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Planning the supply of gas LPG to the filling station network in the concept of stocks controlled by the carrier

Abstract: In this paper, supply system of LPG to fuel station is presented as a specific example of vendor managed inventory replenishment concept. A single hauler of LPG is considered, which operates within the network of domestic depots and performs deliveries to hundreds of final customers being responsible for full accessibility for all supported LPG stations. The carrier is responsible for the entire LPG supply planning process (volume as well as scheduling of deliveries), information process, completed deliveries and any problems arising during execution. In the article the LPG supply process and the planning system which has been developed are presented with a brief presentation of an interactive computer system (DSS implementation) developed and implemented in the reporting enterprise. The work ends with an indication of the benefits of using a system approach to planning and determination of the directions for further research.

Keywords: Hazardous Cargo; Inventory Routing Problem; Vendor Managed Inventory; LPG Deliveries; Optimization

Introduction

The issue of cooperation between the supplier, recipient and carrier is an important part of supply chain management. Many of the literature as well as the experience of the practice show a significant relationship between the depth of the relationship in the supply chain and the benefits they mutual benefits. Closer cooperation between the entities has resulted in new management concepts leading to increased supply chain efficiency. One such initiative is the concept of VMI (ang. Vendor Managed Inventory) or inventory management controlled by the supplier, which was developed in the late 1980s by Wal-Mart and Procter & Gamble [8]. This concept, also known as SMI (ang. Supplier Managed Inventory), is a special case of a more general class of models of cooperation within the supply chain known as CPFR (ang. Collaborative Planning, Forecasting and Replenishment) - the joint planning, forecasting and replenishment. VMI is managing inventory recipient by the provider, who decides on the time and volume of delivery in order to guarantee full availability of products to end customers. In this model, the supplier is not only plans and implements supply but also takes responsibility for ensuring the continuity of sales by responding to information on production, demand and inventory levels, which are made available to him by the recipient.

Skillfully implementation VMI allows you to increase efficiency on the side of the recipient (reducing the cost of inventory control, reduce errors in the ordering process through automation, improve the level of service) and the supply side (reducing distribution costs by reducing restrictions during its planning, optimization of supply , unified communications, faster access to information and the ability to dynamically respond to changes. the implementation of VMI requires incurring some risk for both the recipient (increase in the degree of dependence on suppliers, the disclosure of sales data, exposure to the risk of errors suppliers) and suppliers (responsible for the inventory of the recipient and the risk of incurring penalties for gaps in the continuity of sales, as well as the need for a flexible response to change and improve the algorithms for estimating demand) [9].

One management strategy VMI in the transport industry is HMI (ang. Hauler Managed Inventory) inventory management by the carrier. Often companies engaged in the distribution of products to expect from the carrier not only the performance of specialist transport services but also the planning service delivery to end users. In this case, we can talk about imposing methods VMI as a precondition to fulfill for the implementation of the trade agreement by the dominant partner.

Generally speaking, in practice, there are three common approaches to the implementation of VMI::

1) specialized transport company is rented for an agreed period of time and under the contract of transport entrusted their hardware resources and personnel (drivers and supervising their activities) available to the company dealing with complex distribution of LPG,
2) specialist transport company under the contract with gas distributor assumes responsibility for among other things continuity of sales, realizing transport services on the basis of independently prepared plans to supply on the basis provided by the distributor telemetry data of the inventory of product on autogas stations,
3) intermediate model relies on the delivery of LPG stations by a specialized transportation company based on the plans of routes developed by an external company dedicated to professionally only planning supplies (eg. DMS, Bottomline, Syncron, Tecsys).

The term "specialized transport company" is used implicitly for a transport company meets the requirements of ADR (transport of hazardous materials), which has a specialized tractors with tanks or / and tank trucks with trailers and employing skilled and experienced drivers meet specific legal requirements.

VMI logistics concept has had many models on the basis of operational research, and several methods of solving them. The issue of these are referred to as IRP (Inventory Routing Problem), which is the problem of routing the flow of inventory. In management theory, this issue is also known as JTIP (Joint Transportation and Inventory Problem) [10]. The problem concerns the IRP repeated distribution uniform product from one store using a homogeneous fleet of vehicles to multiple recipients VMI in the planning horizon. It is assumed that each recipient has a warehouse of known capacity for the storage of the distributed product and known wear each recipient. The aim is to minimize the costs of distribution during the planning period in such a way that there were no gaps in any of the recipients. The solution IRP is the strategy of replenishment or detailed manner of distribution of the product, ie. The amount and the terms or conditions of call supply and delivery routes for each vehicle in each period [11].

Review of the literature

Precursory work in this area was led by E. Beltrami and Bodin L. [4], who used a simple algorithms for solving problems routing the flow of inventory using the technique of dividing a set of recipients. Their approach has been supplemented by W. Bell and co-authors [3], who in his work used a technique integer programming to develop daily delivery schedules for the technical gas to end users. As a result, practical application of their model, an operating cost savings of between 6% and 10%. Attempts to solve large tasks IRP were taken in the same period and related problems associated with the distribution of liquid gas for individual consumers and industrial applications.

The beginning of the XXI century brought new algorithms and heuristics to solve problems IRP. An important step was to distinctions the strategy replenishment - the most common are two strategies referred to in the literature as an order-up-to (OU) and the maximum level (ML). The first is to complement the full magazine audience at each delivery, while the latter implies greater flexibility in the limited storage capacity of the recipient. OU

strategy was used in the work of L. Bertazziego, Paletty G. and M. G. Speranza [5] to formulate some form of objective function and to study their impact on the solution. As a result, the authors obtained a reduction in the number of deliveries, which resulted in a decrease in operating expenses.

An advanced method for solving the IRP developed C. Archetti, L. Bertazzi, G. Laporte and M. G. Speranza [2]. This is the exact procedure to solve the problem IRP for 50 customers in the 6-day planning horizon. Very promising heuristics Hybrid also proposed C. Archetti, L. Bertazzi, A. Hertz and M. G. Speranza [1]. For the same problem they obtained results mean error of 0.1% (maximum error 2%) using the programming model of mixed local and improvement of the prohibitions (ie. Taboos cheese).

One of the last works are published by Y.-B. Park et al. [14] concerning the application of genetic algorithms to solve the problem of the IRP strategy VMI for a two-tier distribution network. The proposed genetic algorithm determines separately the amount and timing of deliveries and routes of vehicles maximizing the benefit of the entire supply chain.

Characteristics of the domestic LPG market

LPG (Liquefied Petroleum Gas) is a mixture of liquefied hydrocarbon gas (mainly propane and butane). Is used as a gas but being stored in pressure vessels is in the form of liquid. LPG is one of the most common sources of energy. It is used mainly as a fuel for powering various types of equipment and, in particular, as a gas used to drive a car (LPG). LPG is obtained as a by-product of the refining of crude oil and natural gas deposits (usually when starting a new hole).

In many countries the tax burden on LPG are lower than for petrol and diesel, which significantly affects the attractiveness and economic growth in the popularity of LPG as a motor fuel. In Poland, for several years, the average retail selling price of LPG is maintained at a lower or close to half of the average retail selling price of EU95 (alternative fuel) or the price of diesel, which is an important incentive for the use of LPG as a motor fuel. [12].

The most important segment in the nationwide sale of LPG is LPG, which is approx. ¾ of the total market (in 2014 - 74.8%). In total, at the end of 2014, Poland had 5,460 stations offering LPG and the estimated number of vehicles equipped with LPG installation was 2 846 000, an increase of 3.2% compared to the previous year. Sale of LPG on filling stations has become an indispensable segment of the market - both large oil companies and as private owners equip their stations with modules LPG. The data indicate the role played by a continuously growing segment of the LPG in the national economy and the importance of the transport companies providing services for the distribution of LPG operating in our country petrochemicals.

Polish LPG market has over 20 years of tradition. Deliveries of this product, are held by tankers to stations and reservoirs to supply plant or heating. They are filled on a gas bottling plants, which are usually located near the refinery or rail terminals, to which rail car directly behind the eastern border. LPG is stored in large cylindrical pressure vessels that meet strict standards, among others, hazardous materials (ADR). Due to the physicochemical properties of LPG and the applicable legal provisions, it is permissible to fill the tank up to 85% of its capacity (the so-called behavior. Airbag). In the area of gas terminals they have strict security procedures and functions specific infrastructure adapted to local conditions and regulations. From an operational point of view, the company transporting LPG must take into account the opening hours of terminals (only some of them are open 24 hours a day, 7 days a week). Access is usually difficult (especially in the winter or spring), and must reckon with waiting in line for a feed station (sometimes even a dozen or so hours). If there is shortage of a product originating either from imports or domestic production should take into account the

increased waiting time or a referral to another tanker terminal (away sometimes by tens or hundreds of kilometers).

Vehicles and drivers supplying LPG are legally required to comply with the law on working time of drivers and the rules for the transport of hazardous materials (ADR). In addition, some customers require that additional safety standards (eg. Shortening the daily working time norms drivers, prohibition of night work, additional restrictions speed) and the rules applicable to the individual gas bottling plants. Drivers must follow the procedures QHSE (Quality, Health, Safety and Environment), - one of them is a ban on the use of mobile phones or any other devices that enable two-way communication while driving as well as during reloads tanks for bottling and unloading stations. This provision makes it difficult to extensively communicate with drivers realizing the supply of LPG.

The distribution of LPG are used in special tanks approved for the transport of ADR. The most common are the Transport Sets: tractor and 20-ton semi-trailers, which can be loaded at one time approx. 36 thousand. LPG liter of the mixture of hydrocarbons (mainly propane and butane). The number of loaded liters of LPG decide density, temperature and composition of the mixture. Composition ratios can be different and vary according to season, a mixture of origin and destination of delivery. The maximum filling of tanks shall not exceed 85% of the capacity and the size indicated on the nameplate of the tank (kg) for security reasons.

In practice, the distribution of LPG common are three ways to place orders. The most traditional method lies in the fact that customers are ordering gas helpline provider, agree on the amount, timing and other terms of delivery (including the form and date of payment). The second is the development and delivery schedule for each station on certain days of the week or month. The third way is based on a system of remote telemetry, consisting in the possibility of remote reading level filling tanks with LPG thanks to the GPRS data transmission from the sensors installed at some stations. In practice, the national distribution of LPG we are often faced with a combination of all three of these ways of placing orders.

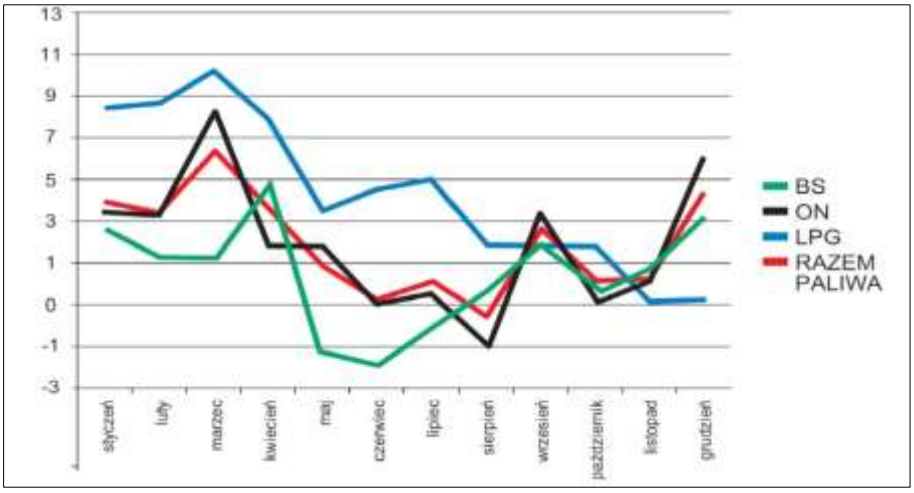
An important factor characterizing the specificity of distribution of LPG is relatively small capacity of containers to customers at the pump in relation to the volume of daily sales. The most common domestic modular installation of LPG stations usually comprises two interconnected ground tanks with a capacity of 4850 l and with a diameter of 1250 mm each, distributor and pump with necessary piping and fittings. Due to limited space at the stations there is usually no possibility of extending the storage capacity for LPG. The specificity of stations selling LPG has a significant impact on the way the performance of its distribution and is the cause of a peculiar approach of the management stations to issue orders for the supply of LPG.

Due to the economic attractiveness of LPG as motor fuel, which is many years the dominant factor in the popularity of LPG sales in Poland, even relatively minor differences in selling prices compared to neighboring stations can cause significant fluctuations in demand for the station. In practice, fluctuations in demand have a significant impact on the process of ordering and delivery of gas to the station network and in particular the level of distribution costs and service levels (number of weaknesses continuity of sales occurring at the end customers).

The impact of variability in demand for planning process

Among the many confounding factors the process of distribution of LPG to petrol station network, the most important role played by the problem of variability in demand. Apart from the volatility resulting from the uncertainty as to the final amount of gas supplied to individual stations making the order, there is a variability resulting strictly from the stochastic variability of sales of LPG stations type M. Retail station shows significant volatility resulting from a number of factors, including both the seasonality as well as volatility price volatility

and demand on stations. Figure 1 shows the growth of retail sales of fuel at petrol stations in Poland in 2014 in terms of percentage month-to-month. Total recorded for the whole of 2014, the average sales growth of fuel stations at approx. 2%, while for petrol by 1%, ON for an increase of 2% and for LPG up by 4%.



1. Dynamics of retail sales at service stations in 2014
the price expressed in [% m c / m-c] own study based on the literature [13]

When analyzing fluctuations in demand in individual monthly basis, you can see the biggest differences in the case of LPG of up to 11%. Based on experience from the practice of fuel distribution we know that the more detailed analysis of the dynamics of the demand for gas stations can talk about the daily fluctuations of up to more than 50% of the differences between the demand and the averaged data on actual sales

It is worth noting that the data aggregated from all national station network illustrated in Fig. 1 does not take into account individual variations of sales at individual stations. Given the strong dependence of the demand for motor fuel retail prices (which are themselves subject to frequent fluctuations resulting, for example, promotion or response to competition), encountered in practice, fluctuations in demand differ significantly from the average values. These fluctuations are analyzed on the example of trying to 1,200 stations supported by the test transport company. In order to determine the variability of demand for LPG filling stations calculated for each coefficient of variation, which is defined as the ratio of the standard deviation σ and the average value μ:

$$CV = \frac{\sigma}{\mu} \qquad (1)$$

The coefficient of variation informs us about the variability of results observed in relation to the size of the average. The results of the analysis of variability in demand for the test group of stations on the monitored inventory levels are summarized in Table 1 on the basis of sales data for the 1200 station for the entire 2014 years.

Table 1. Analysis of variation in demand for the stations monitored by store

Distribution coefficient of variation CV for a station that monitored the level of stocks											
intervals	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	>1
number of stations	12	4	7	90	386	264	168	92	73	49	55

Source: own study based on data from the tested company

In view of the results distribution coefficient of variation does not make sense to carry out the analysis of XYZ, which seemingly could facilitate an approach to the problem of forecasting the future demand and supply planning at the same time. In order to ensure the required level of customer service, there is however, a need to use accurate information about the future value of demand for the product. Inadequate recognition of future demand, burdened with too a big mistake, since he can seriously reduce the efficiency of the supply to the station within the network. The consequence of this will be higher economic costs due to a shortage of the product, perform supply or a too high level of stocks.

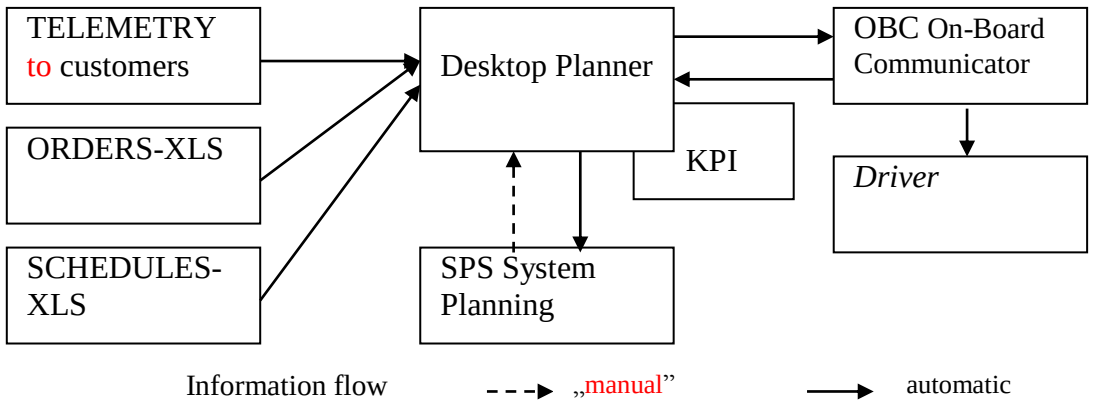
Data integration on the desktop planner

The problem of planning the supply of LPG to the filling station network in the concept of stocks controlled by the carrier regarding the task of network where the network is large and limited rolling stock. A desirable tool for effectively overcoming his daily work in the company transport ADR would be model support the decisions that would help solve complex decision problems for:

- determination of vehicle routes,
- delivery dates on individual stations,
- quantity of supplied LPG,
- with the bottling and how much gas download,
- how to separate drivers to operate vehicles, taking into account the constraints arising from the regulations on working time of drivers,
- how to solve problems arising from the disruptions in the planned service of use stations selling LPG.

Decision making under ideal conditions should be done in a rapid (time to propose a solution should not exceed several seconds), which guarantees a satisfactory solution (close to solving the optimal) and allows a high level of customer service (number of shortcomings stations should not exceed a few cases for all stations per month). At the same time the system should guarantee high economic efficiency calculated ratio of the number of kilometers traveled by a fleet of implementing supply LPG to the number provided on the stations of the product. An important functionality for users is the ability to clear visualization of status and the progress of running processes (routes, filling reservoirs and tanks, alarms and threats).
It is also worth mentioning the need to assess the economic efficiency of the distribution system. This assessment is based on a specifically defined performance indicators KPI (Key Performance Indicators), allowing to track the performance of the entire team performing transport services (planners, coordinators and drivers).
In order to build an effective model for managing the distribution of LPG nationwide network of filling stations on the basis of integrated information VMI in the company which is the subject of research has been developed planning system called SPS.

Schematic diagram of the flows of information in the program is shown below:



2. Schematic flow of information in the program SPSS.

The main element of the system is an application called Desktop Planner (Fig. 2). It allows you to browse the integrated information - such as inventory levels at the stations and in tanks, volumes on the gas terminals planned delivery times and so on.

The program also allows for automatic or semi-automatic creation of paths of distribution for individual vehicles as well as track the status of implementation of individual plans.

All data (both plans as their performance) are stored in a database system, SPS, and can be used in the future to optimize routes using more advanced algorithms.

3. Module planning

In the past few years, the author of this paper observed the results of cooperation of specialized transport company carrying out the services in the transport of hazardous materials (abbreviated - transport ADR) from clients which are in Poland and Europe's leading suppliers of cryogenic gases, LPG gas, liquid fuel and asphalt. In practice, they operate different models of cooperation - from simple transportation orders to the HMI (Haulier Managed Inventory) or a variant VMI of managing inventory by the carrier end customers. At a certain stage of cooperation one of the customers being a major supplier in the country of LPG, using the dominant partner, the company imposed a transport method VMI as a prerequisite to fulfill the implementation of the trade agreement.

In practice noticeable is the significant increase in the efficiency of the use of VMI mainly by reducing distribution costs. The effects can be seen in the optimization of supply processes, standardize communications, faster access to information, reduce the number of errors in the ordering process and as a result - increasing the level of customer service. This approach has become the subject of further research on the basis of information gathered in the selected company transport of dangerous goods by providing services for the distribution of LPG nationwide network of service stations and consumers of that network.

Summary and directions for further work

To complement the SPS in the further course of work will be developed and integrated two additional research tools: module simulation and forecasting module.

The module simulation is to allow in relation to isolated issues to compare the results obtained through computer experiment (based on average historical data on demand at a given time horizon - eg. 5 weeks) with results that actually occur in practice. You can expect to obtain in this way information on when and how many stations you experience gaps, etc.

The authors of most of the work (eg. Coelho et al. [7]) averaged usually demand based on historical data and calculate the average daily sales. On this basis are created algorithms, which aim is to calculate demand forecasts for each region for each day of the week.

One of the tasks will be to demonstrate the effects of such an approach (states stations, shortages, efficiency of the distribution system is calculated, eg. As the number of kilometers driven on average vehicle on the handing over of 1 t of product, the average size of deliveries, etc.), And compare them with the results achieved in practice.

In the next phase, using additional module predictive simulations they will be carried out as above but using the pattern of demand (eg. A week), which will allow for comparison of results with results obtained previously and practice.

n the next step, you can also consider using the method of distribution resource planning (DRP - Distribution Resource Planning), which would allow a reduction of resources (including the number of vehicles) dedicated to serve a client. A separate issue, however, remains to maintain the proper balance between building a lean and agile distribution system (leagle supply chain) constituting a hybrid combining two strategies seemingly contradictory - lean (the examination is great in terms of stable demand and the long reaction time) and agile (large fluctuations in demand and short reaction time) [6].

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