İPƏK YOLU, No.3, 2019, səh.60-71

FACILITY LOCATION ALLOCATION PROBLEM

Umid Mehdiyev

Azerbaijan State Pedagogical University, Baku, Azerbaijan
e-mail: mehdiyevu@gmail.com

Abstract. In this paper, the problems and models of Supply Chain Management is analyzed. The main focus is concentrated on facility location allocation problem. A generic model for solution is presented, then certain sector (manufacturing) is presented. Some improvements are suggested to the generic model taking into account the assumptions and conditions of this sector. In the final the alternative method is described, in order to expand and recommend to use more appropriate methodologies and tools for solving the SCM problems.

Keywords: supply chain management, facility location allocation problem, network location problem, strategic level, tactical level, operational level.

OBYEKTİN YERİNİN MÜƏYYƏNLƏŞDİRİLMƏSİ PROBLEMİ

Ümid Mehdiyev
Azərbaycan Dövlət Pedaqoji Universiteti, Bakı, Azərbaycan

Xülasə. Məqalədə Təchizat Zəncirinin İdarə edilməsi problemləri və modelləri təhlil edilir. Əsas diqqət obyektin yerinin müəyyənləşdirilməsi probleminə yönəldilmişdir. Baxılan məsələnin həll üçün ümumi model təqdim edilir, sonra müəyyən bir sektora (istehsal) baxılır və bu sektorun şərtləri nəzərə alınmaqla ümumi modelin təkmilləşdirilməsi üsulları təklif edilir. Sonda, Təchizat Zəncirinin İdarə edilməsi problemlərinin həlli üçün daha uyğun metodologiya və vasitələrinin istifadəsi üçün alternativ metod təklif edilmişdir.
Açar sözlər: tədarük zəncirinin idarə edilməsi, obyektin yerləşmə problemi, şəbəkənin yerləşmə problemi, strateji səviyyə, taktiki səviyyə, əməliyyat səviyyəsi.

ПРОБЛЕМА РАСПРЕДЕЛЕНИЯ МЕСТОПОЛОЖЕНИЯ ОБЪЕКТА

Умид Мехтиев
Азербайджанский Государственный Педагогический Университет, Баку, Азербайджан

Резюме. В статье проанализированы проблемы и модели управления цепями поставок (УЦП). Основное внимание уделяется проблеме распределения местоположения объекта. Представлена общая модель для решения рассмотренной задачи, после чего был представлен определенный сектор (производство), и с учетом допущений и условий этого сектора были предложены некоторые улучшения в общую модель. В конце предложена более подходящая методология и альтернативный метод использования проблемы управления цепочками поставок.
Ключевые слова: управление цепочкой поставок, проблема размещения объектов, проблема размещения сетей, стратегический уровень, тактический уровень, операционный уровень.

1. Introduction

Supply chain and logistics management deal with “the design and management of productive systems as well as with the planning and control of daily business operations within a company or in transcorporate networks” [13]. For huge companies which operate in the worldwide scales , which have a large variety of products and demand points, which supported by the many production plants distributions centers and retailers, the process of configuring and organizing the network of logistic distribution is very vital and has enormous affect on the companies' performance. For logistic managers the development of effective methods and tools in order to sustain and make more effective the strategic, tactical and operational decisions, is one of the most challenging issues. The proper decisions based on integrated supporting models, tools and methods could help to achieve very distinctive competitive advantage [19].

2. Problems definition

As it was mentioned by Manzini and Gebenini (2008) there are adopted the following two main classification classes of quantitative methods of location problems in logistics [21]:

Facility location allocation problem (LAP). LAP is a challenge for any organization, because it should be decided where locate a set of new facilities in order to compose the flow between new and existing facilities. So the LAP is a multiple problem where is unknown allocation of demand to the available facilities (counted also as sub-problem of allocation). The best amount of new facilities could also be the part of the LAP, in this case the cost of building new facility could be equalized by the decreased transportation expenses and logistics process' improvement. Actually, the number of new facilities could be unknown or known. Determining the optimal location for the new facilities and the optimal allocation of requirements of existing facilities in order to meet all requirements is an essential part of problem.

Network location problem (NLP). This classification of problem is similar to the facility LAP. Nevertheless, instead of approximate determining of the transport network with the assist of a planar multi-facility location based approach (which includes time, distance and cost between new and existing facilities), the network model is involved directly to LAP decisions and requires accurate configuring and constructing. At the same time this problem helps to choose specific ways from different nodes in the accessible network.

Advanced extension of LAP and NLP. There are several problems which are included as the extension to the previous problems and were presented by Sule (2001) [25]. The tours development problem was presented by Jalisi and Cheddad (2000) [26], the vehicle routing problem (VRP, this problem also includes the sub-problems such as travelling salesman problem and the truck routing problem) by Baldacci and Mingozzi (2009), and the multi-period dynamic facility location problem [3]. These extensions efficiently support the operational planning of a logistic network in a supply chain system whereas the context of multi-period operating where the products' demand is varies in different time periods. By operational configuration it is possible to find answer on three important questions. Firstly, what is the most suitable place to locate new facilities. Secondly, what is appropriate capacity to assign the facility. And thirdly, when with taking in account specific location, which periods of time demand, needs the definite amount of production capacity.

Problem focus and models. Facility location allocation problem is one of the most important challenges in SCM. In particular LAP problem in logistics system can be described as the taking the synchronous decisions about design, management and control of a distribution network.

There are nearly 120 articles classified by Melo et al. about the discrete FL and SCM, which are published between 1997 and 2008 [22]. Klose and Drexl (2005) separated the models of the facility location as follow [15]:

- Continuous location models, where the solution space is continuous and the generic distance is measured with a suitable metric.
- Network location models (or p-median model): p facilities have to be located on a graph minimizing an objective cost function.
- Mixed integer programming models: given a set of potential facilities the best one are chosen. Discrete facility location models can be: single- vs. multi- stage models; uncapacitated vs. capacitated models; single- vs. multi- period; multiple- vs. single-sourcing; single- vs. multi- product models; with and without routing options.

There are several models and approaches presented by different researchers to define location of facilities and allocation of demand points simultaneously. Love et al. (1988) and Sule (2001) presented basic models for the facilities LAP. Especially Love et al. (1988) made research and defined the following site-selection LAP models: set-covering (and set-partitioning models); single-stage, single-commodity distribution model; and two-stage, multi-commodity distribution model which deals with the design for supply chains composed of production plants, distribution centers, and customers [17]. Amiri (2006) presented mixed integer linear models for the single-commodity single-period LAP, Manzini and Gebennini (2008) for the 2stage single-commodity multi-period LAP, by Gebennini et al. (2009) for the 2-stage single-commodity multi-period LAP with safety stock optimization, by Manzini and Bindi (2009) for the 3-stage single-commodity multi-period LAP [1]. Many researchers such as Canel et al. (2001), Gen and Syarif (2005), Mahar et al. (2009) suggested algorithms to solve the dynamic location problems but neither focuses on nor applies the models to real logistic networks, whose complication easily compromises the effectiveness of the suggested solving approaches [5,10,18].

Shen (2005) differentiate three levels of decisions in SCM: the strategic, tactical and operational levels [24].

In the base of the facility location allocation problems' solution also lay strategic decisions as it obvious from Figure 1, and in this case should be taken into account some qualitative and quantitative performance metrics such as environmental factors, labor, access to suppliers, access to market, government access, what means that these solutions should be aligned with the strategy of organization, because these decisions are taken for long term as it was mentioned by Beltran (2010) [4]. Furthermore, in many cases there is huge amount of data which is not always suit to the format requirements of the optimization model. The reason why facility allocation is very important, it is because it has consequently influence on the operations, and the main reason is that location decision is belongs to the strategic decisions scope that are irreversible in nature that was described by Javid and Azad (2010) [14].

According to Correia (2010), specifically, the location choice for a manufacturing facility may have a significant impact on the company's strategic competitive position in terms of operating cost, service level, delivery speed performance and firm's flexibility to compete in the marketplace [7].

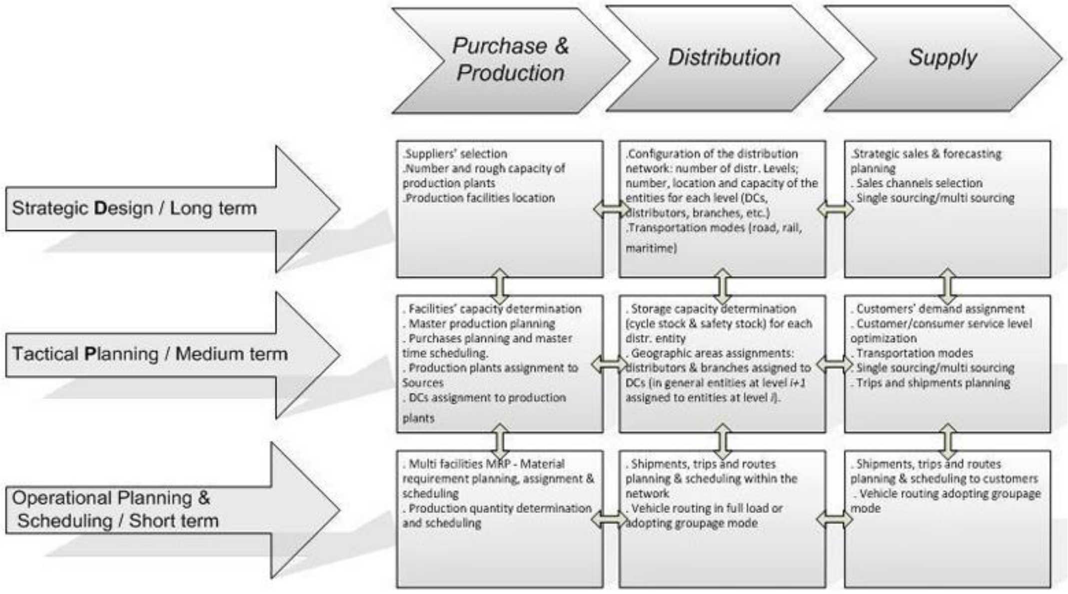

Figure 1. Issues and decisions in distribution network planning and optimization (Manzani and Bindi, 2009)

3. Problem solution and optimization

Manzini and Bindi (2009) emphasized that for solving the LAP there has been developed the mixed integer linear model for the strategic level planning.The model presented on Figure 2 is a 3-stage multi-product and single-period model. It supposes multiple transportation modes and quantifies a lot of logistic costs [19].

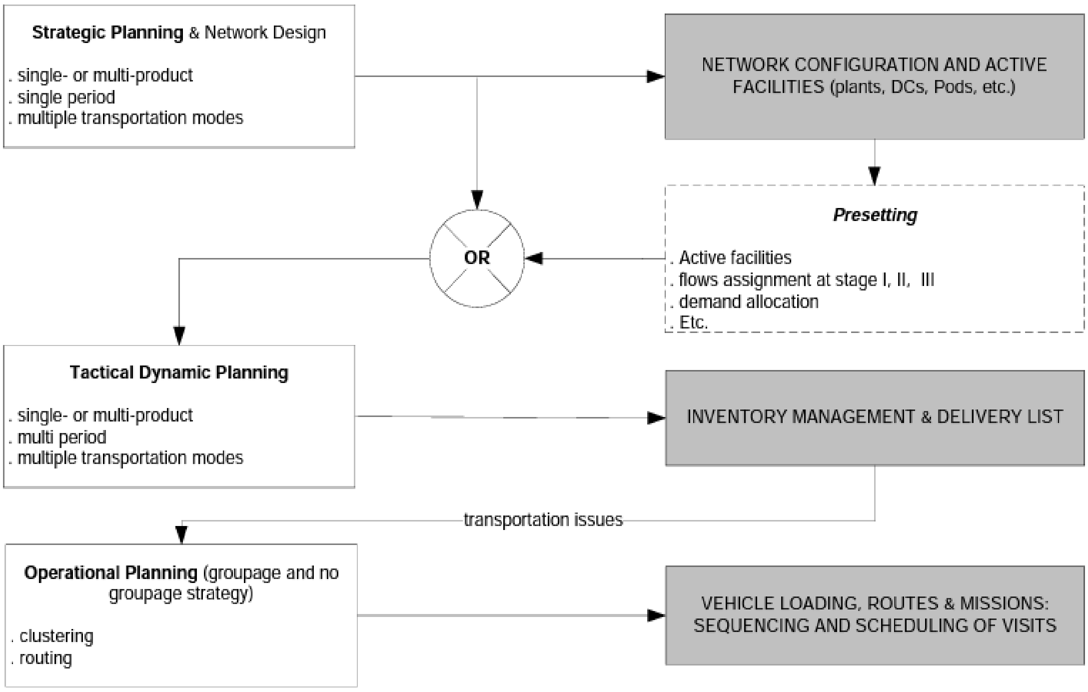

Figure 2. Conceptual framework for an integrated planning

The first researchers who solved a large-scale real problem with using Benders decomposition for 17 products' groups, 14 factories, 45 DCs and 121 customers regions were Geoffrion and Graves (1974)[11]. This Bender's decomposition method was very appropriate approach for operating of large mathematical programming problems with sophisticated variables and structures [12]. The objective function of the optimization problem is defined as:

$$\textbf{\textit{Ctot}} = \sum_{j=1}^{n} f_j^z * y_j + \sum_{h=1}^{p} f_h^{CDC} * y_h + \sum_{k=1}^{q} f_k^{RDC} * y_k + \sum_{h=1}^{p}\sum_{j=1}^{n}\sum_{a=1}^{b} c_{jha}^r * x_{jha} + \sum_{k=1}^{q}\sum_{h=1}^{p}\sum_{a=1}^{b} c_{hka}^s * x_{hka} + \sum_{i=1}^{m}\sum_{k=1}^{q} c_{ki}^t * x_{ki} + \sum_{h=1}^{p}\sum_{j=1}^{n}\sum_{a=1}^{b} v_j^i * x_{jha} + \sum_{k=1}^{q}\sum_{h=1}^{p}\sum_{a=1}^{b} v_h^{CDC} * x_{hka} + \sum_{i=1}^{m}\sum_{k=1}^{q} v_k^{RCD} * x_{ki} + \sum_{h=1}^{p}\sum_{j=1}^{n}\sum_{a=1}^{b} e_{jha}^r * \frac{x_{jha}}{g_a} + \sum_{k=1}^{q}\sum_{h=1}^{p}\sum_{a=1}^{b} e_{hka}^s * \frac{x_{hka}}{g_a} + \sum_{i=1}^{m}\sum_{k=1}^{q} e_{ki}^t * \frac{x_{ki}}{g_a}$$

The linear model is:

$$\min \{C_{tot}\} \quad (2)$$

$$\sum_{k=1}^{q} x_{ki} = d_i \qquad i = 1, \dots, m \quad (2.1)$$

$$\sum_{h=q}^{p}\sum_{a=1}^{b} x_{jha} \leq PC_h^z * y_j \qquad j = 1, \dots, n \quad (2.2)$$

$$\sum_{k=1}^{q}\sum_{a=1}^{b} x_{hka} \leq PC_h^{CDC} * y_h \qquad h = 1, \dots, p \quad (2.3)$$

$$\sum_{i=1}^{m} x_{ki} \leq PC_k^{RDC} * y_k \qquad k = 1, \dots, q \qquad (2.4)$$

$$\sum_{j=1}^{n}\sum_{a=1}^{b} x_{jha} \geq \sum_{k=1}^{q}\sum_{a=1}^{b} x_{hka} \qquad h = 1, \dots, p \qquad (2.5)$$

$$\sum_{h=1}^{p}\sum_{a=1}^{b} x_{hka} \geq \sum_{i=1}^{m} x_{ki} \qquad k = 1, \dots, q \qquad (2.6)$$

$$y_j, y_h, y_k \in \{0,1\}$$

$$x_{jha}, x_{hka}, x_{ki} \geq 0$$

where

$j \in (1, \dots, n)$ production plants allowed to be opened

$h \in (1, \dots, p)$ CDC central distribution centres allowed to be opened

$k \in (1, \dots, q)$ RDC regional distribution centres allowed to be opened

$i \in (1, \dots, m)$ points of demand

$a \in (1, \dots, b)$ transportation modes

d_i	demand from location *i*	[*load*]
g_a	number of loads per container on transportation mode *a*	[*load/container*]
PC_j^z	production/supply capacity of source plant *j*	[*load*]
PC_h^{CDC}	handling capacity for the generic *CDC*	[*load*]
PC_k^{RDC}	handling capacity for the generic *RDC*	[*load*]
f_j^z	fixed operating cost using source plant *j*	[*€*]
f_h^{CDC}	fixed operating cost using source CDC *h*	[*€*]
f_k^{RDC}	fixed operating cost using source RDC *k*	[*€*]
v_j^z	variable cost for source plant *j*	[*€/load*]
v_h^{CDC}	variable cost for the CDC *h*	[*€/load*]
v_k^{RDC}	variable cost for the RDC *k*	[*€/load*]
c_{jha}^r	transportation unit cost per load from the source *production plant j* to the CDC *h* by transportation mode *a*	[*€/load*]
c_{jha}^r	transportation unit cost per container from the source *production plant j* to the CDC *h* by transportation mode *a*	[*€/cont*]
c_{hka}^z	transportation unit cost per load from a CDC *h* to the RDC *k* by transportation mode *a*	[*€/load*]
c_{hka}^z	transportation unit cost per container from a CDC *h* to the RDC *k* by transportation mode *a*	[*€/cont*]
c_{ki}^t	transportation unit cost per load from a RDC *k* to the point of *demand i*	[*€/load*]
c_{ki}^t	transportation unit cost per container from a RDC *k* to the point of *demand i*	[*€/cont*]

The variables are:

y_j	1 if production plant *j* is used, 0 otherwise	[*boolean*]
x_{jha}	product quantity from the source plant *j* to the CDC *h* using transportation mode *a*	*integer*
y_h	1 if the CDC *h* is used, 0 otherwise	[*boolean*]
x_{hka}	product quantity from the CDC *h* to the RDC *k* using transportation mode *a*	*integer*
y_k	1 if the RDC *k* is used, 0 otherwise	[*boolean*]
x_{hka}	product quantity from the RDC *k* to the point of demand *i*	*integer*

As it was mentioned earlier the LAP decisions belongs to strategic decisions and regarded to long term planning horizon. Usually to make the decision in strategic planning field takes time approximately 1-3 years and more depends on target of management and industrial sector. It follows that demand at the points of demand (Pods) are the sum of the exact demand amounts on the whole planning period of time. Similarly the handling capacities and the production, and the quantity of demands are supposed to be measured in standard units.

Manufacturing sector (Steel Industry) assumptions

Conceição et al (2010) in his research regarding the steel industry in South America (manufacturing sector) pointed out some important factors, affecting on LAP problem solution, which must be taken into account. In order to solve facility LAP the following assumptions must accepted: (1) 100% of all demands must be satisfied, even the far regions with small demand. In this situation, the total logistics expenses are higher than revenues from the products' sales. Nevertheless, this strategy could be justified, because company trying to satisfy the needs of all customers without differentiation by distance; (2) demand and orders of large customers should be implemented directly from plant in order to minimize logistics costs; (3) the real demand must be counted only after shipping to customer, because there is option that order will be cancelled; (4) tax expenses have to be considered, even if it involves political decisions, because it belongs to expenses of opening new facility; (5) handling and storage capacity constraints are permitted not to be constant because the current DC could be expanded and in future could be established others with enough capacity; (6) the capacity of production remains stable, while any additional capacity would require long implementation time and high investments; (7) over the years distributors changed the ordering behavior and began to order more frequently in small amounts, than rarely and in big quantities, using a just in time approach [6].

On the Figure 3 is depicted the routes before the optimization and solving the facility LAP.

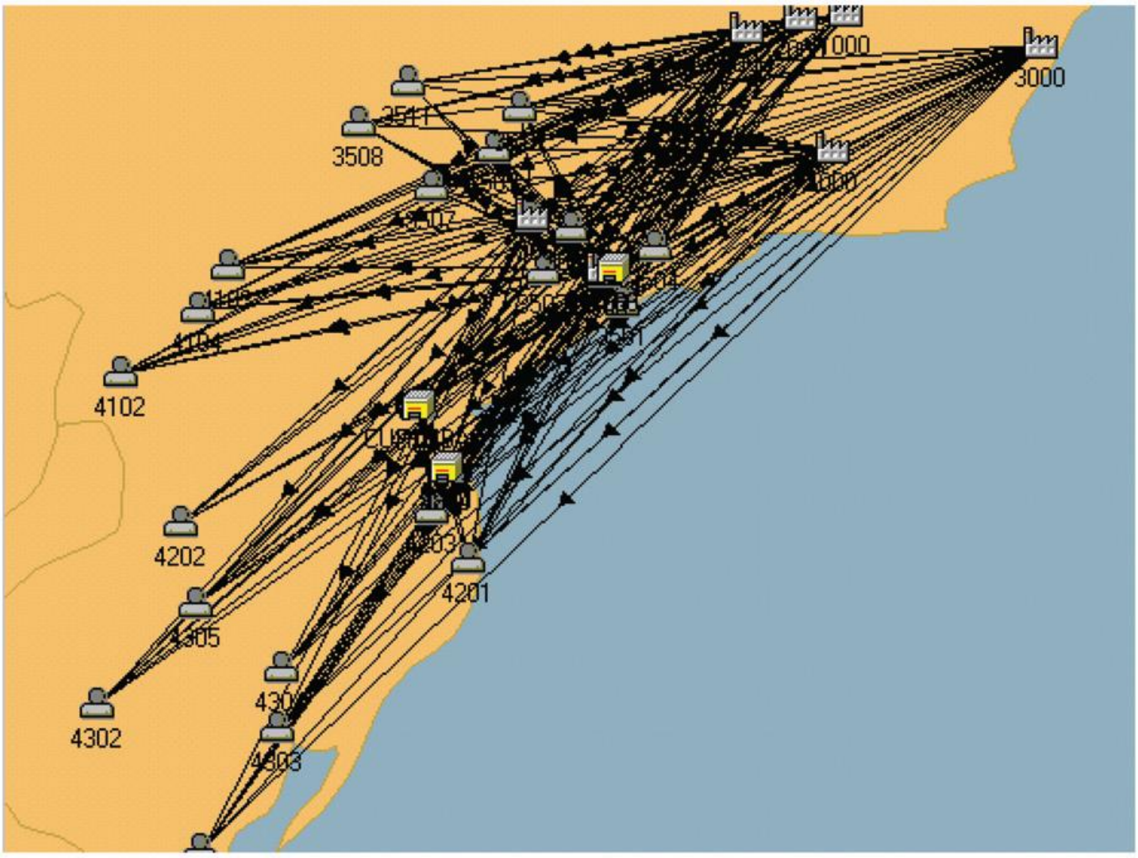

Figure 3. Transportation paths for potential and existing DCs from factory to customer groups in the South–Southwest region before optimization [6]

Conceição (2010) pointed out that there is a huge amount of data which required for the distribution planning model is dispersed in the distribution network. In manufacturing sector, especially when the topic is about steel industry with a broad base of customers and great consumption, it is very hard to gather all information and in this case very helpful was the usage by the steel manufacturing company the ERP system, which really simplified the task [6].

Sustainable development factors integration

In order to improve the generic optimization model from the economic and environmental objective, and taking into account assumptions of the steel industry, where transportation operations costs a lot and covered distance is huge, in the algorithm could be included instead of usual formulas of transportation costs the formulas presented by P.Dejax (2012) where were taken into account following costs to minimize from economic objective [8]:

-Transportation costs of fully loaded trucks and of additional pallets if the truck is incomplete (ZTt)

-Receiving costs (ZAt), including handling cost of pallets and administrative cost associated

to the trucks

- Inventory holding cost of pallets (ZSt)

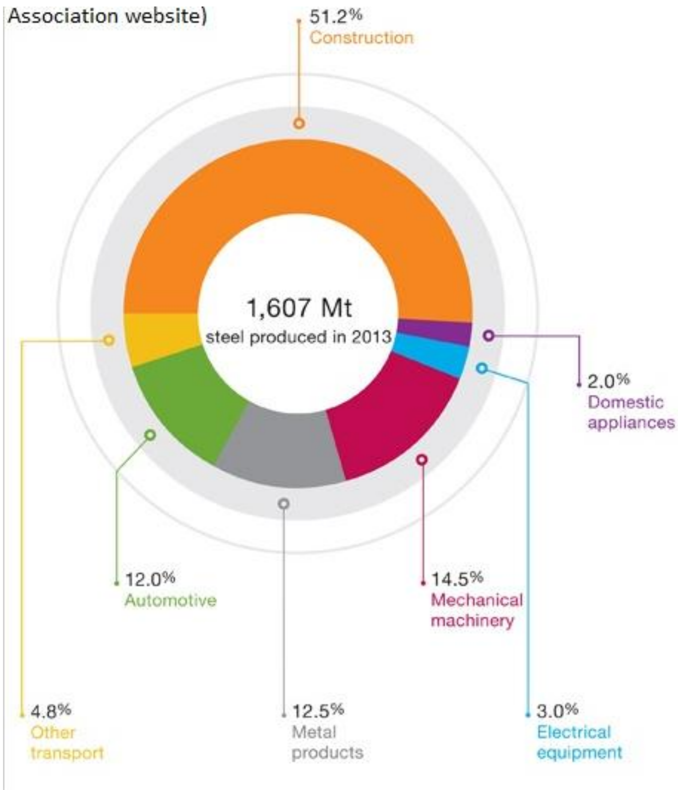

Figure 4. Steel usage in the world 2012 (extracted from Worldsteel Association website)

$$min\ \mathrm{F}_1 = \sum_{t \in T} ZT_t\, ZA_t ZS_t$$

with

$$ZT_t = \sum_{t \in I} CT_i^c * N_i^t + \sum_{t \in I_N} CP_i * R_i^t$$

$$ZA_t = \sum_{t \in I} \left[\sum_{p \in P} CE * A_{ip}^t + CF * (N_i^t + Y_i^t) \right]$$

$$ZS_t = \sum_{p \in P} CS_p \left(SM_p^t \right)$$

From environmental objective consists of minimizing the CO2 emissions quantity due to the transportation operations. The calculations have been made with the next assumptions: the vehicles are Heavy Duty Vehicles of 38 t, the average speed is 80 km/h, a road gradient of 0% is considered. The capacity of the trucks varies from 20 to 50 pallets depending on the product transported.

The formula to evaluate the CO_2 emissions is given by:

$$E_{g/km}(\alpha) = 772 + 324*\alpha$$

with α = loading rate (α∈ 0;1)

Taking into account the distance and load of the vehicle, we obtain the following formula:

$$\varepsilon(d,c,x) = d * \left(\frac{E_{full} - E_{empty}}{c}\right) * x + E_{empty} \left[\frac{x}{c}\right]$$

with *d*=distance, *c*=vehicle capacity, *x*=number of transported pallets and E_{full} = 1.096 kg/km; E_{empty} = 0.772 kg/km

In calculations supposed that trucks loaded fully or partially (0 or 1), finally could be obtained the next expression:

$$\text{Min } F_2 = \sum_{t\in T}\sum_{i\in I} DIST_i \left[e_v(N_i^t + Y_i^t) + (e_c - e_v) * \frac{\sum_{p\epsilon p_i} A_{ip}^t}{Pal_i}\right.$$

4. Alternative method

In the models above have been used optimization models based on quantitative methods in order to solve the facility location problem. However, these models are not universal and not always best way to solve the facility LAP, especially when we have substantial qualitative data to be considered. In this situation, the approach that could capture qualitative data in a best way is the analytic hierarchy process (AHP). By involving both quantitative and qualitative data this multi-criteria decision-making methodology could be applied to solve LAP. According to Saaty (1994) AHP is a decision-making tool that decomposing a complex problem into a multi-level hierarchical objectives' structure, criteria, sub-criteria and alternatives [23]. This method has been applied in solution of broad range problems in logistics, manufacturing and services. For example, Beltran et al. (2010) applied the AHP in order to find the appropriate location for the building of a municipal solid waste plant [4]. Badri (1999) has proposed a hybrid method combining the AHP and goal programming for global facility location-allocation problem [2].

Conclusion. To conclude, in this report the objectives were to show an approaches and tools for solving the facility LAP in logistics with sustainable development factors integration. Also in this report were emphasized the importance of solution this kind of problem, because the decision directly affects on the strategic contribution of the company on the market. For the steel industry as it was mentioned in report the facility LAP is a complicated challenge, because for this huge manufacturing exist a lot of conditions and assumptions that should be measured before making decision, and one the main parts in this case is to gather all data needed for successful decision, in order to make the response and operations of company very effective and with less errors and interruptions in supply chain as possible.

References

1. Amiri A., (2006), Designing a distribution network in a supply chain system: formulation and efficient solution procedure. European Journal of Operational Research, 171, 567-576.
2. Badri M., (1999), Combining the analytic hierarchy process and goal programming for global facility location allocation problem. International Journal of Production Economics, 62, 237–248.
3. Baldacci R, Mingozzi A., (2009), A unified exact method for solving different classes of vehicle routing problems. Mathematical Programming, 120(2), 347-380.
4. Beltran, P.A. et al., (2010), An analytic network process approach for siting a municipal solid waste plant in the metropolitan area of Valencia (Spain). Journal of Environmental Management, 91, 1071–1086.
5. Canel C., Khumawala B.M., Law J. and Loh A., (2001), An algorithm for the capacitated, multicommodity multi-period facility location problem. Computers and Operations Research, 28, 411-427.
6. Conceicao S.V., Pedrosa L.H.P., Neto A.S.C., M. Vinagre and Wolff E., (2010), The facility location problem in the steel industry: a case study in Latin America. Production Planning & Control: The Management of Operations, Vol. 23, No. 1, January 2012, 26–46.
7. Correia I., Gouveia L., and Saldanha-da-Gama F., (2010) Discretized formulations for capacitated location problems with modular distribution costs. European Journal of Operational Research, 204, 237–244.
8. Dejax J.P., Bostel N., Langevin A., (2012), Tactical planning of procurement of a supply chain with environmental concern. Proceedings of the 4th International Conference on Information Systems, Logistics and Supply Chain: Creative Logistics For An Uncertain World, ILS 2012 – Quebec (Canada), August 26-29.
9. Gebennini E., Gamberini R., Manzini R., (2009), an integrated production–distribution model for the dynamic location and allocation problem with safety stock optimization. International Journal of Production Economics, 122, 286-304.
10. Gen M. and Syarif A., (2005), Hybrid genetic algorithm for multi-time period production/distribution planning. Computers and Industrial Engineering, 48, 799-809.
11. Geoffrion A.M., (1972), Generalized benders decomposition. Journal of Optimization Theory and Applications, 10(4), 237–260.
12. Geoffrion A.M. and Graves G.W., (1974), Multicommodity distribution system design by Benders decomposition. Management Science, 20(5), 822–844.
13. Hieber R. and P. Schönslebeh, (2002) Supply chain management. A collaborative performance Measurement approach, Vdf – Hochschulverlag and der ETH, Zürich.

14. Javid A. and Azad N., (2010), Incorporating location, routing and inventory decisions in supply chain network design. Transportation Research Part E: Logistics and Transportation Review, 46 (5), 582–597.
15. Klose A. and Drexl A., (2005), Facility location models for distribution system design. European Journal of Operational Research, 2005, 162, 4-29.
16. Laporte, G., Louveaux, F., and Mercure, H., (1989), Models and exact solutions for a class of stochastic location-routing problems. European Journal of Operational Research, 39, 71–78.
17. Love R.F., Morris J.G. and Wesolowsky G.O., (1988), Facilities Location. Models and Methods (North-Holland: New York).
18. Mahar S., Bretthauer K.M., Venkataramanan M.A., (2009), An algorithm for solving the multi-period online fulfillment assignment problem Mathematical and Computer Modelling, 50, 1294-1304.
19. Manzini R., Bindi F., (2009) Strategic design and operational management optimization of a multi-stage physical distribution system. Transportation research: Part E, 45, 915-936.
20. Manzini R., Gamberi M., Gebennini E. and Regattieri A., (2008), an integrated approach to the design and management of supply chain system. International Journal of Advanced Manufacturing Technology, Vol. 37, p.625-640.
21. Manzini R., Gebennini E., (2008), Optimization models for the dynamic facility location and allocation problem. International Journal of Production Research, Vol.46, No.8, 2061-2086.
22. Melo M.T., Nickel S., and Saldanha-da-Gama F., (2009) Facility location and supply chain management – a review, European Journal of Operational Research, 196, 401–412.
23. Saaty T.L., (1994b). Highlights and critical points in the theory and application of the analytic hierarchy process. European Journal of Operational Research, 74, 426–447.
24. Shen Z-J. M., (2005), A multi-commodity supply chain design problem. IIE Transactions, 37, 753-762.
25. Sule D.R., (2001), Logistics of Facility Location and Allocation (Marcel Dekker Inc.: New York).
26. Jalisi Q.W.S., Cheddad S. (2000). Third party transportation. International Journal of Industrial Engineering 7(4), 348-351.