SUPPLY CHAIN MANAGEMENT OF RETAIL FOOD CHAIN BETWEEN WAREHOUSES AND STORES: A CASE STUDY

Jan Chocholáč – Tomáš Kučera – Dana Sommerauerová

Abstract

Supply chain management of the retail food chain is very unique, because network of the retail food chain is huge and there are many constraints for distribution of goods, for example time window of central warehouses and stores, distribution of perishable goods, more deliveries within the same day or distribution of objects of reverse logistics from stores to central warehouses. A lot of companies are using planning tools based on the subjective opinion now. This procedure is not enough effective. Article describes a diagram of the flows between stores and suppliers of one retail food chain in the Czech Republic which has almost 350 stores. All constraints which are connected with this issue and within the case study will the article present on the part of the distribution network of the retail food chain by the possibility of using selected algorithm of the graph theory – Vehicle Routing Problem with Time Windows.

Key words: supply chain management, retail food chain, distribution, graph theory, vehicle routing problem with time windows

JEL Code: L81, M21

Introduction

Issue of supply chain management of retail food chain is very current, because in the Czech Republic exist some retail food chains and their popularity with customers is steadily rising. Retail food chains are becoming increasingly popular in comparison with small shops and they are turning to high turnovers and profits. It is also caused by extensive sales network, which retail food chains have.

Nowadays customers want fresh products in the best possible quality at a reasonable price, although the most attention is paid to perishable goods (with a shelf life of less 24 hours from delivery to the store). These factors influence producers and retail food chains and they have increased demands on distribution of products to the stores from central warehouses.

Research question of this article is focused on distribution planning tools in the supply chain management of retail food chain between central warehouses and stores. Case study deals with retail food chain which has the most stores in the Czech Republic. This retail food chain specializes in sales of food and non-food products.

1 Theoretical background of the food supply chain management

Companies are under serious threat to sustain their existing supply chain due to globalization, challenging market, demand uncertainty, changing customer buying behaviour and recent economic competitiveness. Simply focusing on internal efficiencies and processes of supply chain will not be sufficient enough for any organization to gain an advantageous position in the market, especially for the retail food chains (Ansari and Kant, 2016).

Asgari, Nikbakhsh, Hill and Farahani (2016) defined supply chain management as the management of activities which maximize customer value and achieve a sustainable competitive advantage for companies, but on the other hand companies should reach suitable sales and profit. Supply chain activities cover everything from product design and development; sourcing of raw materials, materials, components; production and logistics of semi-finished and finished products, as well as the information systems needed to coordinate these activities (Vorst, 2000). Author defined supply chain management as integrated planning, coordination and control of all materials and information flows flowing through the chain with the aim of satisfy the next customer with the lowest costs and fulfil requirements of all stakeholders.

Nowadays authors, for example Liu, Bai, Liu and Wei (2017), emphasis concept of sustainable supply chain management, which is based on the triple bottom line, which consists of economic bottom line, environmental bottom line and social bottom line. Authors stated that supply chain management has also shifted from a reverse or close-loop supply chain to a green supply chain or sustainable supply chain management based on triple bottom line.

Cimler and Zadražilová (2007) defined retail food chains as places where takes place the purchase and sale of goods to the direct consumer, unlike wholesalers, where the purchase and sale of goods is realized for the purpose of selling it to other business. Authors add to the definition that retail food chains specialize in food products, but nowadays they also sell non-food products. Entrup (2005) confirmed the growing popularity of retail food chains in Germany with customers, where five main retail food chains realized in 2015 over 63% of total retail turnover. It was 18% more than in 1995.

Trienekens and Omta (2002) and Entrup (2005) defined four basic aspects affecting food supply chain management, there are: economic aspects, technological aspects, environmental aspects and socio-legislative aspects. Authors included among the economic aspects: reducing costs and margins for whole members of food supply chain; reducing prices of food products, because prices of food products are in West Europe very low; pooling of primary producers to associations, because of the greater degree of the competitiveness; internationalization of enterprises; creating private labels of food retail chains; growing popularity of food retail chains among customers; use of outsourcing for some logistics activities (transportation, inventory management, labelling, marketing activities etc.).

Wezel (2001) and Entrup (2005) also described process of shortening the delivery time between suppliers, central warehouses and stores (Tab. 1). Delivery time from the suppliers to the central warehouses and from the central warehouses to the stores is constantly shortening. Delivery time from the suppliers decreased by a quarter and authors suppose further shortening by one quarter. The process of distribution goods between central warehouses and stores has also a relatively fundamental development, when the delivery time was almost reduced by one third of the original time, and the delivery time is between 18 and 4 hours. Total delivery time from suppliers to the stores was decreased from the range between 168 – 84 hours to the range 30 – 8 hours.

Tab. 1: Comparison of the delivery time between suppliers – central warehouses – stores

Period	**Suppliers – central warehouses**	**Central warehouses – stores**	**Total delivery time**
Past	120 – 48 hours	48 – 36 hours	168 – 84 hours
Present	48 – 24 hours	18 – 12 hours	66 – 36 hours
Future	12 – 4 hours	18 – 4 hours	30 – 8 hours

Source: Entrup (2005), Wezel (2001)

Entrup (2005) emphasized use of some logistics technologies, for example: Efficient Consumer Response, Collaborative Planning, Forecasting and Replenishment, Vendor Managed Inventory, Electronic Data Interchange, Radio Frequency Identification etc. Nowadays customers like to use e-business (e-commerce and m-commerce) which is closely linked with requirements for distribution of goods and setup of whole food supply chain management of retail food chains. These aspects author classified to the technological aspects.

Environmental aspects are nowadays much discussed topic and companies in the food industry try to focus on them. Author emphasizes the much greater interest of the public in their own health, environment, animal safety and protection, which affects all areas of business, especially in the food industry and whole food supply chain. The majority of participants in the food supply chain is applying Quality Assurance Systems to quality and safety standards, which are very often made up of the following pillars: Good Manufacturing Practice, Good Hygienic Practice, Hazard Analysis and Critical Control Point, Standards ISO 9000, International Food Standards etc. (Entrup, 2005).

Socio-legislative aspects, according to Meulenberg and Viaene (1998), consist of: greater differentiation of customer requirements and wishes, companies strive for product differentiation and other innovation, different forms of product promotion and greater emphasis on fresh products, demographical changes and population aging generally, decreasing of the average household size and growing demand for exotic food, fresh products and perishable goods.

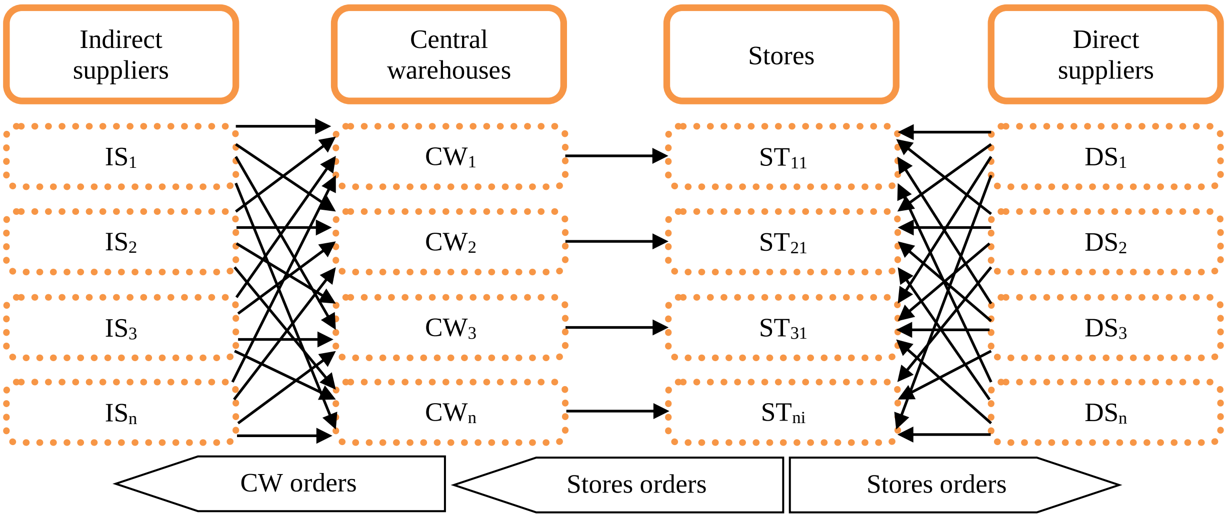
These aspects which affecting food supply chain management and retail food chains are closely related with the increasing distribution requirements. Customers want fresh products every day and every hour in the whole network of stores on the other hand retail food chains try to ensure these logistics activities with the lowest cost and maximal customer service.

2 Methods and data

Article analyses supply chain management of selected retail food chain in the Czech Republic, which has the most stores, between central warehouses and stores. The analysis is based on the semi-structured interviews with employees of the central warehouses. This retail food chain specializes in sales of food and non-food products. Article is focused on used planning tools for food supply chain management between central warehouses and stores; flows which flow between these chains and constraints or limitations of these processes.

Food supply chain divides suppliers to the two groups. The first group is formed by indirect suppliers ($IS_1...IS_n$) who supply products to the central warehouses ($CW_1...CW_n$) based on the orders of central warehouses. The goods are subsequently supplied to the stores based on the orders of stores or based on the decision of the Controlling Department (especially stocks for frontloading during a marketing promotion). The second group of suppliers is formed by direct suppliers ($DS_1...DS_n$) who supply products (especially pastry, beer and some regional products) directly to the stores based on the orders of stores (Fig. 1).

Fig. 1: Supply chain between indirect and direct suppliers – central warehouses – stores



Source: authors

Supply chain management of the retail food chain is very unique, because central warehouses need to distribute products based on the orders of the stores, but on the other hand it is desirable and important to collect some objects of reverse logistics return to the central warehouses (empty transport units, claimed goods, non-selling goods etc.). Nowadays, based on the semi-structured interviews, this retail food chain does not use any distribution planning tool. Employees are managed by own subjective opinion and historical plans and routes. This system of supply chain management causes errors, is ineffective and increases costs.

Supply chain management of retail food chain between central warehouses and stores has many constraints, there are: ND_{ni} number of deliveries within the day (it depends on turnover of the store), prioritization of goods for distribution to the stores (priority has fruits and vegetables and flowers – $NPFV_{ni}$; frozen products – $NPFP_{ni}$; chilled products – $NPCP_{ni}$; dry groceries – beverages, non-food products etc. – $NPDG_{ni}$), NP_{ni} number of pallet locations for each store (total number of palletized locations pick up), NP_{kni} time window of unloading at the store for different types of goods (most stores have two time windows, the first time window is for fruits and vegetables, flowers, frozen products, chilled products and the second time window is for other assortment), transport distance, driving time, TLU_{ni} average time of loading and unloading (it depends on the number of pallet locations and number of reverse logistics objects) and limited car fleet (number of vehicles, drivers and the size of the loading area). This case study was processed for six selected stores ($ST_{11\text{-}16}$) of one central warehouse (CW_1) of retail food chain (Tab. 2), which has the most stores in the Czech Republic, but emphasis is placed only on supply chain between warehouse and stores. Currently this retail food chain does not use any distribution planning tool and employees are managed by own subjective opinion and historical plans and routes.

Tab. 2: Selected stores of one central warehouse and its constraints

ST_{1i}	ND_{1i}	NP_{1i}	$NPFV_{1i}$	$NPFP_{1i}$	$NPCP_{1i}$	$NPDG_{1i}$	$NP1_{ni}$	$NP2_{ni}$	TLU_{ni}
ST_{11}	1	12	2	2	2	6	05:30 – 06:30	--- --- ---	30 minutes
ST_{12}	2	26	5	3	4	14	04:00 – 04:30	13:00 – 20:00	45 minutes
ST_{13}	2	23	4	4	3	12	04:30 – 05:30	12:00 – 18:00	40 minutes
ST_{14}	2	18	3	2	3	10	04:30 – 05:30	12:00 – 18:00	40 minutes
ST_{15}	1	11	3	2	1	5	06:00 – 07:00	--- --- ---	30 minutes
ST_{16}	2	17	3	2	3	9	05:00 – 05:30	14:00 – 20:00	40 minutes

Source: authors

Some constraints or limitations for each analysed store are defined in Tab. 2. Four stores are supplied twice a day ($ST_{12,13,14,16}$) and two stores are supplied only once a day ($ST_{11,15}$). For the analysis was selected average day from the perspective of number of pallet locations for each store and other parameters. Prioritization of goods for distribution to the stores and for loading is following: 1. fruits and vegetables and flowers – $NPFV_{ni}$; 2. frozen products – $NPFP_{ni}$; 3. chilled products – $NPCP_{ni}$; 4. dry groceries – beverages, non-food products etc. – $NPDG_{ni}$), but time windows of unloading at the stores must be strictly respected. Origin-Destination (OD) matrix of each analysed stores (ST_{11-16}) and central warehouse (CW_1) is in Tab. 3. This OD matrix is divided into two matrixes, matrix on the left represents transport distance (km) and the matrix on the right represents driving time (min).

Tab. 3: Origin-Destination matrix of the stores (ST_{11-16}) and central warehouse (CW_1)

Km	ST_{11}	ST_{12}	ST_{13}	ST_{14}	ST_{15}	ST_{16}	CW_1	**Time**	ST_{11}	ST_{12}	ST_{13}	ST_{14}	ST_{15}	ST_{16}	CW_1
ST_{11}	X	16	39	37	36	13	75	ST_{11}	X	18	48	46	42	18	52
ST_{12}	16	X	24	22	20	13	91	ST_{12}	18	X	31	30	27	23	66
ST_{13}	39	24	X	5	19	28	112	ST_{13}	48	31	X	5	27	38	94
ST_{14}	37	22	5	X	23	33	118	ST_{14}	46	30	5	X	32	42	99
ST_{15}	36	20	19	23	X	32	110	ST_{15}	42	27	27	32	X	50	90
ST_{16}	13	13	28	33	32	X	85	ST_{16}	18	23	38	42	50	X	65
CW_1	75	91	112	118	110	85	X	CW_1	52	66	94	99	90	65	X

Source: authors

The aim of this case study is to find an effective and optimal solution for this type of exercise with usage of adequate planning tools that will be respected all defined constraints. This type of exercise is named Vehicle Routing Problem with Time Windows and it belongs to the graph theory. This task and different variations of this task were dealt by many authors, for example Braaten, Gjonnes, Hvattum and Tirado (2017) who were focused on the heuristics for the robust vehicle routing problem with time windows; Lau, Sim and Teo (2003) who examined algorithm with limited number of vehicles; Miranda and Conceicao (2016) who analysed vehicle routing problem with hard time windows and stochastic travel and service time; Güner, Murat and Chinnam (2017) who solved dynamic routing problem for milk-run tours with time windows in stochastic time-dependent networks.

Algorithm of heuristic method for vehicle routing problem with time windows according to Tan, Lee, Zhu and Ou (2001) uses these variables: t_i (arrival time at node i), w_i (wait time at node i), K (total number of vehicles), N (total number of customers), d_{ij} (distance between node i and node j), c_{ij} (cost incurred on arc from node i to j), t_{ij} (travel time between node i and j), m_i (demand at node i), q_k (capacity of vehicle k), e_i (earliest arrival time at node i), l_i (latest arrival time at node i), f_i (service time at node i), r_k (maximum route time allowed for vehicle k). Authors defined formula (1) as the objective function of the problem, relation (1) specifies there are maximum K routes going out of the central warehouse and relation (2) makes sure every route starts and ends at the central warehouse. Relations (2, 3) define that every customer node can be visited only once by one vehicle. Relations (3, 4) are constraints and relations (4-5) define time windows.

$$Minimise \sum_{i=0}^{N} \sum\nolimits_{j=0,\, j\neq i}^{N} \sum_{k=1}^{K} c_{ij} x_{ijk} \;\; subject\ to: \sum_{k=1}^{K} \sum_{j=1}^{N} x_{ijk} \leq K \;\; for \;\; i=0 \qquad (1)$$

$$\sum_{j=1}^{N} x_{ijk} = \sum_{j=1}^{N} x_{ijk} \leq 1 \;\; for \;\; i=0 \;\; and \;\; K \in \{1,\ldots,K\};\; \sum_{k=1}^{K} \sum_{j=0,\, j\neq i}^{N} x_{ijk} = 1 \;\; for \;\; i \in \{1,\ldots,N\} \qquad (2)$$

$$\sum_{k=1}^{K} \sum_{i=0,\, i\neq j}^{N} x_{ijk} = 1 \;\; for \;\; j \in \{1,\ldots,N\};\; \sum_{i=1}^{N} m_i \sum_{j=0,\, j\neq i}^{N} x_{ijk} \leq q_k \;\; for \;\; k \in \{1,\ldots,K\} \qquad (3)$$

$$\sum_{i=0}^{N} \sum_{j=0,\, j\neq i}^{N} x_{ijk} \left(t_{ij} + f_i + w_i\right) \leq r_k \;\; for \;\; k \in \{1,\ldots,K\};\; t_0 = w_0 = f_0 = 0 \qquad (4)$$

$$\sum_{k=1}^{K} \sum_{i=0,\, i\neq j}^{N} x_{ijk} \left(t_i + t_{ij} + f_i + w_i\right) \leq t_j \;\; for \;\; j \in \{1,\ldots,N\};\; e_i \leq \left(t_i + w_i\right) \leq l_i \;\; for \;\; i \in \{1,\ldots,N\} \qquad (5)$$

3 Results

Case study was focused on the real situation of retail food supply chain between central warehouse (CW_1) and selected stores (ST_{11-16}). Tab. 4 presents results and optimal solution based on constraints defined in chapter 2 in accordance with the algorithm for vehicle routing problem with time windows which defined Tan, Lee, Zhu and Ou (2001).

Final loading plan for two vehicles (V_1, V_2), which respects prioritization of goods for distribution to the stores (fruits, vegetables and flowers have priority; frozen products and chilled products – number of pallet locations marked with the star), time windows of unloading at the stores, travel distance and travel time based on Origin-Destination matrix is in Tab. 4.

The first vehicle (V_1) will start in the central warehouse (CW_1), where storekeeper will load some transport units (33 pallet locations). Then (V_1) will distribute goods to the stores (ST_{12} – 04:00 – 04:30), (ST_{16} – 05:00 – 05:30) and (ST_{11} – 05:30 – 06:30). Then (V_1) will go back to the (CW_1) with some objects of reverse logistics from the stores. The second vehicle (V_2) will start in the central warehouse (CW_1) too, where storekeeper will load some transport units (33 pallet locations). Then (V_2) will distribute goods to the stores (ST_{13} – 04:30 – 05:30), (ST_{14} – 04:30 – 05:30) and (ST_{15} – 06:00 – 07:00).

Tab. 4: Final distribution plan and loading plan for two vehicles (V_1, V_2)

V_i	Route	ST_{11}	ST_{12}	ST_{13}	ST_{14}	ST_{15}	ST_{16}
V_1	$CW_1 – ST_{12} – ST_{16} – ST_{11} – CW_1$	12/6*	12/12*	---	---	---	9/8*
V_2	$CW_1 – ST_{13} – ST_{14} – ST_{15} – CW_1$	---	---	11/11*	11/8*	11/6*	---
V_1	$CW_1 – ST_{12} – ST_{16} – CW_1$	---	14	---	---	---	8
V_2	$CW_1 – ST_{13} – ST_{14} – CW_1$	---	---	12	7	---	---

Source: authors

Conclusion

The supply chain management of the food retail chain is unique and popular topic because there are some food chains in the Czech Republic and their popularity with customers is growing. Article described the diagram of the flows between stores and suppliers of one retail food chain in the Czech Republic. Case study in this article was processed for six selected stores of one central warehouse of retail food chain. The aim of this article was to find an effective and optimal solution for this type of exercise, which is called Vehicle Routing Problem with Time Windows and it belongs to the graph theory. Further research could be focused on reverse logistics flows of retail food chains too. All stores produce some objects of reverse logistics, for example empty transport units, claimed goods, goods withdrawn from sales etc., which are important to transport from stores to central warehouses. This exercise is more complicated, because it is for simultaneous loading and unloading.

Acknowledgment

This article is published within the solution of project no. SGS_2017_009 „Traffic Engineering, Technology and Management".

References

Asgari, N., Nikbakhsh, E., Hill, A., & Farahani, R. Z. (2016). Supply chain management 1982-2015: a review. *Ima Journal of Management Mathematics*, 27(3), 353-379. doi:10.1093/imaman/dpw004

Braaten, S., Gjonnes, O., Hvattum, L. M., & Tirado, G. (2017). Heuristics for the robust vehicle routing problem with time windows. *Expert systems with applications*, 77, 136-147. doi:10.1016/j.eswa.2017.01.038

Cimler, P., & Zadražilová, D. (2007). *Retail management*. Praha: Management Press.

Entrup, M. L. (2005). *Advanced planning in fresh food industries: integrating shelf life into production planning.* Heidelberg: Physica-Verlag.

Guner, A. R., Murat, A., & Chinnam, R. B. (2017). Dynamic routing for milk-run tours with time windows in stochastic time-dependent networks. *Transportation Research Part E-logistics and Transportation Review*, 97, 251-267. doi:10.1016/j.tre.2016.10.014

Kant, S., & Ansari, I. A. (2016). An improved K means clustering with Atkinson index to classify liver patient dataset. *International Journal of System Assurance Engineering and Management*, 7(1), 222-228. doi:10.1007/s13198-015-0365-3

Lau, H., Sim, M., & Teo, K. (2003). Vehicle routing problem with time windows and a limited number of vehicles. *European Journal of Operational Research*, 148(3), 559-569. doi:10.1016/S0377-2217(02)00363-6

Liu, W., Bai, E., Liu, L., & Wei, W. (2017). A Framework of Sustainable Service Supply Chain Management: A Literature Review and Research Agenda. *Sustainability*, 9(3). doi:10.3390/su9030421

Meulenberg, M., & Viaene, J. (2005). *Innovation in agri-food systems: product quality and consumer acceptance.* Wageningen: Wageningen Academic.

Miranda, D. M., & Conceição, S. V. (2016). The vehicle routing problem with hard time windows and stochastic travel and service time. *Expert Systems With Applications*, 64, 104-116. doi:10.1016/j.eswa.2016.07.022

Tan, K., Lee, L., Zhu, Q., & Ou, K. (2001). Heuristic methods for vehicle routing problem with time windows. *Artificial Intelligence in Engineering*, 15(3), 281-295. doi:10.1016/S0954-1810(01)00005-X

Trienekens, J. H., & Omta, S. W. (2002). *Paradoxes in food chains and networks: proceedings of the fifth international conference on chain and network management in agribusiness and the food industry*. Wageningen Academic.

Vorst, J. G. A. J. van der. (2000). *Effective food supply chains: generating, modelling and evaluating supply chain scenarios*. Wageningen: Wageningen University.

Wezel, W. V. (2001). *Tasks, hierarchies, and flexibility: planning in food processing industries*. Capelle a/d IJssel: Labyrint Publication.

Contact

Jan Chocholáč
University of Pardubice, Faculty of Transport Engineering, Department of Transport Management, Marketing and Logistics
Studentská 95, Pardubice 2 532 10
jan.chocholac@upce.cz

Tomáš Kučera
University of Pardubice, Faculty of Transport Engineering, Department of Transport Management, Marketing and Logistics
Studentská 95, Pardubice 2 532 10
tomas.kucera@student.upce.cz

Dana Sommerauerová
University of Pardubice, Faculty of Transport Engineering, Department of Transport Management, Marketing and Logistics
Studentská 95, Pardubice 2 532 10
dana.sommerauerova@student.upce.cz