing and providing access to information in a way that is supposed to let an enterprise's users make better business decisions. [21] points out BI benefits that facilitate the connections in the

new-form organization, bringing real-time information to centralized repositories and support analytics that can be exploited at every horizontal and vertical level within and outside the firm. [12] brief on BI which includes effective data warehouse and also a reactive component capable of monitoring the time-critical operational processes to allow tactical and operational decision-makers to tune their actions according to the company strategy.

[9] defined BI as the result of in-depth analysis of detailed business data, including database and application technologies, as well as analysis practices. [9] widened the definition of BI as technically much broader tools, that includes potentially encompassing knowledge management, ERP, decision support systems and data mining. BI includes several software for extraction, transformation and loading (ETL), data warehousing, database query and reporting [1] multidimensional/online analytical processing (OLAP) data analysis, data mining and visualization.

BI systems frequently have been accused by corporates for not getting results to users in a timely manner. This may be due to data-integration problems. However, new BI approaches can process the information quickly enough to make such decisions. [18] introduced an enhanced BI architecture that covers the complete process to sense, interpret, predict, automate and respond to business environments and thereby aims to decrease the reaction time needed for business decisions.

[18] also proposed an event-driven IT infrastructure to operate BI applications which enable real-time analytics across corporate business processes, notifies the business of actionable recommendations or automatically triggers business operations, and effectively closing the gap between BI systems and business processes. [3] suggested an architecture for enhanced BI that aims to increase the value of BI by reducing action time and interlinking business processes into decision making.

[4] discussed the issues and problems of current BI systems and then outlines our vision of future real-time BI. In large organizations, IT departments have had to gather information from multiple databases (heterogeneous data bases) such as those in accounting programs and enterprise-resource-planning applications and normalize it into a single view in a time-consuming, frequently manual process. Many operational decisions (e.g. promotion effectiveness, customer retention, key account information) [20] need actual yet integrated and subject-oriented data in or near real-time.

The primary goal of real time BI is to meld analytics with management functions so that analytics become an integral part of how managers and employee teams perform their job. Information is collected from several operation systems for data integration. Note the different applications of BI emerging from query analysis to score card management. Hence, successful implementation of real time BI needs to focus first on specific business needs (i.e. SCM, customer churn detection and reduction, etc.). [14] evaluated the completeness and adequacy of BI infrastructures based on the information available from: effective data integration process, continuous monitoring processes, automated information delivery process, fully automated warehouse administration infrastructure, availability of information on standardized dimension such as customer, product and geography, higher end-user acceptance.

The BI infrastructure adopted from [14] is presented as a three tier frame. Real time ETL tools collect the operational data from different heterogeneous sources for centralized data integration in real time. The business rules are analyzed in tier 3 through query and reporting tools in real time. [18] proposed an approach to real time BI based on service-oriented architecture (Figure 3). As organizations seek to incorporate intelligence into business operations, a robust infrastructure is necessary to meet mission-critical requirements for high scalability, availability, and performance [18]. [5] proposed a real time BI architecture for an adaptive enterprise.

Limited ability to raise prices, high-customer expectations and low levels of loyalty have led to increased challenges in already competitive market for all retail organizations (Taylor et al., 2004). The retailers are looking forward to supply chain analytics to reduce cost and improve customer service. The retail organizations can expect a better and effective supply chain analytic only by defining the analytical needs of enterprise and a well-defined key metrics for organizational strategy.

2.4 Data Mining

Association rule learning, a class of task under data mining, searches for relationships between variables. Retailers have seen improved decision-support processes leading directly to improved efficiency in inventory management and financial forecasting. The early adoption of dataware housing by retailers has allowed them a better opportunity to take advantage of data mining [13]. The retail industry is a major application area for data mining since it collects amounts of data on sales, customer-shopping history, goods transportation, consumption patterns and service records and so on.

The quantity of data collected continues to expand rapidly, especially due to the increasing availability and popularity of business conducted on the web or e-commerce. [13] described data mining as that which helps to model and identify the traits of profitable customers and it also helps to reveal the "hidden relationship" in data that standard query processes have not found. IBM has used data mining for several retailers to analyze shopping patterns within stores based on point-of-sale (POS) information.

3. FRAMEWORK FOR KNOWLEDGE MANAGEMENT SYSTEM DESIGN

[23] proposed a general framework for knowledge management system design including an architectural pattern to support CoCKPs. This architectural pattern, as shown in figure 3 and figure 4 below is a Component-based architecture consisting of three major tiers. This framework as illustrated below was used as the framework from which the model of this research effort was constructed.

Knowledge Capture: Since a KM system models domain specific knowledge, it should be possible to acquire and to modify this knowledge whenever necessary, providing users with specific tools for the elicitation of knowledge and the maintenance of the developed knowledge base. This is particularly true when considering CoCKPs due to the extreme variability of their knowledge, depending on different factors. Knowledge Capture is very important in the design of KM system for supporting CoCKPs, because the system must grant to users a simple and effective way to update the Knowledge base;

Knowledge Storage: all KM systems should be able to save in a persistent way the knowledge about the domain and the problem they are devoted to;

Knowledge Deployment: Within KM systems it should be possible to provide users and system modules with a sort of controlled accessibility to the stored knowledge.

Knowledge Processing: When implementing a KM application means to support CKPs activities exploiting the knowledge stored and shared in the same system, *Knowledge Processing* (KP) has to be considered. This functionality refers to the process in which, through inferences based o the stored knowledge, a KBS finds a qualitative solution to the problem it has been built for.

Supply chain analytics provides a broad view of an entire supply chain to reveal full product and component [22]. It is implemented for strategic decision making. It reveals opportunities for cost reduction and stimulates revenue growth. It generally maintains historical data and enables an understanding of total cost. Drill down and roll up operations yield figures to reveal what caused the performance level. Ordering products, global outsourcing, and web-based buying and selling, JIT manufacturing are the major key business drivers for supply chain analytics.

3.1 Framework Application: Supporting experts in the Distribution Chain

Figure 1 shows the distribution chain process from the CoCKPs interactions standpoint.

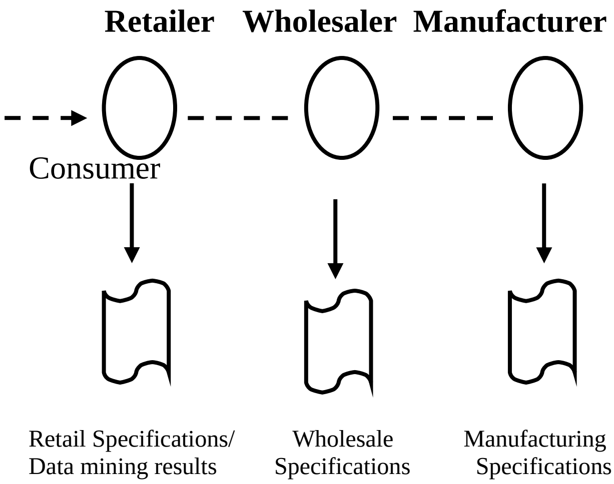
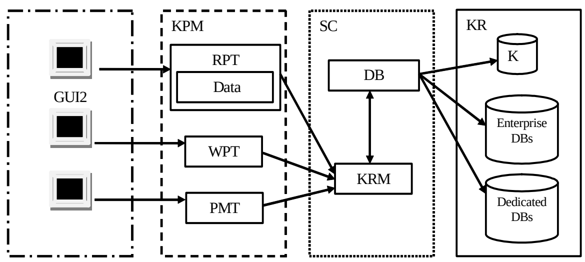


Figure 1: Interactions among different CoCKPs involved in the distribution chain

The dotted lines in Figure 1 show the interactions among the CoCKPs in which consumer data is transformed into information then into action. The dotted arrow depicts *Consumer-Retailer* interaction while the dotted line depicts the interaction among the retailers, wholesalers and manufacturers sharing knowledge in the chain.

The dotted lines in Figure 2 show the interactions among the CoCKPs in which consumer data is transformed into information then into action. The dotted arrow depicts *Consumer-Retailer* interaction while the dotted line depicts the interaction among the retailers, wholesalers and manufacturers sharing knowledge in the chain.



RPT – Retail Product Transactions
WPT – Wholesale Product Transactions
PMT – Product Manufacturing Transactions

Figure 2: Model constructed for Distribution Chain CoCKPs

4. SYSTEM DESIGN

The architecture for the distribution chain of figure 3 was designed according to the architectural pattern described earlier, in order to have a centralized knowledge repository and an improved profit making strategy. The designed architecture provides a lot of benefits, in particular, from the knowledge maintenance and sharing viewpoints.

The introduced Middleware Service Component (MSC) tier for the Distribution chain contains two important modules: the Knowledge Repository Manager (KRM) and the DB Wrapper. The KRM allows the system users to manage the KR content providing them with functionalities like visualization, retrieval and update of the stored knowledge. The DB Wrapper module acts as a configurable interface between KRM and enterprise databases that contain information about the CoCKP activities (RPT, WPT and PMT).

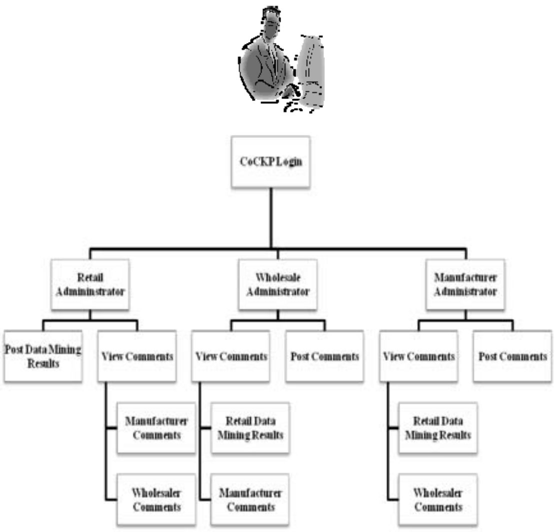


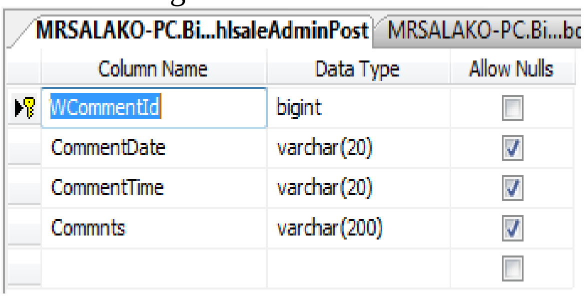
Figure 3: Collaboration diagram of CoCKPs in the Distribution Chain

4.1 Data Mining Algorithm for BI in Distribution Chain Analytics

Business intelligence at the retail end of the distribution chain was achieved using Data Mining. Data mining was implemented in Microsoft SQL Server 2005 Business Intelligence Development Studio. The basic objective is to look for patterns and associations that exist in the data generated from the order of customers within a certain period. Of particular interest is to predict which products customers might want to purchase based on other products that are already in the customers shopping basket. The earlier this is known, the retailer can make the wholesaler and manufacturer of these set of products buy and produce more of it respectively to make more timely profit. The prediction could also make the manufacturer package together such goods that tend to be bought together and maybe give a little discount on the combined package.

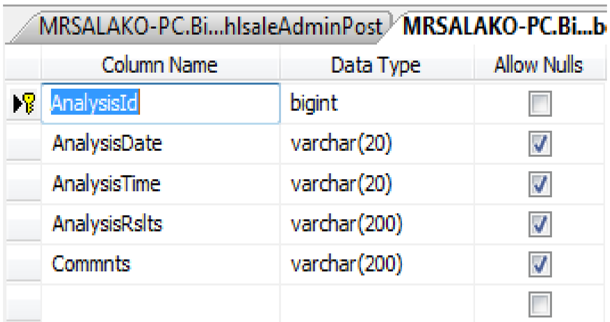
4.2 CoCKPs Database Design

Figure 4, Figure 5 and Figure 6 shows the database design used for the CoCKPs.


MRSALAKO-PC.Bi...hlsaleAdminPost | MRSALAKO-PC.Bi...bc

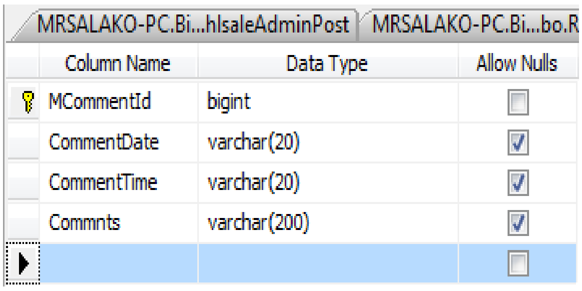
Column Name	Data Type	Allow Nulls
WCommentId	bigint	☐
CommentDate	varchar(20)	☑
CommentTime	varchar(20)	☑
Commnts	varchar(200)	☑
		☐

Figure 4: Wholesaler database design


MRSALAKO-PC.Bi...hlsaleAdminPost | MRSALAKO-PC.Bi...b

Column Name	Data Type	Allow Nulls
AnalysisId	bigint	☐
AnalysisDate	varchar(20)	☑
AnalysisTime	varchar(20)	☑
AnalysisRslts	varchar(200)	☑
Commnts	varchar(200)	☑
		☐

Figure 5: Retail database design



Column Name	Data Type	Allow Nulls
MCommentId	bigint	☐
CommentDate	varchar(20)	☑
CommentTime	varchar(20)	☑
Commnts	varchar(200)	☑
		☐

Figure 6: Manufacturer database design

5. DATA COLLECTION, ANALYSIS AND INTERPRETATION OF RESULTS

A retailer who is into the sales of cycling products was used. The retail analyst first performs data mining on the data obtained from products' transactional sales records. Secondary data sample containing 52,761 records of orders of 21,225 customers were obtained from AdventureWorksDW sales tables (http://sqlserver/sites/SQLServer2005/Downloads). In this step, it was ensured that this large data used did not contain inconsistencies such as flaws or missing entries.

The Data Mining Algorithm used was Microsoft Association Algorithm. The Microsoft Association algorithm traverses a dataset to find items that appear together in a case. The algorithm then groups into itemsets any associated items that appear, at a minimum, in the number of cases that are specified by the *MINIMUM_SUPPORT* parameter. For example, an itemset could be "Mountain 200=Existing, Sport 100=Existing", and could have a support of 710. The algorithm then generates rules from the itemsets. These rules are used to predict the presence of an item in the database, based on the presence of other specific items that the algorithm identifies as important. For example, a rule could be "if Touring 1000=existing and Road bottle cage=existing, then Water bottle=existing", and could have a probability of 0.812. In this example, the algorithm identifies that the presence in the basket of the Touring 1000 tire and the water bottle cage predicts that a water bottle would also likely be in the basket.

Figure 7 below shows a visualization of the dependency network of the mining model viewer of the CoCKPs data mining structure designed in SQL Server 2005 Business Intelligence Development Studio. It shows the dependencies that exist between products sold by the retailer including weak and strong dependencies (links). The itemsets generated for a filtered individual product, water bottle, by the retail analyst is shown in Figure 8 having the following set parameters:

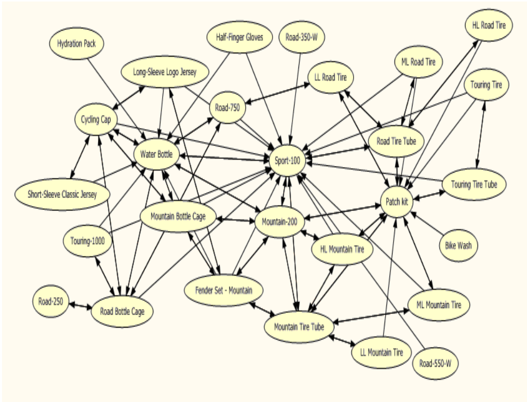
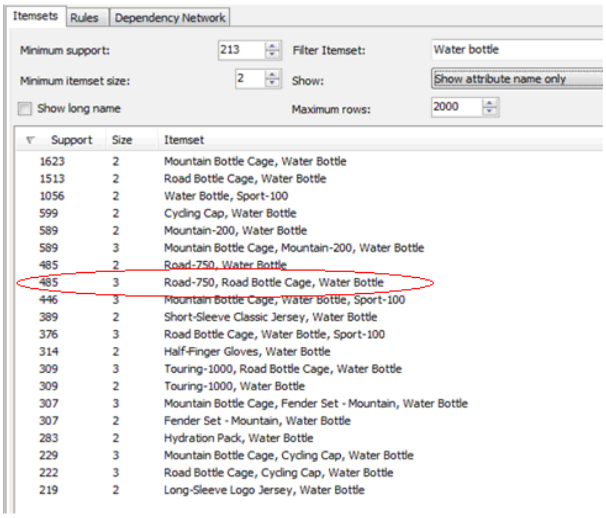


Figure 7: Dependency network of all retail products



Support	Size	Itemset
1623	2	Mountain Bottle Cage, Water Bottle
1513	2	Road Bottle Cage, Water Bottle
1056	2	Water Bottle, Sport-100
599	2	Cycling Cap, Water Bottle
589	2	Mountain-200, Water Bottle
589	3	Mountain Bottle Cage, Mountain-200, Water Bottle
485	2	Road-750, Water Bottle
485	3	Road-750, Road Bottle Cage, Water Bottle
446	3	Mountain Bottle Cage, Water Bottle, Sport-100
389	2	Short-Sleeve Classic Jersey, Water Bottle
376	3	Road Bottle Cage, Water Bottle, Sport-100
314	2	Half-Finger Gloves, Water Bottle
309	3	Touring-1000, Road Bottle Cage, Water Bottle
309	2	Touring-1000, Water Bottle
307	3	Mountain Bottle Cage, Fender Set - Mountain, Water Bottle
307	2	Fender Set - Mountain, Water Bottle
283	2	Hydration Pack, Water Bottle
229	3	Mountain Bottle Cage, Cycling Cap, Water Bottle
222	3	Road Bottle Cage, Cycling Cap, Water Bottle
219	2	Long-Sleeve Logo Jersey, Water Bottle

Figure 8: Itemsets generated for the product 'Water Bottle'

Minimum support: 213
Minimum Item size: 2
Maximum rows: 2000

The row encircled in red in Figure 8 above shows three combinations of products (Water Bottle, Road bottle cage and Road-750) that occurred in 485 transactions.

The rules generated for a filtered individual product, water bottle, by the retail analyst are shown in Figure 9 having the following set parameters:

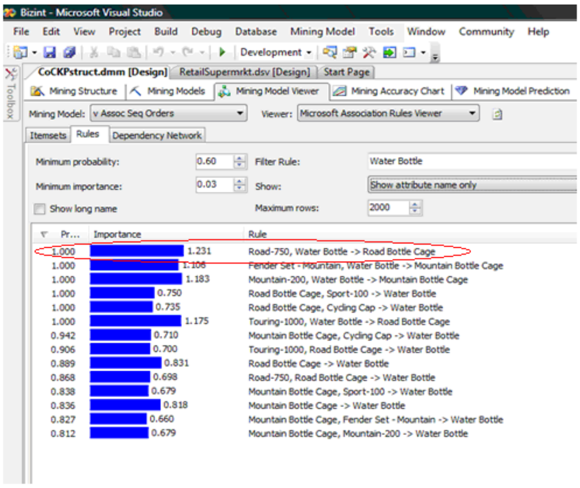


Figure 9: Rules generated for the product Water Bottle

Minimum probability: 0.6
Minimum importance: 0.03
Maximum rows: 2000

The rule encircled in red in Figure 9 shows that if someone buys a Road-750 bicycle and a Water bottle, there is a probability of 1.000 that the person will also buy a Road Bottle cage.

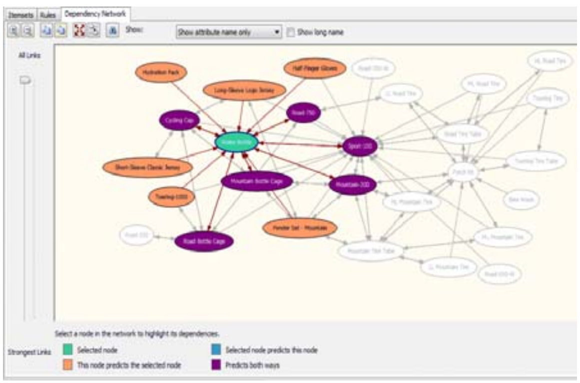


Figure 10: Dependency Network with 'Water Bottle' as the Selected Node

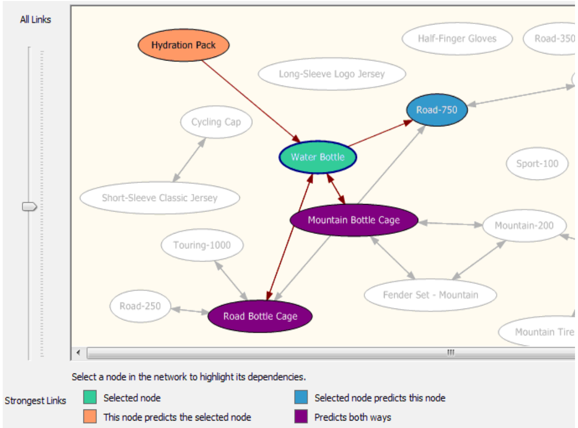


Figure 11: Dependency Network after removing some weak dependencies

Figure 10 shows the all dependency networks with the product 'Water bottle' as the selected node. Also shown in the figure are links to other products in the retail store that the selected node predicts, that predicts the selected node and those that predict each other these all represented in different colours. Removing some weak dependencies gives the result shown in Figure 11.

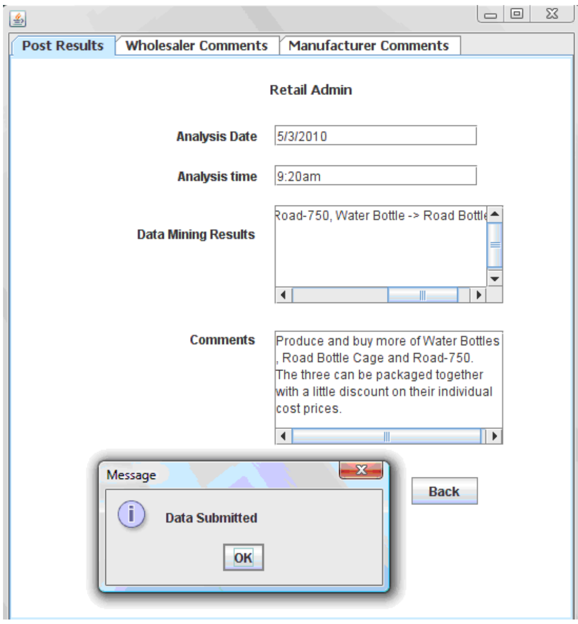


Figure 12: Retailer GUI

The retailer then passes information about particular product combinations generated within the rules that are bought together to other CoCKPs as shown in Figure 12. Also other information about retail activities can be shared. The wholesaler and manufacturer within the same knowledge sharing system can thus, view information posted by the retailer and take action based on the obtained information. Figure 13 and Figure 14 shows the wholesaler and manufacturer graphical user interfaces for knowledge sharing.

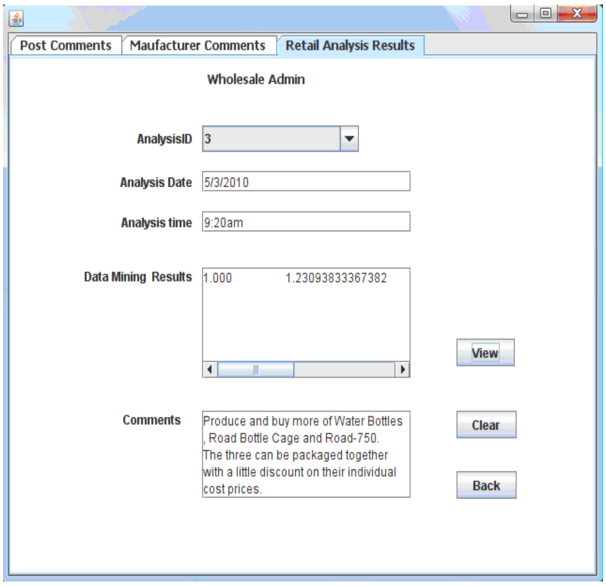


Figure 13: Wholesaler GUI

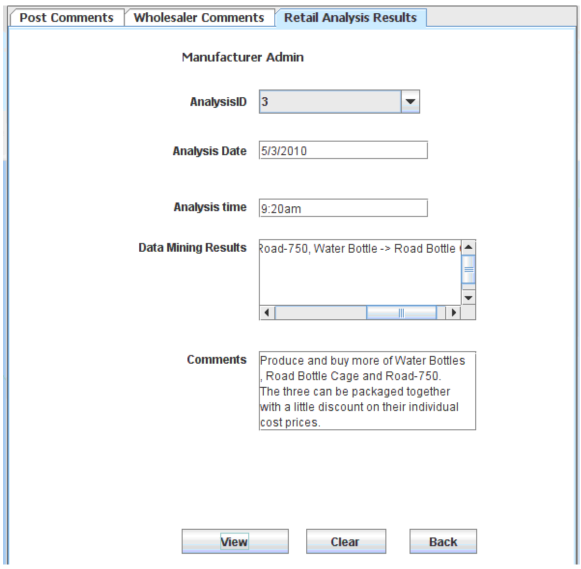


Figure 14: Manufacturer GUI

Other snapshots of the system are displayed in figures 15 and 16.

Figure 15: Select category interface

Figure 16: Interface for CoCKPs login

6. CONCLUSION AND FUTURE WORKS

Business Intelligence (BI) refers to the use of technology to collect and effectively use information to improve business potency. An ideal BI system gives retailers, wholesalers and manufacturers easy access to the information they need to effectively do their jobs, and the ability to analyze and easily share this information with others. BI provides critical insight that helps these CoCKPs make informed decisions. It does not only entail the reuse of data in form of transactional sale orders at the retail end of the distribution chain, but through data mining, helps to find useful associations and patterns within these data eventually increasing the sell-through of products for all CoCKPs. Business transactions, customer demographics, seasonal flows, retail data and inventory levels all have to be carefully coordinated to enable BI enabled distribution chain solutions.

Architecture to support the CoCKPs of the distribution chain has been presented in this paper. An approach to BI in distribution chain analytics was described. It is believed that data mining for business intelligence in distribution chain analytics will increase the operational efficiency of the CoCKPs involved and ultimately make them make timely and higher profit. The paper was able to model business intelligence in a distribution chain consisting of a single retailer, wholesaler and producer of a particular set of goods.

However, business intelligence in a distribution chain consisting of a retailer being mapped with many wholesalers and manufacturers of different products that are being sold by the retailer need to be explored as future work. Also, issues of security and trust within the knowledge sharing system involving these CoCKPs should be looked into. Finally, making business intelligence within the system an embedded real-time business intelligence system would reduce the latency in operational business decision making for the CoCKPs.

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