SUPPLY CHAIN DESIGN – WHERE TO ALLOCATE LOGISTICS FACILITY

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Summary: Current market condition make companies searching for every possibility how to better satisfy their customers either by higher level and scope of logistics services or by lower price than competitors. Supply chain design plays a key role in meeting corporate and supply chain strategy as establish a framework in which operation could be realised. Therefore it highly influences rate of customer satisfaction and efficiency not only of one company but of a whole supply chain. Supply chain design is a complex problem requiring involvement wide range of quantitative and qualitative factors. Regrettably, mainly quantitative ones are used as they can be more easily gathered and processes. Moreover, the fact that supply chain design has long been the area of operation research science concertation on quantitative data that could be incorporated into mathematical models prevailed among researchers. Therefore, authors of this paper want to outline the complexity of factors in both aspect quantitative and qualitative ones that should be used within supply chain design.

Key words: Supply chain design, supply chain, quantitative and qualitative factors

INTRODUCTION

Lack of meaningful differences among product functions product availability and associated logistic services plays the key role in customers´ perception (1). Competition has shifted to the level of the supply chain. The quality of customer service has become a key factor in customers´ loyalty. Thus, selection of the optimal facility location requires encompassing both quantitative and qualitative factors (2).

Facility location and its interconnection with other facilities in supply chain is strategic decision of each company (3), (4), (5). Great importance is awarded to such decision, especially because it is the way how to support competitive advantage not only of one company but of an entire supply chain. Supply chain network design influences 80% (1) of supply chain costs as it creates a framework of operation in terms of logistics service and its quality, flexibility, transportation and storage costs and ecological impact. Operation has to be based on supply chain and company strategy thus, it has to be inevitably incorporated into supply chain design process. Each of the following competitive strategy: low cost, excellent logistic service, short delivery time, ecological impact etc. requires unique supply chain design. Moreover, besides the strategy wide range of other factors can significantly influence optimal supply chain e.g. product feature, customer requirements, nature and location of suppliers, customers and competitors, logistics and transport infrastructure, economic and

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political situation, taxes, logistic facility market, labor market etc. of a relevant and nearby region.

Selection of the optimal logistics facility location and their number has undoubtedly long-term impact on supply chain performance. The facility location problem is not a problem being solved every day or month. However, it would be misleading to consider that a supply chain is designed once forever. Concerning the current market conditions the necessity for supply chain redesign has been substantially intensified due to:

- Extension of outsourcing
- Shrinkage of product life cycle
- Competition
- Rise of customer logistics service requirements
- Merges and acquisitions

Companies prone to outsourcing of logistics services mainly warehousing and transportation (6). Shift from insourcing to outsourcing does mean not only supply chain redesign at the time of the change but also the length of outsourcing of warehousing service contract varies from 3-5 years. Hence, it enables companies present in a supply chain more frequently to redesign their supply chain as companies make the decision every time when they organizes a tender to change logistics provider or a developer renting logistic or production facility.

In recent years, shrinkage of product life cycles make company reconsider structure of supply and distribution channel to adjust it to features of new products and their customers (1). Moreover, it increases a pressure on streamlining supply chains which inevitable is related with number and location of logistics facilities.

Ever-increasing competition leads to either change in customer service strategy or to reconsideration of relationship with direct competitors in assets sharing and achievement of synergic effect. Therefore, companies can endeavor to allocate their facility away from their competitor to spatially differentiate or on a contrary to be present as close as it is possible to share warehousing, transportation and the same center of gravity. Furthermore, fierce competition on a particular market can lead to reconsideration of company strategy and withdraw its presence on the market and so redesign of supply chain.

Growth of individual customer requirements has substantial impacts on supply chain design as individualization in delivery times, packaging, batch sizes and other delivery terms curtails long term delivery and thus centralization of warehousing. It results in horizontal increasing of supply chain elements and reducing the size of the served area.

Merges and acquisitions establish a necessity to supply chain redesign as supply chains from two companies have to be aligned and it can also completely change of center of gravity and other significant factors used in location of logistics facility.

Aforementioned factors are changing throughout the time and thus company has to be able to mix the cocktail of services individually tailored for each customer hand in hands with

overall efficiency. Otherwise they will quickly lose its competitiveness on the market. Location of the logistics facilities is therefore to be considered in the long term perspective, in order not only to meet current market requirements, but also to be able to respond to new challenges over the time.

Ability to meet customer´s demand in today's fast moving and changing environment is highly dependent on facility location.

1. THEORETICAL BACKGROUND

The modern scientific approach in supply chain design can be dated back to the theory of industrial facility location problem that was formulated by Alfred Weber at the beginning of 20th century. However the theory itself was emerged in 1960´s. Weber built up the theory on searching of minimum cost of serving customer by minimization of transportation and production cost within triangle of which one point represents a customer and the other two suppliers. Since Weber formulated the theory based on these presumptions: constant returns to scale, free capacity of supply with fixed price in each location, demand is fixed in terms of amount and location, transportation cost is proportional to distance and weight transported.
Since then the market conditions have changed dramatically and researchers have started changing mainly the mathematical models to incorporate new and new quantitative factors by changing objective function and/or constraints to name a few distance based approach, maximization of demand coverage, limited capacity model, fixed and variable cost model, multi echelon model, multi-objective optimization, etc.

Quantitative methods

Distance based approach

Distance based approach is based on minimizing a travel distance that has to be realized in average to serve a demand. Thus, the facility is allocated as near to the center of gravity to reduce traveled distance weighted by demand or supply if used for inbound logistics. However, some customers especially those of small demand quantities could be allocated too far to meet their delivery requirements.

Maximization of demand coverage

Maximization of demand coverage searches for locations enabling distribution of goods to predetermined distance which expresses a required share of total demand that should be satisfied within a particular delivery time. Unlike to distance based approach this method can assign a facility farther away from the center of gravity and prolong the average weighted delivery time but can guarantee to meet delivery requirements of all customers.

Limited capacity model

Limited capacity model consider constraints of storing capacities. Each of the location in a supply chain can have different capacity. In previous methods the capacity is not an issue as it

assumes that each of the location can have similar capacity and/or customers demand could be divided among more facilities.

Fixed and variable cost model

Fixed and variable cost model reflects different fixed and variable costs in searching of optimal logistics facility location. Decision makers can incorporate different costs of hiring or building a warehouse, labor force, logistics services, taxes etc.

Multi echelon model

Multi echelon model optimizes inbound and outbound supply chain costs by defining location of three and more supply chain elements e.g. producer, distributor and retailer participating on customer satisfaction.

Multi-objective optimization

Multi-objective optimization help identify tradeoff between two decisive criteria when each would lead to different results such as cost and delivery time.

Additionally, the models could be based on stochastic or deterministic factors. However, majority of research in facility location problem is conducted by operation researchers. Thus, mathematical models are preferred to research of complex aspect of supply chain design e.g. relevance and importance of both quantitative and qualitative factor. Moreover, recent operation research is focused on incorporation of one or a combination of few factors (constraints) into a model or changing objective function, however decision making process within supply chain design is today multi-criteria decision-making problem rather than single factor decision. Hence, the process firstly requires identification of key factors in both quantitative and qualitative area and then their usage in building a supply chain design model. Authors of this paper don´t want to degrade the importance of operation research methods within supply chain design but highlight the relevance of analyzing decisive factors that are currently omitted by research main stream. Therefore, the authors dedicated this paper to analyzing factors that should be involved in supply chain design.

Supply chain design is a complex discipline in which wide range of factors can be involved. However, necessity of incorporate a particular factor in decision making process about number and location of supply chain elements highly depends on unique specifics of particular supply chain and a company. Therefore, authors present here the most common and important factors that are relevant. Nonetheless, it doesn´t mean that all of them have to be involved within a particular case.

Quantitative supply chain design factors

Supply chain design factors could be divided into quantitative and qualitative. Quantitative ones particularly wage rates, material costs, utility costs, transportation costs and taxes are commonly researched and used (7).

Quantitative

Quantitative factors can be incorporated into mathematical models and directly embedded into objective function or constraints.

Facility type

Facilities could be classified regarding there size of gravity: international, regional and local. Moreover, they can be distinguished based on their function: assembly plant, warehouse, distribution centre, cross-docking centre, logistics centre, and terminal of multimodal and combined transportation. This factor falls into quantitative as gravity size and even function could be set based on a capacity of the facility, maximum delivery time or minimum demand coverage within a maximum delivery time.

Density of demand

Spread of customer demand belongs to key factors as it highly influences transportation cost which is a key driver in logistics costs. Moreover it can trade off savings of centralized storing and manipulation. Less scattered demand requires higher number of smaller vehicles as drivers spent more time on road and thus they cannot serve the same number of customers within allowed working hours. However, this is relevant under condition of the same level provided logistics service. Density of demand and customer service requirements have great impact on number of facilities needed for customer satisfaction. Density of demand steps into objective function by defining usually annual demand per particular area.

Scope and volume of provided logistics services

Besides logistics costs customer service shapes the boundaries of gravity field as the rest of the time left of subtracting order processing lead time, order completion lead time, packaging and expedition lead time from customer delivery time provides maximum time left for transportation. Moreover, customer order value or profit and a delivery distance are used for calculation of Minimum Order Quantity that directly influences the frequency of delivery. Hence, number of facilities and their location is effected by that.

Transport infrastructure

Type of logistics facility predetermines accessibility to a particular transport infrastructure. Logistics centres and terminals of multimodal and combined transport have to be connected with more modes of transportation, commonly road and rail at least, sometimes even air freight or inland water transport is appreciated. In addition to that, low density of highways, lack of city rings, insufficient number of rail/road terminals increase number of logistics facilities operating in a particular gravity field as otherwise required service level wouldn´t be able to be provided. Transportation infrastructure is usually defined by the length of delivery time in supply chain design. Moreover, transportation infrastructure influences transportation costs there could be explicitly involved in objective function of the supply chain design model. The accessibility to particular mode(s) of transport could be used as clarification criterion to P set of locations that are further used in searching the optimal location.

Available structure and amount of workforce

Availability of workforce and its qualification structure can influence supply chain design in two aspects. Firstly, differences in cost wages has an impact on both variable and fixed cost of facility operation and so either change ratio between storage and transportation cost or favour

location with lower wages and discriminate those with higher ones. Secondly, availability of labour can be used for identification of suitable locations into P set thus locations without required labour are disqualified.

Storing and manipulation services/ market of logistic properties and services

Availability of adequate warehousing properties and rents or prices and scope of logistics services supply substantially effects supply chain design. Availability can be used for identification of suitable locations into P set thus locations without proper warehousing properties e.g. warehouse of particular class or equipment for storing of chemical substances are disqualified. Warehouse rents, cost of related utilities and price of logistics services are all involved in fixed and/or variable costs and so influence the suitability of each location.

Ecology

Ecology can play important role when the preferred location in which logistics park or industry zone is not approved in urban plan. Furthermore, when a company store and distribute chemical substances close proximity to ecologically valuable and protected area can induce significant cost of measures or even make it impossible to go life. Additionally, this factor could be part of transportation costs as the cost of more ecological mode of transport could be used in the supply chain design model.

Local authority support

Local authority support/opposition is usually dependant of total effect of proposed location project on local environment and economy. A project bringing new job opportunity of tens or hundreds in case of small city and hundreds or thousands in case of big city, some investments into new city infrastructure could be easily promoted. Therefore, some marginal negative effects in terms of insular increase of noise could be overweighed.

Local authority factor could have devastating consequences and thwart initial investments due because of local people and authorities' opposition to proposed project. However, local authority can also provide financial support to attract investments to a particular region, hence the positive attitude of local authorities could become significant factor due to it beneficial financial impact on facility location project. Investment incentives could be provided not only on local level e.g. city but also on region or state level. This factor can be reflected in operational costs due to some subsidies and lower taxes approved for a particular period can increase convenience of some locations over the others.

Competitors

Presence of a competitors´ facility in a particular place could have contradictory effects and make the particular place either more attractive or less attractive for placing s facility. Presence of new location next to competitors could enable utilization of established local demand e.g. allocation of retail stores or can benefit from asset sharing within transportation and warehousing provided by one logistics provider. However, this factor could significantly influence preferred location as the operational costs either transportation or/warehousing can be reduced by asset sharing. Moreover, it can also increase forecast of demand in future.

Economic cycles

Economic cycles predetermines evolution of demand throughout a time and so capacity requirements and economy impact of that. It is assigned to quantitative factors as macroeconomic figures e.g. GDP could be used in supply chain design model as shadowing of demand in demand areas.

Qualitative factors

Qualitative factors are those that can neither be reasonably expressed in values nor embedded into supply chain design model. All factors could be somehow expressed in values at least by binary system and then qualify or disqualify a particular location from P set. However, the importance of each factor and quality scale of the qualitative factors can be properly identified only by qualitative methods. Although qualitative factors are usually neglected, however some authors have also introduced certain qualitative issues such as community attitude, availability of labor, probability of labor unions, cultural attributes, quality of schools, etc. (8) Authors want to briefly explain two fundamental qualitative methods used in supply chain design: Fuzzy logic and AHP.

Fuzzy logic

Fuzzy logic is mainly applied to several criteria decisions assuming that these criteria seem difficult to express in a quantitative measure. As an example, detailed information about costs of implementation for strategic actions are usually not available, while linguistic judgements on costs can be easily obtained. (9)

(Kumar and Kumanan, 2011) used fuzzy approach to measure the relative degree of importance for each location requirement with the location criteria in the QFD process (10). Fuzzy logic was also used to implement the costs and benefits of each location criteria implementation.

Fuzzy logic was used to evaluate service factors considered in the real case application since the workgroup agreed to adopt a linguistic approach (11).

(Zhang, Kwon, Kim, 2011) employed fuzzy logic to identify the relevant factors in order to select the city logistics facility (12). They interviewed 40 respondents in order to rate each factor with respect to the selection of a city logistics facility by using a 3-point scale ("very important," "important," and "less important").

AHP

The AHP, developed by Saaty (1980), has been employed by many researchers in several fields - such as planning, selecting a best alternative, resource allocations, resolving conflict, optimization, etc. - in the applications related with multiple criteria decision making (MCDM) over last two decades. (13)

In logistics field, AHP is usually combined with another technique in order to consider not only both qualitative and quantitative factors, but also some real-world resource limitations.

(Badri, 1999) used the combined AHP–GP approach to deal with the location-allocation problem. First, the AHP was adopted to evaluate the alternative locations with respect to

several criteria, such as political situation, global competition and survival, government regulations, and economics related factors (14).
Partovi (2006) used the combined AHP–QFD approach to evaluate and select facility location for a company producing digital mass measurement weighted products for industrial use (15).

Quantitative supply chain factors

Quality of infrastructure

Quality of infrastructure could be both quantity and quality factor. When it is not quantified the quality could be asses e.g. by LPI index based on which P set could be established or when two locations would have the same preferences LPI could become the decisive factor.
Supply chain vulnerability
Risk associated with dependency on sole either sourcing, storing or production facility has to be assessed and usually cannot be quantified. Supply chain design methods of operational research neglects this aspect. But this factor could be involved e.g. by AHP method or identified as critical by Fuzzy logic.

Local authority support

Besides quantifiable aspect mentioned above local authority support could express attitude of local authority and community to a particular company and its plan to allocate a facility into or near the area. Moreover, rate of red type can be also hardly quantified but influence an attractiveness of an area for location of a logistic facility.

Political stability and judicial system

Political stability, unclear legislations, rigid judicial system, corruption and fear of putting some business or properties under state control (nationalization) can downgrade attractiveness of a location.

Proximity to competitors

Proximity to competitors could be both quantifiable and qualitative factor and desirable or undesirable.

Availability of suitable utilities

Availability and capacity of infrastructure of utilities should be considered as disqualifying criterion when poor service can worsen operation due to blackout of electricity or communication with business partners because of insufficient ICT infrastructure.

Geographic and weather characteristics

Frequent earthquakes, eruption of volcanoes, snow storms, flats and other natural disasters can stoppage of material and information flow across supply chain and endanger its competitiveness on the market.

Company strategy

Company strategy can hardly be quantified to be implemented into operation research method. Hence, it has to be reflected in supply chain design process either by parametrizing

quantifiable factors e.g. service level, transportation etc. to reflect company strategy. Otherwise, P set of location has to be defined by the company strategy.

Ecology

Ecology can be involved by selection of ecological mode of transport and type of vehicle and quality of a warehouse property.

Logistics service supply

Particular locations can be assessed regarding quality and quantity supply of demanded logistics services. LPI is used to rank particular countries.

2. PRELIMINARY SURVEY

Authors of this paper formulated two hypotheses in the area of supply chain design factors. These hypotheses are verified based on preliminary questionnaire survey conducted during July and August 2015.

As stated earlier supply chain design process is a complex decision-making problem. The complexity derives from the number of factors, both quantitative and qualitative that influence the decision. Concerning the fact that retail and wholesale companies are closer to the final market and are even more exposed to current market condition authors formulated H1which should proof that wholesale and retail company realize necessity to incorporate quantitative factors into supply chain design process.

(H1) Manufacturing companies prefer quantitative factors whereas retail and wholesale companies prefer qualitative factors when deciding about facility location. (

Since the Czech Republic is still considered as a country with relatively cheap and available workforce, skilled labour would be a factor with high importance within international context. However, authors assume that the skilled labour won´t be one of the most important factors for Czech companies and so formulated H2.

(H2) Skilled labor does not belong to the most important factors across all sizes of companies.

3. DATA COLLECTION

The data collection period was established to 2 months during July and August 2015. Questionnaire was sent to the sample of 100 selected manufacturing or business companies belonging to all sizes (small, medium and large enterprises). Authors prepared a list of 2000 companies as a target group for further research. Target group are companies with the representation in the Czech Republic within following sectors: automotive, toys, clothing industry, electronics and pharmaceutical industry.

Questionnaire was sent to the sample including companies from above described sectors, from different regions in Czech Republic electronically. Since the questionnaire encompasses the wide range of questions concerning the strategic decisions of the company, authors selected carefully the key informants. Thus, the recipient of the email is logistic or supply

chain manager (if this role is not held within the company, it is sent directly to the CEO). Questionnaire response rate is expected to be around 20 %. Every company is contacted by email that includes cover letter, instruction sheet and the questionnaire. To increase the response rate as well as to send the questionnaire to the right person, prenotification calls were made. Managers were invited to participate and authors offered them a copy of the questionnaire´s results.

The objective of the first round was to gain feedback on the questionnaire. Although most companies understood well the questions, there were some discrepancies in a few questionnaires. Moreover some companies were not able to finish the questionnaire due to different reasons. The response rate was 25 % but for above described reasons some of them had to be discarded.

4. RESULTS

Recipients were asked to rate the selected factors from 1 to 18 and assign them corresponding weights. They had to allocate 200 points among 18 factors. Table 1 indicates the ranking of factors ordered by relevance within manufacturing and business companies.

Since the requirements of manufacturing and business companies are different in nature, factors that influence the facility location are different as well. As Table 1 shows, the most important factor for manufacturing companies is the distance to production centers whereas business companies appreciate most the nearness to their customers. However both mentioned quality of infrastructure, the rest of the factors at the first third of positions is quite different. Manufacturing companies are more focus on cost and distance factors compare to business companies that emphasize customers and all related factors that can attract them. There are three factors - population in regions, availability of properly skilled labor and competitor´s location – that have significantly higher importance for business companies. The most important factor for manufacturing companies – production centers - is one of the least important for business companies.

We can conclude that among the six most important factors for manufacturing companies are mainly quantitative factors (cost or distance that could be minimized). However quality of infrastructure could be deemed qualitative factor, it can significantly diminish the total cost. Business companies are mainly interested in factors that cannot be simply optimized by mathematical methods.

Thus, the hypothesis 1 is confirmed. Manufacturing companies favor the quantitative factors and business companies prefer the qualitative factors when deciding about facility location.

Tab. 1 - Factors ´ranking: manufacturing vs. business companies

Ranking	Manufacture	Business
1	production centers	nearness to markets
2	cost of rent	business risk
3	nearness to markets	quality of working environment
4	quality of infrastructure	future development expectations
5	3PL cost	quality of infrastructure
6	location of logistic centers	population in regions
7	scope and volume of provided logistics services	availability of properly skilled labor
8	business risk	competitor´s location
9	ecological aspect	cost of rent
10	quality of working environment	scope and volume of provided logistics services
11	suppliers´ centers	ecological aspect
12	future development expectations	established business in region
13	established business in region	3PL cost
14	combined transport terminals	local authority support/opposition
15	local authority support/opposition	production centers
16	availability of properly skilled labor	suppliers´ centers
17	population in regions	location of logistic centers
18	competitor´s location	combined transport terminals

Source: Authors

When comparing the importance of the factors from the point of view of small, medium and large companies, there is a significant difference in perception of business risk. Small companies placed business risk perception at the 2nd position, the medium sized companies to the 5th position and large companies at the 8th position. The comparison is shown in Table 2. Regarding the availability of skilled workforce, none of the three different sizes of companies assigned high importance to this factor. Small and large companies placed the availability of properly skilled labor at the 11th position and medium sized companies at the 14th position. Since the weight for this factor was relatively low for all companies, we can confirm hypothesis 2, availability of properly skilled labor does not belong among the most important factors when deciding about facility location.

Tab. 2 - Factors ´ranking: small vs. medium vs. large companies

Ranking	Small	Medium	Large
1	production centers	production centers	nearness to markets
2	business risk	nearness to markets	location of logistic centers
3	future development expectations	cost of rent	quality of working environment
4	quality of infrastructure	quality of infrastructure	cost of rent
5	nearness to markets	business risk	future development expectations
6	3PL cost	3PL cost	population in regions
7	cost of rent	scope and volume of provided logistics services	quality of infrastructure
8	quality of working environment	established business in region	business risk
9	scope and volume of provided logistics services	suppliers´ centers	combined transport terminals
10	ecological aspect	ecological aspect	3PL cost
11	availability of properly skilled labor	quality of working environment	availability of properly skilled labor
12	local authority support/opposition	local authority support/opposition	ecological aspect
13	established business in region	future development expectations	scope and volume of provided logistics services
14	suppliers´ centers	availability of properly skilled labor	suppliers´ centers
15	competitor´s location	location of logistic centers	established business in region
16	location of logistic centers	population in regions	local authority support/opposition
17	combined transport terminals	competitor´s location	production centers
18	population in regions	combined transport terminals	competitor´s location

Source: Authors

CONCLUSION

This paper proposed factors that should be included in supply chain design process based on literature research, practical experience and preliminary research. Authors emphasize necessity to considered not only narrow number of quantitative factors but establish a complex approach embedding both quantitative and qualitative factors.

Preliminary survey results confirmed that the importance of qualitative factors should not be neglected. Their relevance in supply chain network design is noticeable.

Survey conducted in the Czech Republic confirmed the importance of multi-criteria approach to facility location in supply chain.

Such approach is relevant in all business environments, where other considerations beyond total costs are crucial in supply chain design e.g. future development expectations, quality of working environment or competitor´s location.

Results of preliminary survey acknowledged that incorporation of a particular factor in supply chain network decision highly depends on unique specifics of particular supply chain and a company.

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