Global Journal of Human-Social Science: E
Economics
Volume 14 Issue 1 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-460X & Print ISSN: 0975-587X

The Model for Decreasing the Costs in Supply Chain with Importance of Suppliers

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GJHSS-E Classification : FOR Code: 349999p

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I. Introduction

The supply chain management became an important part of business units without respect to field of activity. The concepts of supply chain, vendor or logistics are common words of business communication in most firms. Supply chain management going like red thread throw the all business activities like for example delivery, production, sales, storage etc. and join these activities in the one complex set of lead activities. It is very hard to lead all these activities, particularly in the current economic environment, when all companies around the world are under big economic pressure to hold up or alive in the global economic environment. The aims of firms are to streamline these activities and recognized what is important and especially decreased the costs of these activities, which are parts of supply chains. In this article I try to outline the cost model on the base of authors Bahareh Amirjabbari and Nadia Bhuiyan to set save costs supply chain in chosen firm with roles of particular suppliers on the way to obtain desired materials or finished products and decreased the costs in the supply chain.

a) *Literature review*

According to the literature we could meet with many sorts of approaches and methods how to lead the whole supply chain in the given economic conditions and how to solve the particularly supply problems (bull whip effect, delays, disruptions, capacity constraints, optimal portfolio of families products). Consequences of supply chain disruptions might be financial losses, negative corporate image or a bad reputation eventually accompanied by a loss in demand as well as damages in security and health (Jűttner et al., 2003). These problems are especially joining with problems of different inventory drivers like level of supply chain cooperation, forecast accuracy, order pattern, the policy of safety stock, visibility, external and internal effects (Chopra, Sodhi, 2004), quality of leading, customer requirements (Yu, Gonzalez-Zugasti and Otto, 1998), product families and the relationship between suppliers and given firm. But the aims of all firms around the world are very similar. On the one hand it is an effort to maximally the level of service and availability of products, because when you are not able to deliver the desired amount of products, you will lost the customer (profit) and also the goodwill of firms and on the other hand companies want to minimalist the costs of whole supply chain and became more competitive. Any obstacles at any node and level of supply chain can result in unavailability of products to their customers (www.rhsupplies.org) and every tier and member of supply chain can influenced the whole performance of supply chain and others members (Amirjabbari, Bhuiyan, 2011).

Moreover we can not to ignore the role of risk in the supply chains. For example (Atkinson, 2006) deals with lean manufacturing and global sourcing in the context of supply chain risk management, (Kumar, DuFresne and Hahler, 2007) highlight the importance of pitfalls in outsourcing, which has led to increased dependence on interconnected supply chains that are vulnerable to associated risks. (Őkmen and Őztaş, 2010) point out an importance of analysis of the uncertainty of estimated costs in supply chain.

Safety stock plays an important role in the live of company's supply chains. His role is irreplaceable and he is joining with procurement, transport, production level, service, storage, holding and etc. It is plaster, than the supply chain is weakened or resisted some internal or external problems and thus became in the last time a subject of numerous surveys. For example (Yang and Wee, 2000) proposed an ordering policy for a vendor–buyer integrated model, (Keskin and Uster, 2007) trying to find the relationship between stocks and transport,

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(Jeet, Katanoglu and Amit, 2009) proposed the model for network design and inventory stocking problem. (Cetinkaya et al., 2009) designed the multi model with relationships between the production outputs, finished product inventories at the factory warehouse, warehouse at the DCs and bins, plant to store shipment quantities to direct customers and interplant shipment quantities to the other plants, shipments quantities from the DCs and bins to customers and customer demand that can be satisfied by shipments from DCs, bins or direct from factory warehouse. Finally (Cunha, Agard and Kusiak, 2007) presented strategy assemble-to-order (ATO) production strategy considers a tradeoff between the size of a product portfolio and the assembly lead time. There are exist some others surveys that considered the transport, stock, holding costs or capacity in the traditional stock models with simultaneously flows and set up time horizon by software using. But the model of authors (Amirjabbari, Bhuiyan, 2011) focused to adjustment sizing of safety stock with minimize of costs with its optimum location in the stream.

II. Model Structure

The optimization model is described like possible value streams of each product, material or intermediate product of company to result in the adjustment sizing of safety stock for these items with focus to calculating of probability of failures for contracted suppliers and their alternative suppliers. The model contains two parties along the supply chain: contracted supplier or alternative supplier and production plant, who is the buyer. The model has variation basis (discrete). The procurement department of the company is responsible for procuring the raw materials or semi-finished parts, finished products through suppliers to manufacturing plants or even supplying parts from one manufacturing plant to other business units. The final products are sold to final customers.

The model is developed on the basis of the following assumptions. (1) The stream of material or finished products is different for every type of final product. It means, that every product has own deliver way. (2) The every contracted supplier has own probability of deliver, which is given by historical data from database of suppliers. In our case we take the alternative approach from cost minimizing model of (Amirjabbari, Bhuiyan, 2011) and their First Filled Rate (FFR) of their case study from aerospace company. We used historical data from database of corporate information. (3) Every alternative supplier has own probability of delivery performance and the role of alternative supplier occurs when the contracted supplier is not able to arrange the required items. (4) The safety stock is adjustment on the historical data of suppliers from the last time period, forecast of demand from last period, the requirements of particular business units and new factor is add in the form of probability delivery performance of both sorts of suppliers. (5) The last assumptions is fixed amount of delivery agreed between the supplier and plant on the basis of historical data.

It should be noted that procurement's location can be different from manufacturing ones. This availability should be guaranteed through safety stock, but the optimum safety stock level and location should also minimize logistics costs. Moreover, the aim of this article is designs and describes the model of cost minimization with probability failures of suppliers and possibility to use alternative suppliers. In the model we can use many different sets of semi finished products, materials or finished goods with combination of unlimited numbers of suppliers and end customers, shortage and overage costs, delivery performance of particular suppliers (S) with their probability of failure, the amount of alternative suppliers (W) are the inputs of the model. The model is in generally form describes on Fig.1 and mathematically expresses by equation (1). List of regarding parameters used in general model are included in appendix A.

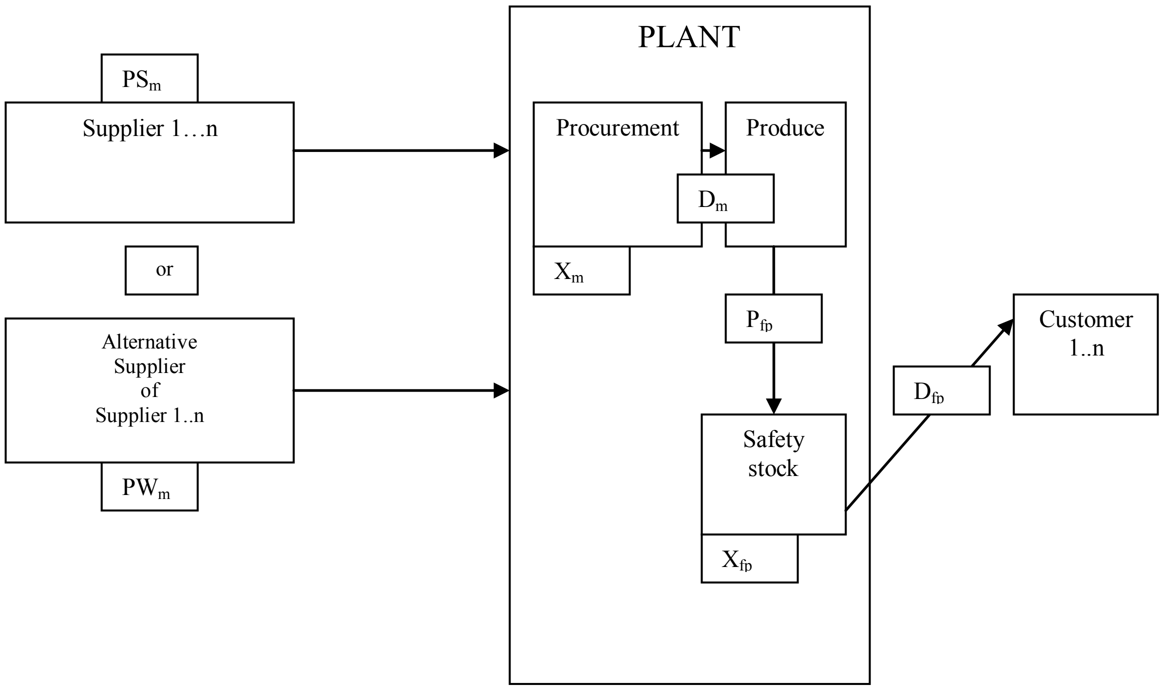

Figure 1 : General stream in cost model

The model serves the choice of the best supply chain system. It is possible to write as follow

$$C_i=\sum_{S}^{a_i}\sum_{W}^{b_i}\sum_{m}^{c_i}\left[CS_{SWm}q_{SWm}(1-P_{SWm})+CO_{SWm}q_{SWm}(D_m-P_{SWm})\right]+\sum_{fp}^{d_i}\sum_{c}^{e_i}\left[CS_{fp,c}q_{fp,c}(1-D_{fp,c})\right]+$$

$$+\sum_{fp}^{d_i}\sum_{c}^{e_i}\left[CO_{fp,c}q_{fp,c}(D_{fp,c}-(P_{fp,c}\square D_m))\right]. \qquad (1)$$

The cost of any variant is calculated as follows.

$C_i = a_i + b_i + c_i + d_i + e_i$

a_i is sum of contracted supplier

b_i is sum of alternative supplier

c_i is sum of material

d_i is sum of finished products

e_i is sum of customers

$$i_{op}=\arg\min C_i$$

$$i\in S$$

Here i_{op} is the best variant, S is set of variants, C_i is cost of the i^{th} variant.

The equation (1) contains basic parameters. CS_{SWm} is the costs of shortages of material, which should be deliver by contracted supplier (S) and by alternative supplier (W). The parameter q_{SWm} is on time delivered material by contracted supplier (S) and alternative supplier (W). Expression $(1-P_{SWm})$ is difference between the highest delivery performance and supplier delivery performance to procurement of material. The constant 1 means that delivery performance is set to 100% percent. It means that every delivery from both type of supplier will be in required time in company. CO_{SWm} are the costs of overage of material, D_m is delivery performance of procurement to manufacturing, $CS_{fp,c}$ are shortage costs of finished products for customers, and $q_{fp,c}$ is on time delivered finished products for customer. Expression $(1 - P_{fp,c})$ is difference between highest delivery performance of finished products to customers and manufacturing performance. The constant 1 means, that boundary is set on the 100%. In the last part of equation we can find the parameter $D_{fp,c,}$ which is the delivery performance of manufacturing or procurement to costumers. The product between manufacturing performance for finished part and delivery performance of procurement to manufacturing of material we must deduct, because, material is input to finished products. In the next section, these above parameters will be developed by mathematical substantiation.

III. Model Development

The purpose of model is to provide minimum costs in supply chain with consequence adjustment of safety stock. In the design of model are needs to by analyzed particular parameters to identify the important elements of costs model. List of regarding parameters used in development of model are included in appendix A.

Important part of minimize model is determination of costs. In our model are cost shortage and cost of overage. Shortage costs (costs of safety stock violation) have different definitions for materials and finished parts as they are located in different stages within the supply chain and their shortages have different effects on firm. The shortage cost of material is the summation of the expediting cost on the supplier, transportation and overtime of the manufacturing section. On the other hand, shortage cause disruptions and stock not pulled for all the other parts related to that finished part and also its finished product in different locations of the supply chain. In addition, shortage of the finished part causes the finished assembled product to be held up unreleased. In addition, the unreleased production is the loss of profit and visibility, goodwill by customers, which is very hard to calculate, because it is qualitative elements. Therefore, the shortage cost is defined as follows:

CS_{fp} – [(standard costs of final product · the average number of days, in which the product stand like product in the form of non-final product · interest rate or the unselected best opportunity for interest of money) / (365 days per one year)] + (lost profit).

The cost of overage (*CO*) is defined as the interest that the company is losing by holding inventory instead of having it in cash. Hence, it is the multiplication of standard cost of the part and the annual interest rate or unselected best opportunity for interest of money.

The model for decreasing the costs in supply chain model in our article is based outside the supplier delivery performance to procurement, manufacturing performance for finished part, shortages costs, overage costs, delivery performance of procurement to manufacture, delivery performance of manufacturing or procurement to costumers also the two types of probability. The first is the probability of delivery performance for contracted supplier and the second is probability of delivery performance for alternative supplier, when the contracted supplier failed to calculate the parameter P_{SWm}.

P_{SWm} is supplier delivery performance to procurement and contains both delivery performance of the contracted supplier (S) as well as the performance of alternative supplier (W). The parameter P_{SWm} is sum of on time probability of the contracted supplier and alternative supplier. When we use, the concept of "odds", which is defined as the ratio of probabilities defined in the usual way to the probability that an event occurs the opposite: odds = *a / (1 - a)*, where (a) is then we calculate P_{SWm} like:

$$PR_{SWm} = \sum_{S=1}^{M} PRqit_{Sm} + \left(\frac{PRF_{Sm}}{\sum_{W=1}^{M} PRqit_{wm}}\right), \qquad (2)$$

where, $PRqit_{Sm}$ is probability of in time delivery of contracted supplier for material, PRF_{Sm} is failure of supplier in deliveries and $PRqit_{Wm}$ is probability on time delivery of alternative supplier.

The same procedure can also be used in the calculation of performance in the supply chain of finished products, when the index (m) is replace by (fp).

Later, PRq_{itSWm} is the sum of right time deliver of contractual supplier (S) and delivery performance in right time by alternative suppliers (W) of material. The number of alternative supplier and their delivery performance is the wage, which play an important role in the case of minimum costs in the whole supply chain and adjustment of safety stock. The equation (3) presented the sum of probability.

$$PRqit_{SWm} = \sum_{S=1}^{M} PRqit_{Sm} + \sum_{W=1}^{M} PRqit_{Wm}, \qquad (3)$$

where PRq_{itSm} is probability of the in time delivery by contracted supplier, PRq_{itWm} is probability of the in time delivery by alternative supplier.

Then, the probability of failure of alternative suppliers for finished products and material or intermediate products (PRF_{Wfpm}) is sum:

$$PRF_{Wfpm} = \sum_{W=1}^{M} PRF_{Wfp} + \sum_{W=1}^{M} PRF_{Wm}. \qquad (4)$$

Subject to, PRF_{Wfp} and PRF_{Wm} are probabilities of failures of alternative supplier for material and finished products.

In the equation number (5) is describe the probability of the all alternative suppliers to deliver the material or finished products qit_{Wmfp} is on-time delivery of alternative supplier. The alternative supplier (W) is defined like supplier, who fills the role of supplier, if the agreed supplier is not able to deliver the goods.

$$PRit_W = \sum_{W=1}^{M} PRqit_{wmfp} \tag{5}$$

In the equation number (6) the probability of failure for supplier of material or semi-finished product is described and the same approach is also in the equation number (7) with the difference for probability failure for supplier of the finished products. The parameters F_{Sm} and FS_{fp} are failures of contracted supplier for material, respective for finished products.

$$PRF_{Sm} = \sum_{S=1}^{M} PRF_{Sm}\ , \tag{6}$$

$$PRF_{Sfp} = \sum_{S=1}^{M} PRF_{Sfp}\ . \tag{7}$$

The whole derivation process is completed of parameter P_{SWm} is based on the probability for successful deliveries to the amount of all deliveries during the time period for one supplier of material or finished products. F_S is failure of contracted supplier, q_{itsm} is number of in time delivered material of contracted supplier and n is the number of deliveries during the researched time period.

$$PRF_s = \frac{qit_{Sm}}{n} \tag{8}$$

The next important parameter to derive a model of decreasing costs is delivery performance of procurement to manufacturing (D_m). D_m is the sum of the availability percentage of material, semi-finished part for manufacturing through procurement based on the absolute performance of contractual or alternative contractual suppliers (P_{SWm}) and the availability of safety stock for these above items *(Xi/Qi)*. Indeed, procurement can deliver whatever quantities they received on time through suppliers plus their safety stock to the manufacturing. The same situation is also in the case of D_{fp}, which is the sum of percentage availability of finished part, which is dependent on the own manufacturing performance P_{fp} and also on the D_m, because the material and semi-finished products are inputs for final products and their performance are important for manufacturing and we must also calculate the availability of safety stock for finished products (X_{fp}/Q_{fp}).

Moreover, manufacturing can deliver whatever quantities of final products they can produce on time which is also dependent on the deliveries of their previous stages in the chain plus their own safety stock quantities to their customers.

The related formulas of D_m and D_{fp} are as (9) and (10):

$$D_m = P_{SWm} + (X_m/Q_m) \qquad m = 1,2.....n \tag{9}$$

$$D_{fp} = P_{fp} \cdot D_m + (X_{fp}/Q_{fp}). \quad fp = 1,2.....n \tag{10}$$

$D_m \leq 1$

$D_m \geq PSW_m$

$D_{fp} \leq 1,$

$D_{fp} \geq P_{fp} \cdot D_m.$

We must also emphasized, that P_{SWm} and P_{fp} are average numbers based on the historical firm's data from the last reviewed period. A report called the First Filled Rate (FFR) and it is used for calculation of these parameters (Amirjabbari, Bhuiyan, 2011). In our case study we use the historical data from corporate database, which has the same explanatory power like FFR. The FFR obtain the results the total on hand stock in its calculation, which does include safety stock. It means the presentation of availability of right part in the right time. It should be noted that P_{SWm} and P_{fp} should be the absolute delivery performance of supplier and manufacturing without the contribution of the safety stock that may be used during the last period. Therefore, the safety stock has been excluded from the FFR report for this purpose. Indeed, P_{fp} is the manufacturing performance without taking into account the stock out of raw materials (Aleotti, Qassim, 1998). Hence, with refer to (Amirjabbari, Bhuiyan, 2011) to calculate the required absolute value of P_{fp} from FFR, three other parameters should be defined. First one is K'_{fp} which is the exact number extracted through FFR, the other one is P'_{fp} which is the FFR's result excluding safety stock contribution. And the third one is D'_m which is the historical previous stage's delivery performance; by dividing this by P'_{fp} the absolute manufacturing performance is measured $(P_{fp}=P'_{fp}/D'_m)$.

IV. Computational Results of Model Bahareh Amirjabbari and Nadia Bhuiyan

The case study of these authors was performed in one aerospace industry company. Company is characterized by high demand variability and long lead time and it is multi-stage manufacturer. Company has two different manufacturing plants. The procurement of the company is responsible for materials and semi-finished product or even final products. Finished parts from manufacturing are sell to final costumers. The availability of parts in right time and right parts can be assured for the internal customers; on-time delivery performance to end customers will be assured as well. The availability should be guaranteed through safety stock, but optimal safety stock saves the costs not only in the firm, but also in the whole supply chain. Results of the model were applied in some chosen value streams. In our case study, we focused on the base value stream, which will be denoted by "A". The stream A contains supplier, procurement, manufacture, two customers and one material. The all inputs are characterized in the Tab.1. such as delivery performance, parts quantities, costs along the parameters required to calculate them (exact number from FFR - $D'f_p$, P'_{fp} – FFR results without safety stock and historical delivery data of performance - D'_m). The table also shows the level of new and old safety stock and total costs to compare previous situation with new one. Authors mentioned that due to confidentiality the data were masked.

Shortage costs of two main customers are the first highest costs, so the model focused to this problem. Recommend to increased delivery performance to 100% be keeping safety stock for finished parts. These two main customers must compensate 39% and 70% of unavailability of parts by asking manufacturing to keep safety stock. Then the third and fourth are overage costs of same entities. Hence, the model suggests keeping some level of safety stock in the raw material as well to lover the level of finished parts, because how we mentioned above, the delivery performance of procurement to manufacturing is part of or conditionality the delivery performance of manufacturing finished parts to other departments of firm or to final customers. It is shown that procurement can count on-time delivery performance about 57% and they have to reimburse 43% by having safety stock. Safety stock has been increased in both levels of supplier and manufacturing, of course before applying the recommend and capacity will be set up due to new demand and input respectively.

Table 1 : Results of value stream “A“ in model of authors Amirjabbari and Bhuiyan

Value stream	A	A	A
Part	B	AB	AB
Entity	MF	C1	C2
D'_m	0,65	-	-
P_m	0,57	-	-
Q_m	1400	-	-
P'_{fp}	-	0,4	0,2
P_{fp}	-	0,61	0,3
Q_{fp}	-	1100	900
D'_{fp}	-	0,53	0,46
Costs	40$	120$	120$
CS	2$	500$	480$
CO	4$	12$	12$
Old X_m	0&500	-	-
New X_m	602$	-	-
Old X_{fp}	-	1&8	300
New X_{fp}	-	429	630
Total old cost	497 732$		
Total new cost	15 116$		

V. Final Minimize Cost Model – Case Study

The case study was undertaken in one food company on the middle Moravia in Czech Republic. The company produces a wide array of food products like snacks, cookies, cereals etc. In our case we use simplifying value stream *(j)* of two suppliers with product (material) of corn flour. This case is so little limited, because it is very hard to capture for example shortage costs in upstream stages of supply chain, but for our necessities is important the existence of suppliers in the supply chain with existing some products and end customers. This value stream is described on the Fig.2 and mathematical express by equation (11). The average order of corn flour is 7.8 tons and these delivering cycles are eight times per month. In year 2010 the firm used 750 tons of corn flour and safety stock is set up on the 20% of one month delivering amounts, it means 13 tons. The costs are 8020 CZK per one ton. Sale price of product is 16 CZK per one piece. All necessary inputs of equation are illustrated in the Tab.2. Furthermore, the aim of the model is cost minimization and the upstream stages' contributions towards cost are significantly less than the downstream stages, thus this simplifying assumption should have a negligible effect on overall results (Amirjabbari, Bhuiyan, 2011).

Global Journal of Human-Social Science (E) Volume XIV Issue I Version I Year 2014

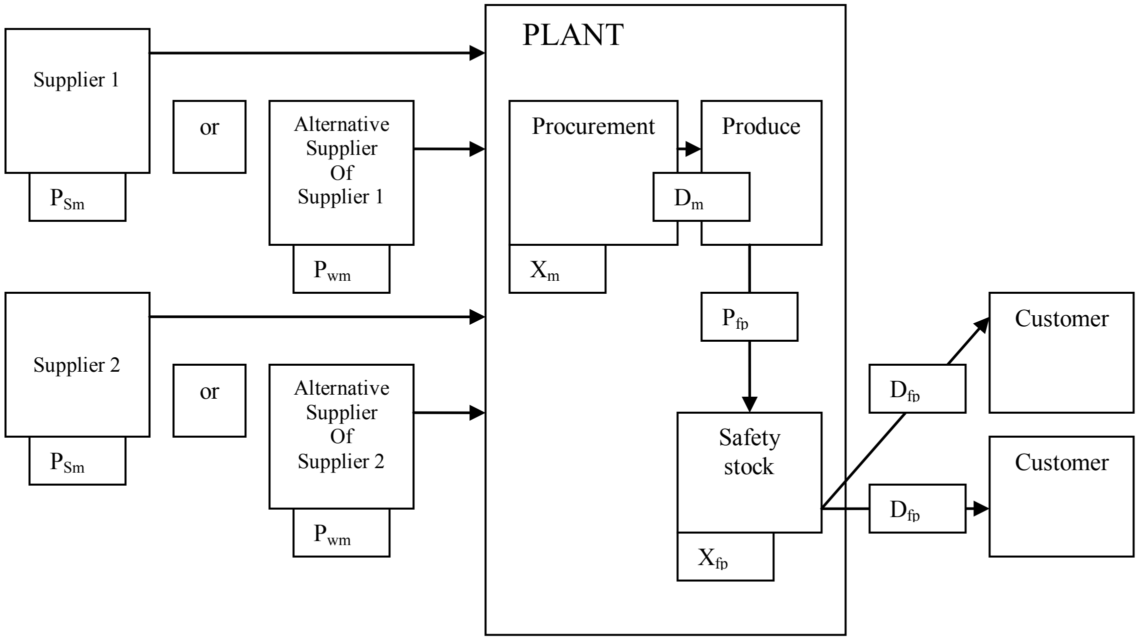

Figure 2 : Stream of material and finished products in supply chain

Table 2 : Inputs of model for case study

Probability of delivery contracted supplier	98%
Probability of delivery alternative supplier	90%
Price per one ton – contracted deliver	8.000 CZK/ton
Price per one ton – alternative supplier	9.000 CZK/ton
Consumption	750 tons/year
Wage costs	1 CZK/kg
Sale price	16 CZK/pcs.
Safety stock 20% from 1 order	13 tons (0,2 · 62.4)
Amounts per one month	62,4 tons
Costs stock of finished products	1,2 CZK/kg
Profit	5,65 CZK/pcs.
Interest rate	1,5%

The equation (11) contains the sum of two suppliers (contracted + alternative) with their costs of shortages. It is very important, because, when supplier is not able to deliver the desired amount of material or finished products, company lost the potential customers. Parameter q_{SWm} means on-time delivered material in number of pieces. Expression $(1 - P_{SWm})$ is difference between supplier delivery performance to procurement and boundary of delivery level, which is adjustment to 100%. This parameter setting limits the level of service can take values in the interval 0 to 1. Parameter CO_{SWm} are the costs of overage of material, D_m is delivery performance of procurement to manufacturing, $CS_{fp,c}$ are shortage costs of finished products for customers, and $q_{fp,c}$ is on time delivered finished products for customer. The sum is product of on time delivered amounts of material with difference between delivery performance of procurement to manufacturing and supplier delivery performance to procurement. The second part of equation deals with the problem of finished products. In our case we have sum of two customers, which are join with also shortages and overages costs. Expression $(1 - D_{fp,c})$ is difference between level of deliveries to customers, which is adjust on 100% and identified real fact. The last part of equation $D_{fp,c} - (P_{fp,c} D_m)$ is difference between delivery performances of manufacturing or procurement to costumers and product of manufacturing performance for finished part with delivery performance of procurement to manufacturing for material, because the finished products are depend on the material flows.

$$C_j = \sum_{S}^{3} \sum_{W}^{3} \sum_{m}^{3} \left[CS_{SWm} q_{SWm} (1 - P_{SWm}) + CO_{SWm} q_{SWm} (D_m - P_{SWm}) \right] + \sum_{fp=1}^{1} \sum_{c=1}^{2} \left[CS_{fp,c} q_{fp,c} (1 - D_{fp,c}) \right] +$$

$$+ \sum_{fp=1}^{1} \sum_{c=1}^{2} \left[CO_{fp,c} q_{fp,c} (D_{fp,c} - (P_{fp,c} D_m)) \right] \qquad (11)$$

The first part of given above equation is determining the cost of shortage (CS_{SWm}) of contracted and alternative supplier. This calculation comes from price of one ton corn flour. The one ton of corn flour costs 8.020 CZK. From data of firm, one ton corn flour by contracted supplier cost 8.000 CZK and by alternative supplier 9.000 CZK. The result price is product of probability of delivery with particular given price.

Price of corn flour per one ton = [(0,98 · 8.000) + (0,02 · 9.000)] = 8.020 CZK. It means that 98% of all corn flour is delivered by contracted supplier and 2% of alternative supplier with given prices. The price 8.020 CZK is also potential lost, because company lacks this material for next treatment. In reality we have cash, but we do not have material, so we can not calculate with some interest rate in this case.

Expression $(1 - P_{SWm})$ is difference between supplier delivery performance to procurement and boundary of delivery level, which is adjustment to 100%, from this reason constant 1. Delivery performance is product of delivery performance of contracted supplier and alternative.

$P_{SWm} = 0{,}98 \cdot 0{,}9 = 0{,}882$; so difference will be equal *0,118* like *(1 – 0,882)*.

CO_{SWm} are costs overage of material and it is sum average amount of corn flour in tons in the safety stock + wage costs + interest rate. The average amount inventory in safety stock of corn flour from firm's historical data is 21,4 tons per month. Because the average price is 8.020 and average inventories are 21,4 so it is multiple of *21,4 · 8.020 = 171.628* CZK. It means that average sum represents 171.628 CZK. The numbers of deliveries per month are 8 and it means that 21.454 CZK could be add to one delivery *(171.628/8 = 21.454)*. To this amount it is needs to tack the amount 21.400 CZK, which represents the wage costs (21.400 kg · wage 1CZK/kg) + interest rate, which is 1,5%, that is multiple

[(21.454 + 21.400) · 0,015] = 642,81 CZK. The final result of CO_{SWm} is 43.496 CZK.

D_m is delivery performance of procurement to manufacturing and in our case is set up on the 100%, so it means constant 1. It is from the reason, that procurement are able to delivered the desired amount and the also firm has average inventory of 21.4 tons in safety stock From historical data firm had consumption in last period of 750 tons and one order quantity is 7,8 tons on the base of optimal cost of order quantity, so it means that this order quantity cover the demand of costumers.

The second part of equation is focused to final products. Again we can meet with costs of shortage and overage, but in the case of final products.

CS_{fpc} are shortage costs of finished products for customers, and $q_{fp,c}$ is on time delivered finished products for customer. The sale price of product is set up on the 16 CZK per one piece. From one order quantity of 7,8 tons, the company is able to produced 7.500 pieces of product. The parameter $D_{fp,c}$ is 1, because it is delivery performance of procurement or manufacturing to customers. It is logical, because, then parameter D_m is set up on the 100%, the $D_{fp,c}$ is also 100%, because it is parameter, which is derived from parameter D_m. In our case the costs of shortage is multiple of *(16 · 7500 · (1 – 1))*, so it means 0. In this case, the company has enough material to produce the desired amount of products and in addition the company has 21.4 tons of material on the safety stock, so the threat of shortage should be not happen.

The second part of product costs is link up with overage costs. The expression

$[(CO_{fp,c} \cdot q_{fp,c}) \cdot (D_{fp,c} - (P_{fp,c} \cdot D_m))]$ is sum of above mentioned costs. The sum of overage costs per one product will be purchase price per one kilogram of material + wage costs in safety stock of material + production and labor costs + interest rate. In our case it is sum *[(8,02 + 1 + 1,2) + 1,5%]* interest rate. The costs are 10,353 CZK per one piece of product.

The last parameter in our model is defined (P_{fp}) that is manufacturing performance for finished part (ratio between on time manufactured and planned manufactured of finished part). From historical data of firm was found the value 0,98. So it means that 98% of all products were delivered in time.

The expression $[CO_{fp,c} \cdot q_{fp,c} \cdot (D_{fp,c} - (P_{fp,c} \cdot D_m))]$ is equal *[10,353 · 7.500 · (1 – (0,98 · 1))]* so it is value 1.552,95 CZK.

VI. Final Result of Model in Case Study

For better clarity of results we remind the prescription of equation in given case study.

$$C_j = \sum_{S}^{3} \sum_{W}^{3} \sum_{m}^{3} \left[CS_{SWm} q_{SWm} (1 - P_{SWm}) + CO_{SWm} q_{SWm} (D_m - P_{SWm})\right] + \sum_{fp=1}^{1} \sum_{c=1}^{2} \left[CS_{fp,c} q_{fp,c} (1 - D_{fp,c})\right] +$$

$$+ \sum_{fp=1}^{1} \sum_{c=1}^{2} \left[CO_{fp,c} q_{fp,c} (D_{fp,c} - (P_{fp,c} D_m))\right].$$

Global Journal of Human-Social Science (E) Volume XIV Issue I Version I Year 2014

After the derivation of all parameters in the model, the resulting equation of value stream (C_j) will have the following form.

C_j = [8.020 · 7,8 · (1 – 0,822) + (21 454 + 21 400 + 643) · (1- 0,822)] + [16 · 7.500 · (1 – 1)] + [(10,353 · 7.500 · (1 – (0,98 · 1))] =[(62.556 · 0,118) + (43.496 · 0,118)] + [0] + [10,353 · 7.500 · 0,02] = 7.381,61 + 5.132,53 + 1.552,95 = 14.067,09 CZK.

The cost of one order quantity of corn flour is 14.067 CZK. When we multiply this amount of costs of value stream with number of deliveries per month, we final result will be 112.537 CZK. From result costs of value stream in the given products of corn flour, we can observe some interesting conclusion. At first, the level of safety stock is unnecessarily high. The order quantity is set up on the minimal order costs, but from this optimization model influenced, that the minimal order costs should not be the main requirement for order system in company. The level of 20% from month order quantity is so high a bind the financial resources for others activities, in addition also wage costs will decrease with smaller amount of material. Second the parameter $P_{fp,c}$ trying to increase to more than 98%, it could has it better impact on the loyalty of customers and firm could improve company name itself on the competitive market. Third, trying to redesign the probability of delivery of given supplier to achieve better results and decreased costs, which are linked up with supply chain like (monitoring of contracts, search of new suppliers, administration). In the end of this section, it should be mentioned, that everything should be set up by way of new data of demand and forecast of customers and take account all relationships in the internal and external environment of company.

VII. Conclusion

The article deals with the cost model for minimum costs in supply chain and improves by suitable way to adjustment of safety stock. It should be mentioned, that this model is not versatile for all cases, which could happen in the firm, but this model reveals the importance of suppliers in the supply chain management, particularly the role of alternative suppliers and try to compensate the weakness of the supply chain. The ability of deliver the right goods or material in the right time is now evaluate like very good competitive advantage (Mentzer, 2001). If the supplier does not deliver the desired amount and quality, the plant must expend the finances to find new alternative suppliers. This process brings the higher costs of transportation, administrative function, overtime etc. Failure of non-delivery is then reflected in the company itself. Plants are not able to deliver the finished products to their customers, and firm lost the potential profit, but also the trust of these customers and goodwill of firm, which is very hard to quantify the costs of losing reputation. We can talk about domino effect.

The set up of safety stock is then based on the combination of suppliers and alternative suppliers and their delivery performance with combination of better demand forecast, trust between customer and supplier, communication or relative new approach of vendor managed inventory, precise and unambiguous requirements of individual business units and these important facts actually help to reduce the costs in whole supply chain. In case study of authors Amirjabbari and Bhuiyan in their base value stream, pointed out the importance of shortage and overage costs by two main customers. They trying to find some optimal level of safety stock not only in the area of procurement material, but also in safety stock of finished products in the line with increased delivery performances. In this case value stream the role of increasing delivery performance is particularly important, because the delivery of performance also influenced the performance of manufacture. Depending on these facts, the level of safety stock in manufacture could not be so high and company saves the cash and on the other hand the high level of material safety stock improves the situation in manufacture. Through this procedure, the company can improve its profitability more than 480.000 dollars, become more competitive in the market and can for example make resourcing of theirs suppliers, improving quality, increasing capacity, etc.

In the case study of Czech firm we can meet also with some interesting results. At first the role of safety stock is so high oversized and binds financial resources, reveal the opportunity to redesign of suppliers and manufacture performance. In addition with combination of implementing seasonal logistics tactics for finished goods distribution (Tardiff, Tayur, Reardon, Stines and Zimmerman, 2010), this model could be very helpful for firms with seasonal demand, because the Czech firms also deals with seasonal demand.

In addition, it should be mentioned, that every firm used its own delivery system (lot for lot, fixed amount of delivery) and management of stocks (kanban, manufacturing resource planning) and these facts also influence the safety stock of given firm and relationship between firm and suppliers and their performances, but also the level and location in the supply chain of safety stock is important. Accurate definitions of the inputs in the model such like costs, quantities of the parts are critical to find the appropriate level and location of safety stock with setting limits on the ability of a delivery that may not be strictly 100%.

In the next research it will be appropriate to used simulations programs to compare the useful of model in the various approaches of stock management. Also the enhancing of visibility and control of the upstream stage will be more helpful to set up the level and location of safety stock in supply chain and research with sufficient temporal data may show trend and thus the development costs over time based on various economic fluctuations.

Appendix A

Sets and Indices

m - raw material/semi-finished part
fp - finished part
c - customer (internal plant, end customer)
S - contracted supplier in given supply chain
W - alternative supplier

Parameters

P_{SWm} - supplier delivery performance to procurement (if supplier is a manufacturing plant, then P_{SWm} would be manufacturing performance for semi-finished part)
P_{fp} - manufacturing performance for finished part (ratio between on time manufactured and planned manufactured of finished part)
CS - costs of shortage [currency unit per unit]
CS_m - costs shortage of material, semi-finished products [currency unit per unit]
$CS_{fp,c}$ - costs shortage of finished products of customer [currency unit per customers]
CO - costs of overage [currency unit per unit]
CO_{SWm} - costs overage of material of contracted supplier and alternative supplier [currency unit per unit]
$CO_{fp,c}$ - costs overage of finished products for customers [currency unit per customers]
D_m - delivery performance of procurement to manufacturing [%]
D_{fp} - delivery performance of manufacturing or procurement to costumers [%]
$D_{fp,c}$ - delivery performance of manufacturing or procurement to costumers [%]
$P_{fp,c}$ - manufacturing performance for finished part to customers [%]
P_{Sm} - supplier delivery performance to procurement of material [%]
P_{Wm} - alternative supplier delivery performance to procurement of material [%]
P_{SWm} - delivery performance of contracted supplier + alternative supplier [%]
X_m - raw material/semi-finished part safety stock [unit]
X_{fp} - finished part safety stock [unit]
Q_m - raw material/semi-finished part quantity ordered [unit]
Q_{fp} - finished part quantity ordered [unit]
PR - probability [%]
PRF_{Wm} - probability of failure for alternative supplier of material [%]
PRF_{Wfp} - probability of failure for alternative supplier of finished products [%]
PRF_{Wfpm} - probability of failure for alternative supplier of finished products and material [%]
PR_{SWm} - probability of deliver for contracted supplier + alternative supplier [%]
$PRqit_{SWm}$ - probability of deliver in right time of supplier + alternative supplier of material [%]
$PRqit_W$ - probability of in-time delivered of alternative supplier [%]
$PRqit_{Wm}$ - probability of in-time delivered of alternative supplier of material [%]
$PRqit_{Sm}$ - probability of in-time delivered of contracted supplier of material [%]
PRF_{Sfp} - probability failure for supplier of final products [%]
PRF_{Sm} - probability failure for supplier of material or semi-finished products [%]
$PRF_{W,fp,m}$ - probability of failure for alternative supplier of material and finished products
F - failure of delivery [%]
F_{Sm} - the percentage of failures in delivery of material or semi-finished products by supplier during the last reviewed period [%]
F_{Sfp} - the percentage of failures in delivery of finished products by supplier during the last reviewed period [%]
F_{Wm} - the percentage of failure of delivery for alternative supplier for material, semi-finished products [%]

F_{Wfp} - the percentage failure of delivery for alternative supplier for finished products [%]
q_m - delivered material [unit]
$q_{fp,c}$ - delivered finished products for customer [unit]
q_{SWm} - delivered material by contracted supplier + alternative supplier [unit]
qit - in-time delivered quantity of material, finished products [unit]
qit_{Sm} - in-time delivered quantity of material, intermediate product of supplier [unit]
qit_W - in-time delivered quantity of alternative supplier [unit]
qit_{Wm} - in-time delivered quantity of material, intermediate product of alternative supplier [unit]
n - the number of deliveries per reviewed period [number of orders]

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