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# ROUTE PLANNING MODULE AS A PART OF SUPPLY CHAIN MANAGEMENT SYSTEM

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Today, the demand for creating a systematic approach for managing sales, ordering, and logistics has increased. Supply Chain Management (SCM) is one of the responses to problems that have arose with the need for managing complex supply chains. Nowadays, most of the activities of Supply Chain Management is realized or supported with computing technologies. Route planning is an important part of Supply Chain Management related to both procurement and distribution. Route planning systems specify the sequences in which the selected transport vehicles should supply the demand points by requested quantities of goods at the right time. The paper is focused on the analysis of a route planning system which could be used as a part of Supply Chain Management information system or as a standalone application. It describes basic techniques and frameworks of transportation problems as well as important functional requirements, considering recent trends in the field of distribution planning. As a result, functional specification of basic features and other components of system are provided. The paper is a result of a joint initiative of the authors and a vendor of business information systems.

Supply Chain Management, route planning, Route Planning Module, systems of transportation

One of keys aspects of a successful company is the ability to quickly and effectively react to changes in the supply chain. The supply chain is a system consisting of independent economic subjects which are oriented to various fields of activities. The system‘s internal structure is complex and individual internal elements are connected in many different ways. Therefore, the demand for creating a systematic approach for managing sales, ordering, logistics and others has increased. Supply Chain Management (SCM) is one of the responses to problems that have arose with the need for managing complex supply chains. SCM can be understood as the flow and management of resources across the enterprise for the purpose of maintaining the business operations profitably. Resources include materials (raw materials, work-in-progress, finished products), people, information, money, negotiation or any other such resources that must be managed for profitable business operations (Sehgal, 2009; Rosenbloom, 2004). Logistics, which is considered to be a part of SCM, can be defined as the real time positioning of resources or the strategic management of the supply chain (Toma, Vasilescu, Popescu, 2009). According the place where are the logistics activities performed, internal and external logistics can be defined. Procurement (inbound) logistics focuses on supplies of goods from sources to the companies and outbound (distribution) logistics deals with delivery of goods from companies to recipients (Gudehus, Kotzab, 2009).

Nowadays, the most of the activities of Supply Chain Management is realized or supported with information technologies (IT). These technologies are in fact the glue that holds the supply chain together (Russel, 2007). IT systems often support or take responsibility for logistics planning of the vehicles of companies and the companies are searching for new technologies that increase the quality of their services (Gehrke, Woltusiak, 2008).

Incorporating a SCM approach in a company usually involves implementing an information system which facilitates information sharing and coordination between internal and external partners in the chain (Williamson, Harrison, Jordan, 2004). Enterprise Resource Planning (ERP) systems have played a major in developing SCM and can represent an optimum technology infrastructure that when integrated properly with a process-oriented business design can support the SCM systems effectively (Gunasekaran, Ngai, 2004). One of SCM's key aspects in such the integration is standardized and scalable interface which helps to connect SCM system with other company systems. When the data and possibly functions/services from both systems are shared they might be effectively exploited which helps to minimize data redundancy and inconsistency.

If a company serves as a supplier it needs to focus on supplying its business partners with their own production or resold products. The products need to move to desired places, at required amounts, at the right time etc. It is therefore necessary to determine the order in which the products will be moved or which ways is the best. The shortest, the fastest, the most cost-efficient, the most time-efficient – what is the best choice? It is sometimes very difficult to say. The decision depends on the specialization of the company and on all aspects that define company's culture, interests etc. The problem of planning the transportation can be solved by a tool that is called route planning system or transportation planning and vehicle scheduling system whose objective is the design of optimal vehicle routing and loading on the basis of shipment requirements (Stadtler, Kilger, 2008; Breunig, Baer, 2004).

Because a very low variation in logistic expenditures may lead to a very large cost savings in absolute terms (Toma, Vasilescu, Popescu, 2009) efficient planning of distribution and related activities are of a significant importance for companies. For example, large retailer can have thousands of stores, supported by a large number of warehouses, the efficiency of the distribution of merchandise from warehouses to stores is very important and can have a substantial impact on profitability (Sehgal, 2009). When the company is smaller it needs to solve similar problems (in smaller scale) with transportation planning as well. Companies can use freely available tools like Google maps *(maps.google.com)* that can provide a calculation of the shortest path between several places but that is not able to consider constraints related to the cargo, vehicles, delivery times etc. The objective of the paper is to provide an analysis of a module of enterprise information system that can be used for supporting activities related to transportation of goods from factories/warehouses to final customers. The paper is a result of a joint initiative of the authors and a vendor of business information systems Flores software.

## MATERIAL AND METHODS

How to perform transportation effectively and efficiently? It depends on several factors. The companies mostly focus on the lowest costs in terms of finances. However, not only this type of costs has to be the only important for company orientation. Another important factors could be the time (time's interval between loading and delivery), the right moment in time (e.g. for just-in-time inventory management), number of transported products etc. The primary objectives of company logistics therefore usually include performance, service quality and cost efficiency and possibly other goals that depend on general goals of the company and other specific requirements (Gudehus, Kotzab, 2009).

Chosen kind of transportation determines the route, selected vehicles, their capacities, number of stops etc. In the supply chain the following transportation processes can be generally identified (Stadtler, Kilger, 2008):

- The supply of materials from external suppliers or from an own remote factory to a production site. Both cases are identical from the viewpoint of logistics.
- The distribution of products from a factory to the customers.

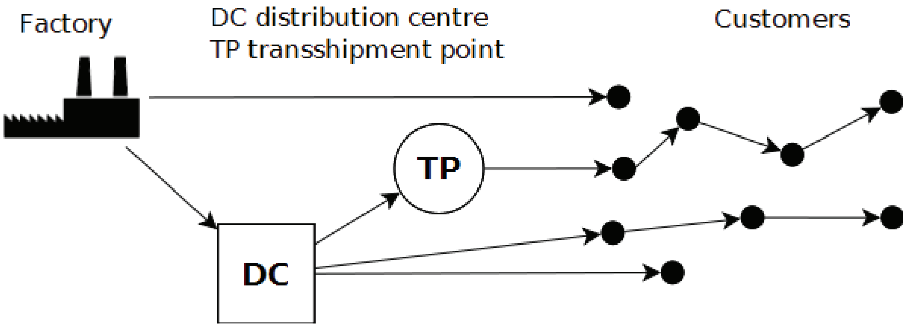
From the technical point of view, both processes are very similar and the same methods can be used for their planning and management.

The distribution system depends on the type of products (Stadtler, Kilger, 2008):

- *Investment goods*, e. g. machines or equipment for industrial customers, are shipped only once or seldom on a certain transport link.
- *Materials* for production are also shipped to industrial customers, but regularly and frequently on the same path.
- *Consumer goods* are shipped to wholesalers or retailers, often in very small order sizes (with an average below 100 kg in some businesses), requiring a consolidation of the transports.

### Distribution systems

Distribution or transport systems focus on distribution of products to consumers. Much of the production often needs to be delivered to many stores or, in some cases, it is moved directly to customers. Basically, there exist two different ways of how the merchandise can be shipped. Shipments may go directly from the factory or from a distribution center to the customer, with a single order. This simplest form of distribution is only efficient for large orders using up the vehicle. Smaller orders can be shipped jointly in supplies starting from the factory or distribution center and calling at several customers. A stronger bundling of small shipments is achieved by a joint transport from the distribution center to a transshipment point and delivery in short distance tours from there, see Fig. 1. A recent concept for the supply of standard materials is the vendor managed inventory (VMI), where the supplier decides on time and quantity of the shipments to the customer but has to keep the stock in the customer's warehouse between agreed minimum and maximum levels. In this case, the customer's warehouse has the same function as a distribution center (Stadtler, Kilger, 2008).




1: *Distribution paths (Source: Harmut, 2002)*

### Procurement Logistics Systems

Procurement logistic systems are focused on supplies. In this case the manufacturer controls the transport of materials or other resources from its suppliers. Several logistic concepts might be applied. The whole logistics system is defined by the structure of the transportation network and frequency of shipments. The manufacturer decides about both criteria, it can combine individual approaches or use them in parallel (same or other structure).

*Cyclical procurement* is a concept when receiving factory is supplied in intervals of a few days up to a week. The company, whose management prefers the just-in-time method of supplying (see e.g. Lai, Cheng, 2009) will use *JIT procurement*. With the daily shipments passing of the inbound material through the warehouse is avoided. More efficient is the situation, when supply is synchronized with the production processes. The latter case is called *synchronized procurement* (Stadtler, Kilger, 2008).

How supplies can move to the factory? At first, the supplier can transport directly to the factory. This is useful when the distance is very short or in the case of day-to-day supplies. Suppliers can also ship the supplies to transshipment points and after the condition for the shipment is satisfied the material// goods can be moved to the factory. This service can be realized by a *Regional Logistic Service Provider (LSP)*. A LSP warehouse is close to the receiving factory, is responsible for satisfying the short-term calls from the receiver by synchronized shipments thanks to keeping the stock in the warehouse between agreed minimum and maximum levels by appropriate shipments, like in the VMI concept (Stadtler, Kilger, 2008).

### Distribution Networks

A supply chain can be understood as a specific network (Kotzab, Bjerre, 2005) consisting of interconnected entities of several types. The purpose of distribution networks is to deliver goods to customers. From a certain perspective, transportation of material or goods from suppliers to a factory and from a factory to customers, are the same or very similar processes. In both cases, the objective is to move something between several locations under certain constraints.

All transactions in such networks are initiated by orders. Every order basically includes order lines (which article), quantities, addresses and time information. It is favorable that the logistics system provides information about delivery ability, status, due dates, tracking and tracing articles and shipments, and provides additional services like inventory management, scheduling of supplies, invoicing, reminding and others (Gudehus, Kotzab, 2009).

A general transportation system's properties create three disjoint sets:

- Set of locations V connected by roads E, forming a roadmap graph G = (V, E),
- Set of mobiles M which traverse the roadmap,
- Set of portables P which can be at a location or carried by a mobile.

The goal of the transportation system is to move a subset of portables to their final destinations in the most efficient way. It is necessary to consider capacity constraints, fuel constraints, movement costs, pickup costs, number of mobiles, mobile types, roadmap graph types, initial locations, initial fuel, goal location and other possible special features (Helmert, 2008).

### Route planning systems

Route planning systems specify the sequences in which the selected transport vehicles should supply the demand points by requested quantities of goods. To find the most cost-effective trips traveling salesman models can be used. However, when there is a large number of locations and many constraints the resulting number of combinations doesn't allow the model to be solved exactly. Route planning is an NP-hard problem that is difficult solve optimally. Instead, route planning modules can use heuristics or expert rules (Knolmayer, Mertens, Zeier, 2002; Laporte *et al.*, 2000). The most well-known classical heuristics are the Savings and Sweep algorithms and the most successful metaheuristic approach is the tabu search heuristics (Gayialis, Tatsiopoulos, 2004).

Besides the travelling routes, the route planning package can graphically display the travel routes, provide various lists (routes, customers, orders, vehicles), or check the economics by calculating some statistics (Knolmayer, Mertens, Zeier, 2002).

Route planning systems bring many advantages to customers (improved service, increased reliability, reducing delivery times, quick response to special requests), management (increased transparency, independence on planner's intuition, simpler training of new employees, reliable data for decisions) or schedulers (reduction of routine tasks, less errors) (Knolmayer, Mertens, Zeier, 2002).

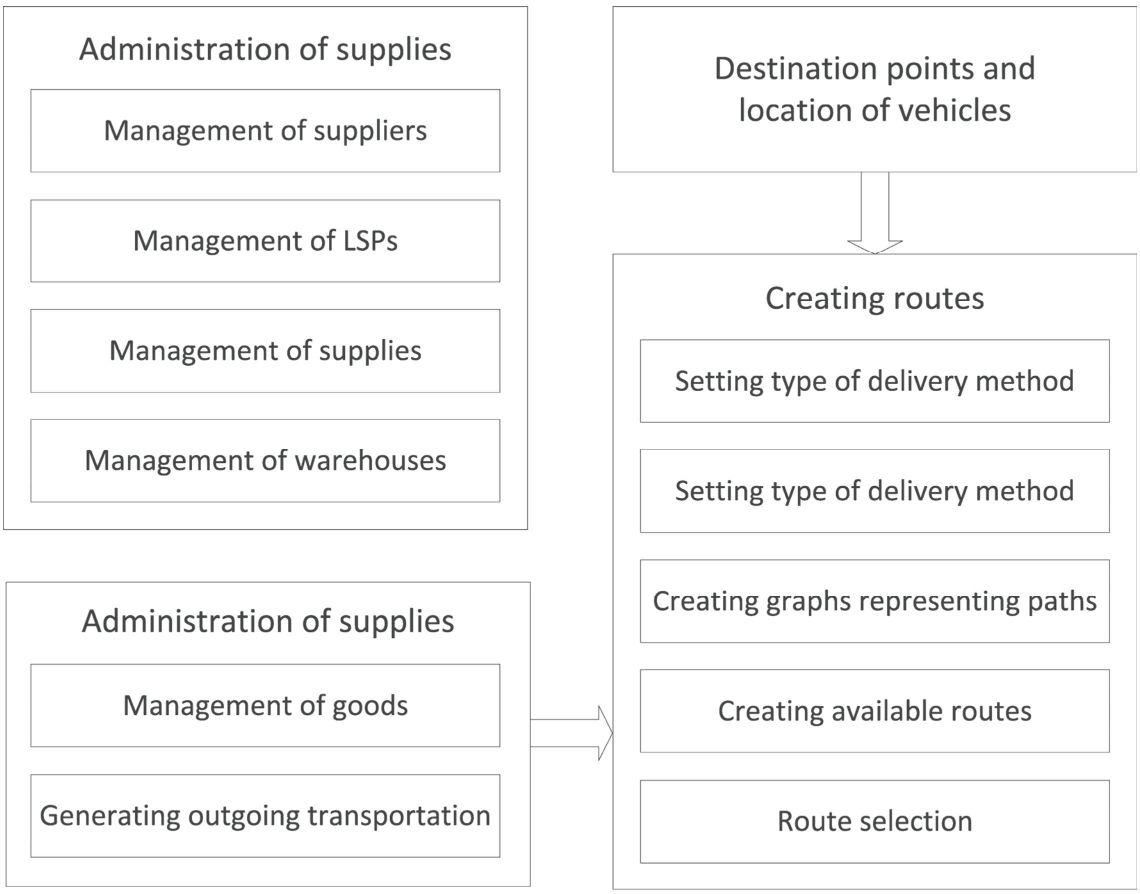
Currently, there exist several standalone or integrated modules that support transportation and route planning in information systems, e.g. JDA Transportation Planner (*www.jda.com*), Transportation Planning and Vehicle Scheduling library or Advanced Planner and Optimizer (APO) for SAP (*www.sap.com*), Routing module for Canias ERP (*www.canias.com*), SimCrest Route Planner fully-integrated with Microsoft Dynamics NAV (*www.simcrest.com*) and others.

## RESULTS

Both types of transportation (distribution and supply) need to be planned. This functionality is usually provided by a module that can be referred as a Route Planning Module (RPM). This system is often included as a subsystem of another information system such as ERP (Enterprise Relation Management), CRM (Customer Relation Management) or SCM; the reason is that RPM usually needs some data that are recorded in these systems (e.g. information about customers, goods, locations). For the process of transportation planning, the list of merchandise and list of available vehicles are needed. Both lists are composed from detailed information such as dimensions of the cargo space, maximum weight of cargo, places of loading, places of delivery, quantities etc.

Input data has to be provided using a predetermined format (typically generated by an information system). Similarly, the planner module should be able to provide desired output information, such as a list of generated routes with their descriptions, assigned vehicle and driver and with the list of merchandise. The result should be dynamical and flexible in the sense that the data can be modified during the journey (e.g. state transported / shipped / waiting for transport) according current conditions and needs.

Every top-level function (that can be represented by a software module) of the transportation planning module focuses on some substantial problem of the transportation planning process. Some functions can be useful in both supplying and distribution




2: *Major functions of route planning module* processes. The data needed for successful operation of the system can be obtained from a data base (when the system is a part of a larges system, such as SCM or ERP) or on the input, structured according a predetermined format (typically XML). The analysis of essential functions is provided in below.

## Administration of supplies

The main task of this module is managing the list of supplies which is one of the most important parts of transportation management process. Each item in the list is received from a particular manufacturer. Some services could be outsourced to a Logistic Service Provider (LSP) in the cases when the merchandise has to travel far away or in other extraordinary cases. Orders can be realized on a periodical basis (e.g. every week) or ad-hoc when the need is identified. This function can be used together with all methods mentioned above or together (JIT, cyclic, with or without a warehouse, outsourced to an LSP or not).

### *Management of suppliers*

Information about suppliers is important for many reasons. The most important data include the locations for cargo loading, addresses, contact details and others for ordering and invoicing, a catalog of products (accessible through hypertext links, directly from internal systems etc.), or evaluation of the supplier, which is related to reliability, overall satisfaction, precision, quality etc.

### *Management of LSP's*

An LSP represents a provider of outsourced services. It can be useful for extraordinary or complicated deliveries. It is important to keep the record about places of loading and unloading, types of product transportation, prices, evaluation, contacts etc. More information about management of LSPs can be found in Panayides, So (2005) and Wong, Karia (2010).

### *Management of warehouses*

It focuses on management of a list of warehouses, together with their addresses and locations. The locations are subsequently used for calculating the routes of moving the goods. There are several items inside each repository as well as the state of each item (ordered, delivered, or expedited). Each item has defined the amount, dimensions, weight and other information necessary for distribution planning.

### *Management of supplies*

The module enables creating lists of products with the places of their delivery. The orders are recorded and sent to contractors. For every order the date of issue, list of products, delivery and price must be recorded. The merchandise is simultaneously listed to stock with order with the status ordered.

## Management of shipped products

This functionality is intended for adding, updating, removing, and retrieving items for transportation (in the list they might be contained data about goods, which for some reasons could not be delivered). Operators typically prepare the data (about supplies) and the drivers update the state of each of the items. Some of the transportation services could be also outsourced to an LSP in the cases where merchandise has to travel far or in extraordinary cases. If company uses warehouses the system should inform about them.

### *Management of goods*

This module maintains information about products which are ordered by customers and that are needed to be delivered somewhere. Every product has its dimensions, weight, destination, current placing etc. If company uses warehouses, each of them provides a list of goods on stock. If some of the merchandise cannot be currently transported, it is added to next delivery.

### *Generating outgoing transportation*

Before the route generating process can start, the system has to know whether the company uses warehouses, LSPs or directly delivers to its customer. In the first case, the whole cargo needs to be transported to the warehouses.

In the second case, the LSPs realize some parts of the journey instead of the company where two possibilities can be considered. An LSP can deliver the goods directly to the customer or an LSP transports the shipment only within a part of the entire path (somewhere in the middle).

The simplest way of transportation is direct distribution between two places. These places are typically represented by a supplier and a customer.

For each of above mentioned approaches it is necessary to generate the distribution path differently. The paths differ in the number of nodes (loading and unloading) and sections (sections realized by an LSP don't need to be planned).

## Destination points and location of vehicles

All vehicles need to have a terminal point of their journey (after delivery of the last item) – a depot, a place of driver's residence etc. recorded in the system. This information influences the operating time of the vehicle and the plan of the route. At any time it is favorable to find out where the vehicle exactly is (e.g. provided by GPS).

## Creating routes

The most important and complicated part of the module is the creation of the routes for all available transportation facilities that are able to carry some material.

#### *Setting type of delivery method*

Setting this up has an impact on the way of generating the routes. If the company uses LSPs, it is necessary to specify places of unloading and loading (loading might be optional). The process of routes generation will be executed twice.

If the company uses warehouses, the transportation can be divided in two parts. The first one involves movement of the goods to the warehouses. This usually happens in the simplest way, so only two places of the route must be considered (the same situation is when the company delivers the goods directly to the customers). The second part is more complicated. At the beginning there is a list of undelivered goods. A vehicle can load more than one product, so it has to pass through several places (in each of them a part of the cargo can be unloaded).

From the time perspective, the module allows periodical orders. Person in order does not need to plan the orders repeatedly, but the module can do it automatically.

#### *Dividing products into groups*

The products can be classified into groups according the place of their loading or unloading or according to other criteria, such as merchandise with huge dimensions or which requires to be transported by special vehicles.

After the system contains information about the merchandise it divides it into groups according the dimensions and weight (to fit dimensional and weight limits of the vehicles). Subsequently, these groups can be divided into sectors (according the distance between places of loading and unloading). All goods should be moved within a time limit. The merchandise which was not transported in the past (thus having higher priority) can be preferred. Each of the groups has assigned a vehicle which is able to transport the cargo. For the goods which is for some reason undelivered is increased the priority.

### Creating a graph from groups of goods

The module takes all places from a sector and generates the connections between all pairs. All places are connected by the shortest possible paths, taking additional constraint into consideration. The connections between pairs of places are evaluated by their distance which can be provided e.g. by an external map service provider (like Google maps). The result is a continuous graph, where all nodes are neighboring witch each other. This graph can be considered to be oriented, because direction leading from places of loading to places of unloading can be distinguished. In other cases orientation is bidirectional.

#### *Creating available routes*

In order to solve this problem the Traveling Salesman Problem (there exist also several other names for this type of problem), which is perhaps the most well-known combinatorial optimization problem, can be used. It is a typical hard optimization problem that has many modifications: Ghaziri and Osman (2003) deal with this problem using neural networks, the classical approach can be enriched by a heuristic algorithm (Palleta, 2002) or many other modifications can be employed (Gutin, Punnen, 2004).

#### *Route selection*

This function is able to choose the optimal route according given criteria and additional conditions or restrictions. For example, if the shortest route is needed, the system considers the length of all possible routes and then choses the route with the smallest value.

## CONCLUSION

As shown in the previous sections, there are many different approaches to management of the supply chain and of its individual components. The paper provided a simple overview of the most common practices in SCM with the respect to transportation planning and also described the analysis of a module intended for supporting the route planning process.

The module is designed as an independent (standalone) application that is connected to other enterprise systems. The designed concept supports a wide range of current trends and practices such as JIT. The main benefit of this solution is hidden in its independence and universality. It can be used to calculate a simple single route, as well as for complex distribution paths, which repeat in time and need to go through many places. Incorporating the GPS technology allows authorized persons to monitor the progress of individual routes of the vehicles. This allows monitoring of the route and also provides the possibility of future development (e.g. connection to an external system providing current traffic information).

The most complex part of the module is the function for calculating the best route. The planning process should consider the directions of moving of the goods, characteristics of the goods, many different constraints or take into account LSP services which can be used for specific goods and need some way of integration within the entire system.

It is possible to say that we managed to provide an interesting analysis of a route planning module, whose implementation and deployment in companies engaged in the transportation or supply, can deliver significant cost reductions and streamlining deliveries.

## SUMMARY

Today, the demand for creating a systematic approach for managing sales, ordering, and logistics has increased. Supply Chain Management (SCM) is one of the responses to problems that have arose with the need for managing complex supply chains. Nowadays, most of the activities of Supply Chain Management is realized or supported with computing technologies. Route planning is an important part of Supply Chain Management related to both procurement and distribution. Route planning systems specify the sequences in which the selected transport vehicles should supply the demand points by requested quantities of goods at the right time. The paper is focused on the analysis of a route planning system which could be used as a part of Supply Chain Management information system or as a standalone application. It describes basic techniques and frameworks of transportation problems as well as important functional requirements, considering recent trends in the field of distribution planning. As a result, functional specification of basic features and other components of system are provided. Every top-level function of the transportation planning module focuses on some substantial problem of the transportation planning process. Some functions can be useful in both supplying and distribution processes. The data needed for successful operation of the system can be obtained from an enterprise data base or on the input, structured according a predetermined format. The presented essential functions include administration of supplies which is one of the most important parts of transportation management process, management of shipped products intended for adding, updating, removing, and retrieving items for transportation, management of destination points and location of vehicles, and creating routes which is the most important and complicated part. The module is designed as an independent (standalone) application that is connected to other enterprise systems. The designed concept supports a wide range of current trends and practices such as JIT. The paper is a result of a joint initiative of the authors and a vendor of business information systems.

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