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Supply Web Mapper *

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Abstract

This article introduces the concept of Supply Web Mapper which is a visualisation, mining, and assessment application allowing analysts or decision-makers to explore in a summarised and efficient way the Supply Web created through the interactions of multiple organizations. The mapper allows a visual mining of a Supply Web by exploiting available partner's databases while protecting their confidentiality. A Supply Web is an open generalization of the well known notions of logistic networks and supply chains. The mapper leads to the representation of a large quantity of data supplied by inter organizational information systems, in several multi-dimensional synthetic diagrams. These diagrams take the form of spreadsheets, data graphs, conceptual and geographical maps. The article presents a prototype developed in our laboratories and tested on a large scale case in a retail Supply Web.

Key words: Supply Webs, Business Intelligence, Mining Tools, Multidimensional Mapping, Interactive Viewers

1 Introduction

A supply chain is generally associated with the relations established by a company with its suppliers and their suppliers and with its customers and their customers. However, a company can operate within and/or orchestrate several supply chains, constituting more complex supply networks. When several supply networks are in relations, often involving competing companies, interactions take place through networks of networks. To define the larger space in which these relations take place we introduce the concept of Supply Web. In this context, extracting pertinent well adapted views and information related to decision- maker tasks or to specific situations becomes extremely complex. This complexity results from the inherent flow dynamics of thousands of products and from the difficulty of treating adequately the numerous client-supplier relations established between thousands of actors who can be partners, competitors or both at the same time.

The information and communication technologies offer new perspectives for the analysis of Supply Webs. Managers face the challenge of using and analyzing data in order to exploit their potentials at various levels of aggregation according to multiple dimensions and perspectives (temporal, geographical, etc.). The available

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information in Supply Web concerns several companies and the interactions uniting them. For example shared data concerns sales, orders, forecasts, inventories and deliveries. Multiple business software solutions exist on the market and provide applications centered on the management processes of a company. Among the features offered in these solutions we generally find automated placement of orders, inventory policy determination, product flow control and shipment monitoring. The investments made by companies in these solutions implies the deployment and exploitation of information systems, mainly aimed toward cost reduction, revenue increase, uncertainty control, and customers need satisfaction [7].

Many of these solutions were deployed during the last decades. However, « *86 percent of supply chain professionals believe that current supply chain techniques are not meeting the needs of the marketplace, while 53 percent of respondents are not satisfied with the return on investment (ROI) in SCM software* » [1]. There is a perceived gap between the needs and the available computer solutions initially conceived for departments such as finance, accounting and production. As companies indicated a growing interest in business software, new solutions appeared. However, the satisfaction of the companies' needs remains limited with regard to solutions integrating data from external partners, [6]. The implementation of transversal collaborations leads to the need for interorganizational information systems supporting the decision-making process in such contexts, [2]. This underlines the improvements needed to increase the synergies between companies evolving within Supply Webs.

In this article we present the conceptual objectives and the development stages of a Supply Web Mapper. Such an application helps to see, mine and assess a Supply Web created through the interactions of multiple organizations through their customers-suppliers relations. The Supply Web Mapper that we prototype consists of three main interfaces which will be detailed in the next sections. The application was tested on a large scale with the company Procter and Gamble Canada and its clients. The figures which illustrate the interfaces are modified for respecting confidentiality agreements. The article is structured as follows. The second section is dedicated to the literature review relative to the main approaches in Supply Web software. The third section describes the methodology associated with the development of the Supply Web Mapper. The fourth section presents three key interfaces. The fifth section concludes this article and defines the perspectives associated with this research.

2 Literature review

To help grasp the objectives of the current research we first define the concepts related to Supply Web software. Through this literature review we do not attempt to provide an exhaustive state-of-the-art of functionalities offered by the multitude of software solutions available on the market. Our approach consists rather in highlighting the conclusions of several studies reported in the literature. Centerfold is the lack of flexibility found in the current generation of software solutions, which sets the stage for introducing elements to be taken in consideration in the proposition of a generic solution that will meet the companies' need. This then leads us to focus on a review of schematization and mapping concepts.

2.1 Supply Web software

Supply chain management software is confronted with two major challenges. The first one consists in integrating Supply Chain Management solutions based on the Web with a legacy of current internally oriented applications focused on a single company, mostly based on other technologies such as a central server or client-server software architecture. The second challenge is to connect information systems of different partners, and which are sometimes heterogeneous, so as to facilitate the virtual integration of organizations in networks whose members can be partners or competitors, [4]. It is crucial to understand why current software solutions are unable to meet these challenges adequately. Information and communication technologies have an enabling role in the implementation of collaborative practices. These technologies are at the origin of evolutions in capabilities and in the sophistication of architectures supporting the new forms of interactions, [10]. Implementing collaboration among diverse partners can turn out to be extremely complex given the size of available data, the variety of organizational structures and the heterogeneity of software architectures.

According to the classification proposed in [5], supply chain management software applications mostly deal with optimization and advanced planning. As Enterprise Resource Planning systems, these applications integrate

functions such as purchasing, supply, production, transport, distribution and sales [9]. The main limits and the points to improve in the deployment of these solutions are found in [12]. Given the dynamics of Supply Webs, these software solutions are not sufficient and additional features are necessary, notably to deal with inter organizational coordination and complexity. Supply chain management software supports communication, information and management in companies and between companies in a supply chain, [13]. Furthermore, coordination and flexibility are necessary to tackle the fast dynamics of Supply Webs.

The increasing need for information exchanges creates an evolution toward new technologies such as Internet, [10], providing an opportunity for evolving the communications between computer systems of multiple companies, [5]. At the information level, the objective is to guarantee transparency throughout the supply networks, the accessibility to desired views, the import toward other applications, and the respect of confidentiality at various levels of accessibility. At the management level, the objective is to have applications that enable aggregated or detailed analyses, acting as decision support systems for a variety of users from different companies with each user having his dynamic set of objectives.

The limits of commercial software solutions concern four aspects: conception, implementation, architecture and availability, [6]. (1) At the conceptual level, the applications do not only have to integrate data from one company but also, data originating from various partners. (2) The implementation of generic software requires an adaptation of the company systems. The development of an adapted solution requires a considerable development time which is often related to the complexity of the implied organizations. (3) From an architectural perspective, it is difficult for computer systems to integrate real-time connections with other partners. Various communications technologies such as Web services facilitate this type of access to internal data and to the data stemming from external partners. The development of a customized solution can catalyze integration by creating connections between organizations involved in the implemented software solution. Finally, (4) regarding availability, most systems limit the number of users through licensing contracts. Internet technologies authorize the access to applications hosted on Web servers to an unlimited number of users while dealing with issues such as secure access control and data confidentiality protection. The integration of Web-Internet technologies to the software solutions on the market is thus necessary to meet the large-scale access and integration needs.

2.2 Mapping a Supply Web

As supply chains and networks developed, schematizing and mapping them became more and more complex. There are numerous manners to schematize flows and activities of an organization. So there is a variety of software solutions aiming to support schematization, [3]. Commercial software solutions with high graphic features, such as Flowcharter 2007©, are available, yet the generation of diagrams remains manual. Indeed, the proposed diagrams do not update according to the real data of the company or set of companies connected to databases accessed by the application. Automatically generating a diagram for a new configuration or for a new view of a Supply Web has not been achieved. Furthermore, none of these tools offers the possibility of representing flows associated with a product or a family of products in an interactive way, feeding mining capabilities.

The generic objective of mapping a supply web is to obtain a representation of the existing relations between several selected actors, resources and/or products. The result appears generally as conceptual or geographical maps to visualize existing relations according to identified perspectives. The graphic representation of the results can be displayed according to an axis system in several dimensions. The mapping process integrates the notion of map elaboration and facilitates the communication of the information. Generally, map creation is associated with the definition of dashboards for the visualization of status and performance indicators for the mapped entities.

In regard to schematisation processes, two aspects are of high importance: resemblance and simplification, [8]. A schematisation process aims to represent reality with as best as possible an equilibrium between accuracy and simplicity. According to [8], the schematisation of the supply chain allows the improvement of sharing key information, the redesign or the improvement of the supply chain, the clarification of the logistics networks dynamics, the supply of a common perspective, the improvement of communications, the monitoring of supply chain strategies and the supply of a base for the analysis of supply chains. In [8], three characteristics of

schematisation are defined: the geometry, the perspective and the implementation. The geometry includes the number of elements, the degree of aggregation and the spatial relations. The perspective considers the point of view proposed to the user. As for the implementation, the choice of the information displayed makes the difference between a simple and a strategic schematisation. The tools must support various degrees of concordance with the reality, multiple modes of representation (dashboards, maps, etc.), and different features for updating the displayed information, including real-time updating.

3 Research objectives

In this section we expose the research objectives and the methodology used for conceptualizing and prototyping a Supply Web Mapper. To facilitate the representation of multiple interactions between several companies, we present the computing tools used for the development of the application and the exploitation of the results. Finally, we introduce two generic concepts inherent to the process of schematisation: nodes and flows.

3.1 Objectives and approach

Based on information directly stemming from databases, we propose a generic application capable of supplying conceptual maps, geographical maps and schematics adapted to the user needs. The first facet of the research problem consists in exploiting a large quantity of heterogeneous data. The second facet concerns the development of the schematisation and mapping process involving a variety of organizational entities according to various levels of aggregation and multiple dimensions. The third facet consists in displaying flows of organizational entities according to multiple time scales, from data grouped by years down to real-time data. The fourth facet concerns the various levels of aggregation and disaggregation to consider when users define the nature of flow elements to observe (physical flow, informative flow, financial flow, etc.). The fifth facet concerns the mode of mapping the information by defining the interfaces used to display data in tables, graphs, schematics and maps. Finally, the sixth facet concerns the style of elements displayed on maps and the users' selections fitting their particular needs. The union of the schematisation and mapping processes defines the conceptual framework of this research that derived the proposition of a Supply Web Mapper.

3.2 Computer environment used for developing the prototype

In the next sections we refer to a prototype application developed by our team to demonstrate the nature and the viability of a Supply Web Mapper. The development of this application was achieved by using Visual Basic.NET© and exploiting the SQL Server database management system. The application can export data to spreadsheets and\or to image files to facilitate the appropriation of the figures by the users to easily analyse the obtained results. Geographical maps are generated with Map Extreme (Map Info©) to display personalized maps including additional elements such as nodes and flows. These elements are defined in the following sub-section.

3.3 Generic elements: nodes and flows

A node is an organizational entity within a Supply Web. The nodes can be of various types. Within the framework of this research, we have classified basic nodes as retailers (stores, boutiques, etc.), warehouses, distribution centers (with the responsibilities to distribute products toward the other types of nodes, combining cross-docking, storage, consolidation, etc.) or factories. Certain nodes play more than one role, for example a node can be at the same time a factory and a distribution center. A node can organizationally contain several sub-nodes, as is often the case with business units. For example a business unit can group distribution centers and retailers. A node is characterized by various elements. Basic generic ones include: i) a unique identifier, ii) a name, iii) no, one or several addresses as necessary, and iv) an inclusion relationship with a parent node business. More elaborate and specific node characteristics are presented in the following section.

A flow is an element which represents the physical, informational or monetary transfers between two nodes. A flow takes place between two nodes of a Supply Web. A flow is characterized by attributes including: i) the product-s circulating on the flow, ii) the source node, iii) the destination node, iv) the physical volume, v) the total weight, and vi) the financial volume. More characteristics will be presented in the next section.

4 Supply Web Mapper

A Supply Web Mapper is a business intelligence tool enabling users to better understand and analyze their Supply Web by exploiting available databases. It helps visualize, mine and assess a Supply Web and its performance. It allows the representation of multisource data in multidimensional and synthesized schemas and provides a snapshot of the selected Supply Web, or of one of its embedded networks, for a certain time interval. Then, it allows the users to mine the data by drilling down and up trough each dimension providing, thus, a multidimensional snapshot that can be explored from different points of view. The Mapper is designed to meet the requirements of different managers in order to allow each one to obtain an adapted overview of the Supply Web based on his own needs and functions. Structured as displayed in Figure 1, our prototype Supply Web Mapper involves a combination of two main interconnected interfaces. First, the Selection Interface is used to select a Supply Web, network or node. Second, the Display Interface which contains a control board and four specific interactive viewers: *the Conceptual Map Viewer, the Geographical Map Viewer, the Data Mining Viewer, and the Graph Viewer*.

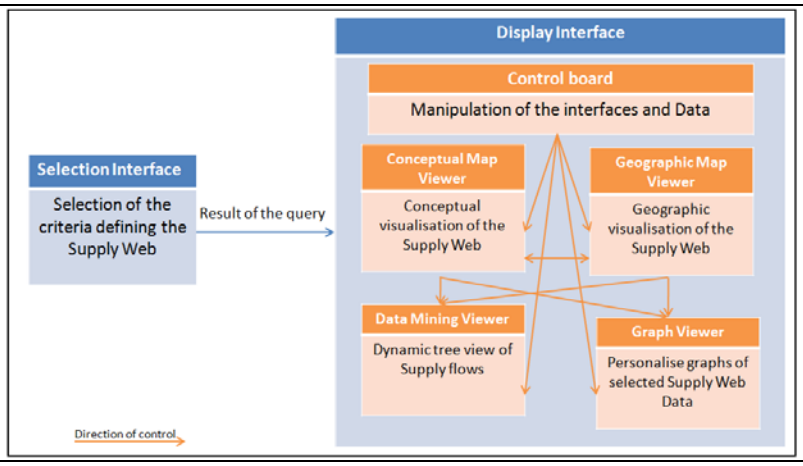

Fig. 1. Structure of a Supply Web Mapper

In section 4.1, we describe the key concepts and features of the Supply Web Selection Interface. Then in section 4.2, we describe those of the Display Interface. We start with the control board that offers various personalisations and mining tools. Then we describe the four viewers of the Display Interface. The conceptual map viewer provides a representation of the selection as a network of nodes and flows. The data mining viewer represents the data using a dynamic tree view which can be manipulated at ease. It provides the ability to drill trough different data dimensions to get more detailed or summarized view. The geographical map viewer deals with the presentation of the selection on a geographical map. There is no specific section on the graph viewer since it is easy for the reader to understand its nature. For each one of the viewers we describe the associated dashboards. The figures presented in sections 4.1 and 4.2 provide examples among the multiple ways this application can deliver value to users for decision support and analysis.

4.1 Supply Web Selection Interface

In order to efficiently focus user attention and to limit the quantity of data to synthesize, the user has to choose the network in which he is interested and the time span that he wants to investigate. This is done through the Selection Interface. In fact, in a context where a combination of supply networks belonging to multiple partners is considered in granulated levels of detail, and where the physical, informational and financial flows going through or generated by each one of the sites belonging to this Supply Web are tracked on a daily base, it becomes very important to provide Supply Web players with a tool that filters the data they are interested in and subtracts non relevant data. This pre-selection of relevant data is a key step in the design of a flexible tool that can handle large amounts of data efficiently and rapidly. The Selection Interface, which is used for this pre-selection, is the first screen that appears after launching the Supply Web Mapper. It provides the possibility to select the node to focus on, the network related to it, and the time interval to consider (figure 2).

In the prototype, we have the user first select a supply chain node that can be a company, a business unit or a specific site of a company. This action is done through the tree view presented on the upper part of the window, identified as point 1 in Figure 2 (hereafter 2.1). The selected node appears in the 'Selection' section of the interface (2.2) where it is possible to read the selected node name and its identifier. The 'View 'section (2.3) allows the construction of the Supply Network related to the selected node. It determines the depth of the network starting from the selected node and going either ways: downward to the network of clients, upward to the network of suppliers, or both. Six options are available: (i) its direct clients, (ii) its direct suppliers, (iii) its direct clients and suppliers, (iv) its client network, including clients of its clients as far downward as possible, (v) its supplier network, including suppliers of its suppliers as far upward as possible, (vi) its overall client and supplier network combining (iv) and (v) above. These six options allow the user to focus his attention on the desired part of the Supply Web. This can be either customer-centric, supplier-centric or both. This can be narrowly focused or may have a broader perspective. Indeed, the user can even request a mapping of the entire Supply Web by selecting 'All Center' in the tree view, requiring synthesizing all information which he is entitled to observe. Obviously, in huge Supply Webs, such a request may be highly time and resource consuming.

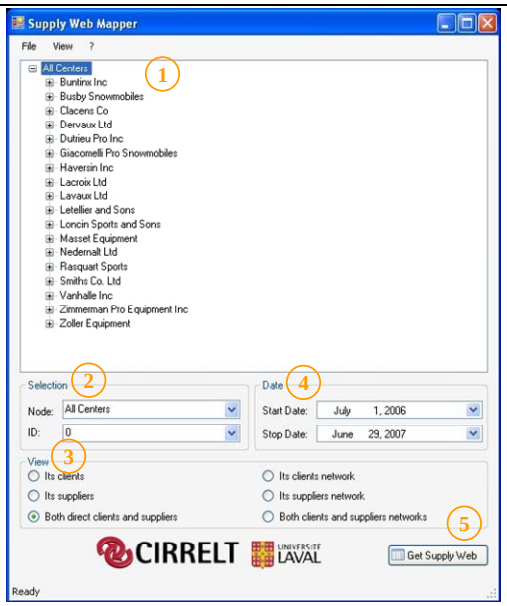

Fig. 2. Selection Interface

It is also possible to limit the data to a specific time span by choosing a starting and ending dates in the 'Date' section (2.4). This can provide results by season, for example, or give information on dates related to important supply chain management decisions; therefore helping to measure their impact.

The selection drives the results to be shown later in the Display Interface since only the data related to the selected node and network will be loaded resulting in the display interface. After choosing all the desired criteria on the selection screen, the user can launch his query by clicking the 'Get Supply Web' Button (2.5). The time required to return the query result depends on the size of the flow exchanged by the selected network nodes. Once the result of the query is loaded and prepared, the Display Interface allows the user to visualize and manipulate it in multiple ways.

4.2 Display interface

The roles of the display interface are first to depict the results of the user's query in an intelligent, navigable and attention drawing manner and, second, to allow further analyses, manipulations and data mining. The first role relies on the conceptual map viewer and the geographic map viewer. The second role relies on the control board, the data mining viewer, and the graph viewer. The two latter viewers allow the user to explore the data in order to answer questions arising while investigating the conceptual or geographical maps. The user can customize the

construction of the graphs based on the results presented in the other three interfaces. The graphs can for example show the evolution of different key performance indicators (KPIs) over time, illustrate market shares of different sites, or yet trace different products. The content of the data mining viewer and the graph viewer are affected by what is performed by the user on the conceptual and geographic maps, since these determine what should be shown in the data mining and graph viewers, as shown in Figure 1. The geographic and conceptual maps are mutually affecting each other as manipulations on one should be reflected on the other, as indicated in Figure 1.

In addition, the display interface provides many tools for investigating, mining and exploring the selected Supply Web, the nodes or the flows from different points of interest such as products, shipped trucks, volumes, weights or quantities. This allows highlighting key performance indicators (KPIs) most relevant to the user. These tools or controls are mostly grouped in a control board which can be seen as an extension to the Selection Interface since it provides more filtering and investigation options. In general, the display interface is equipped with tools that allow digging in and out among the results of the user's query.

As can be seen in Figure 3, the display interface of our prototype is divided in two parts. An upper part (3.1) contains three tabs. Each leads to one of the three completed viewers, the graphic interface currently being under construction. The retractable lower part (3.2) represents the control board through which the user can customize the display on the viewers, choose his preferred units of measure (e.g. 3.b, 3.c), and set the KPIs to be highlighted. The user can choose the data to display by selecting the desired elements in the 'Displayed Information' section (3.a). The default displayed information is the number of distinct SKUs, the number of cases, the financial flow, the number of shipped trucks, the weight and the volume. The 'Export Options' section (3.f) exports the current selections to an Excel file, while the 'Bitmap' button saves the Conceptual Map in an image format (e.g. bitmap).

In the 'Filter Options' section (3.e), the user can exploit node aggregation through grouping and ungrouping functionalities. More aggregation and disaggregation options of nodes and flows are available in the conceptual map by right clicking on nodes and links. In fact, the user can be interested to see the network with nodes corresponding to aggregated business units, actual sites, or a combination of both. By default the presented data is aggregated by business units. The 'Ungroup All' button disaggregates all business units to their sub-sites, detailing flows by sites rather than by business units. The button 'Products' (3.g) displays the product category hierarchy as an expandable dynamic tree view. The user can dig in or out through the product category tree to choose any combination of products or product categories contained in the pre-selected Supply Web.

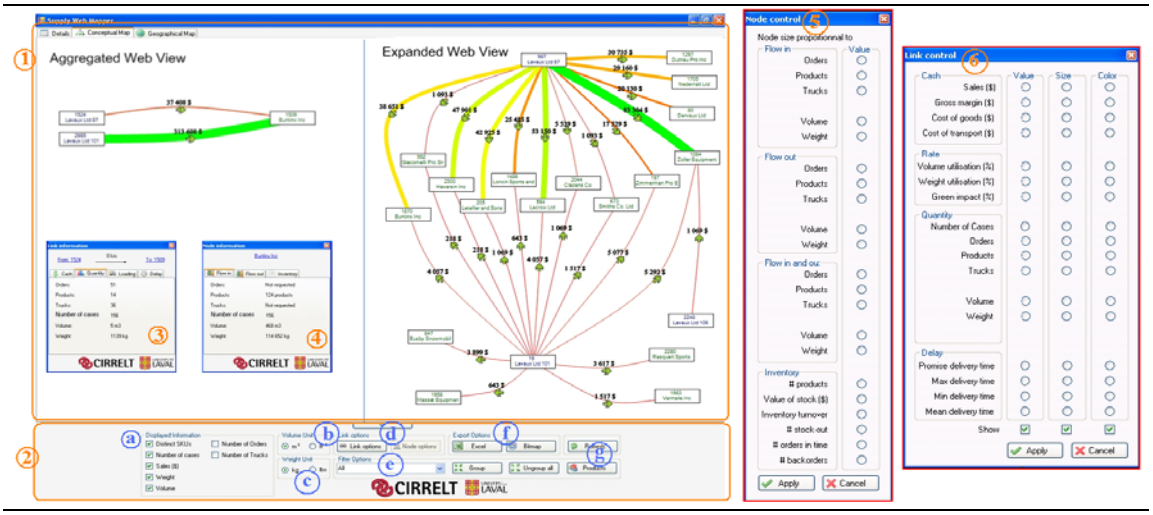

Fig. 3. Conceptual Map Viewer

4.3 Conceptual Map Viewer

The conceptual map viewer is a core component of the Supply Web Mapper. The flows resulting from a user's query are mapped as shown in Figure 3. The nodes, either sites or business units, are represented as rectangles showing the name and the identifier of the node. The flows are represented through links shaped as curved lines joining nodes together.

The user has the possibility to customize the Conceptual Map via different tools made available to him. First, he can adjust the position of nodes and links by dragging them. He can group or ungroup a node or a link either via the control board, as presented in the previous section, or by accessing the disaggregation options through textual menu displayed by right clicking on the node or the link. It is possible to have a global, aggregated view as a network of business units, or a detailed, disaggregated perspective depicting physical sites. Each set of sites belonging to a certain business unit can be identified by a color code and/or a business unit identification. Moreover, some business units can be aggregated while others are disaggregated, allowing the user to mine the network easily at his convenience. The right clicking textual menu on a node or a link provides also the option to show a pop-up containing information about the selected element. In addition to a clear identification of the selected node, the pop-up of a node contains three tabs: (i) 'Flow in' tab which shows key quantitative data about what the node received, (ii) 'Flow out' which gives the same quantitative data about what the node shipped and (iii) 'Inventory' tab which shows key inventory data of the selected node. The link information pop-up contains four tabs: Cash, Quantity, Loading and Delay. The 'Cash' tab contains financial data about the flow that went through the selected link. The 'Quantity' tab gives quantitative information such as the volume, the weight, the number of trucks, and the number of orders that transited the link. The 'Loading' tab displays key information about the volume and the weight utilisation of trucks that transited through the link. Finally, the 'Delay' tab displays information about the delays related to the flow (e.g. expected shipping date and effective shipping date).

The link color, width and value can be associated with different criteria. For example, the color can be related to the volume transited through the link, the width to the number of trucks, and the value to sales. Largest is the value criterion associated to the width, the ticker is the link (Figure 3). The association between the link color, width and value, and different criteria is done via the 'Link Control' pop-up (3.6) which is generated after clicking the 'Link Options' button (3.3). In the same manner, the 'Node Control' (3.5), displayed by clicking the 'Node Options (4.4), allows customizing the size, color, boarder size, as well as the font text color and size of the nodes. More customization is possible by using other features provided by the control board such as grouping and ungrouping all nodes, selecting the preferred combination of products and product categories, and the desired system unit.

4.4 Geographical map Viewer

While the conceptual map viewer represents the selected Supply Web conceptually, the geographical map viewer illustrates it physically, allowing zooming and panning as desired. The same flows found on the conceptual map are presented on the geographical Map according to the real location of the involved sites. An example of the geographical mapping is presented in Figure 4. The nodes are drawn as coloured stars on the map of Figure 4. Each star is located in the exact geographical position of the site related to it, using its latitude and longitude coordinates. The flows are presented as lines between the nodes. The color and the size of a node or a link are customizable in the same way as on the conceptual map. The white stars represent the nodes that shipped the finished goods sold in the selected network, the blue stars illustrate the final destination of the products and the red stars are nodes through which the products transited.

4.5 Data Mining Viewer

As can be glanced in Figure 5, the Data Mining Viewer is a textual tri dimensional representation of the user's query result. It represents the synthesized data as flows between pairs of nodes of the selected Supply Web and is structured as a dynamic data tree view. First the tree view is presented as a two-dimension table with lines showing the returned flows and the columns representing various measures such as number of SKUs that constituted the flow, the weight, the volume, the number of orders and trucks. The third dimension is available by expending the lines, so that the user can easily investigate the flows. By successively expanding the flows, the shipped trucks, the shipped orders and order lines, the user can visualize their content and see different

measures for each one, as shown in the figure 5. A primary goal of this viewer is to enable the user to dig in and out to better understand an aggregated measure or to explore in-depth some complex problem issues.

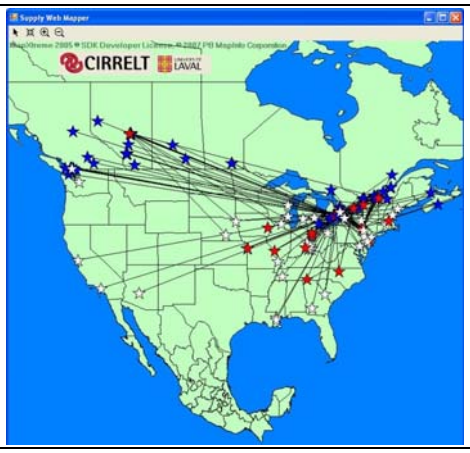

Fig.4 . Geographical Map Viewer

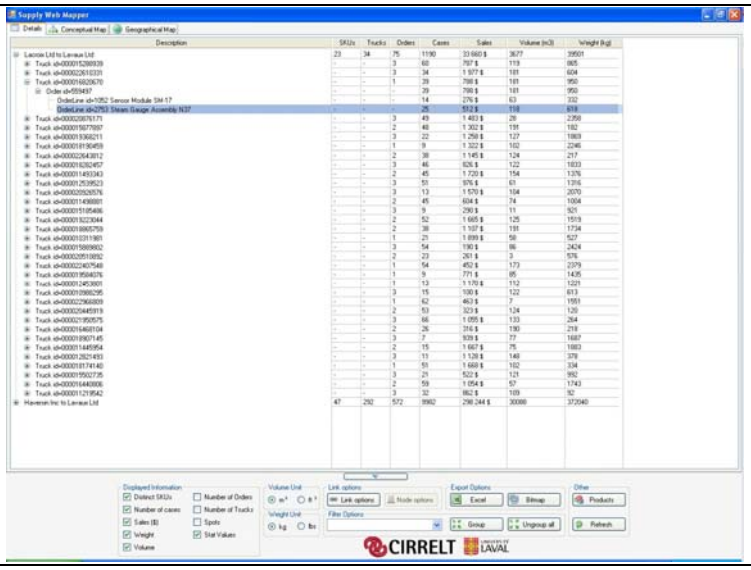

Fig. 5. Data Mining View

The selection of KPIs, the grouping and ungrouping actions taken on the control board or on the conceptual map are reflected automatically on the data tree view. In fact, another primary goal of this interface is to support the other interfaces since it is the one that focuses the most on the numerical display of data, and the least on the representation and attention drawing. In addition, selection of links and nodes on the conceptual and geographical map highlights automatically the corresponding data on the tree view.

5 Conclusions and research perspectives

The ability of companies to gather and store data exceeds by far their ability to analyse it and use it efficiently. This is the reason why more research needs to be done toward providing managers with tools that help them to use the available data. On one hand, the new concepts influencing the supply chain field such as traceability, B2B and end-to-end collaboration are driving a huge need to different kinds of data. On the other hand, the

advances in monitoring and communication technologies produce an increase in the variety and the size of the collected data. Moreover, the concept of supply chain itself is forcing the managers to take in account more than their company's internal issues. Even the concept of supply chain is too narrow to express the complexity faced by actors in the field, so managers have to think in terms of supply networks embedding multiple supply chains, and in terms of Supply Webs, embedding multiple supply networks.

In this paper we introduced the concept of Supply Web Mapping, enabling the visualisation, the investigation and the mining of supply webs according to multiple dimensions such as time, horizontal flow-driven structures and vertical organizational node structures, and product hierarchy. We demonstrated our research with a Supply Web Mapper prototype in order to make explicit the concepts of data extraction, schematisation, simplification and mining.

The introduction of a Supply Web Mapper is one step toward developing the full scope of functionalities necessary for managers and engineers to help their companies thrive in fast-paced, fast-evolving and wide-reaching Supply Webs. A supply web mapper allows the visualisation, the investigation and the mining of the supply web, providing a current snapshot a selected time interval and network frame. Following researches should focus on enabling better visualization of the dynamics involved, on enabling targeting of user focus to facets of the supply web requiring his attention, and on developing decision models and approaches helping specific types of users, for example in manoeuvring in a supply web and in influencing its improvement.

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