$$HC = C_{h_i}\left[{Q_i}/{2} + SS_i + (1-\alpha_i)E(X_i - r_i)^+\right] \tag{3}$$

Where:
HC: Total holding cost,

C_{hi}: Inventory holding cost per one unit,
Q: Order quantity (a decision variable),
SS: Safety factor,
α: Fraction of back-ordered demand during the stock-out period $0 \leq \alpha_i \leq 1$,
$E(X-r)^+$: Expected number of shortage,
i= SKU index.

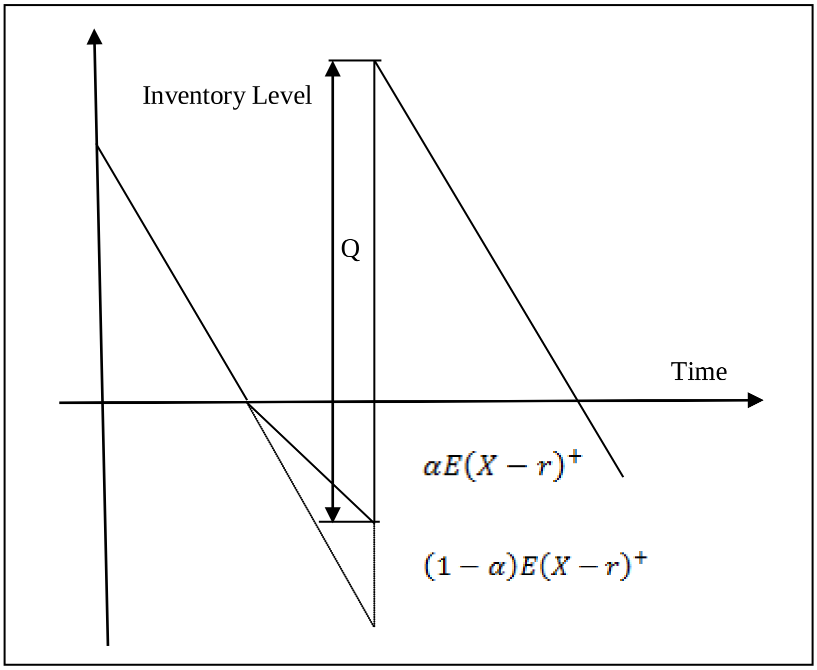

Figure 1. Inventory model with partial back orders

Based on the questionnaire result, the received order is not totally accepted because it may contain a percentage of defects (p). The defect items are instantaneously removed from the received order and refunded to their suppliers. Therefore, the received order quantity is reduced by the factor $(1-p)$. Therefore, the suppliers' share factor is used to calculate the total weighted average holding. Hence, (3) is reformulated to be applicable to the proposed model.

$$HC = C_h\left[{\sum_{j=1}^{m} Q_j(1-p_j)\vartheta_j}/{2} + SS + (1-\alpha)E(X-r)^+\right] \tag{4}$$

The safety stock is defined as the difference between the reorder point and the expected demand during the lead time (Bera et al., 2009; H.-C. Chang et al., 2006; H. Chang et al., 2004; Lin, 2008; Ouyang & Yao, 2002; Varnas et al., 2009) and can be calculated as per equation (5).

$$SS_i = r_i - E(x_i) = k_i\,\sigma_{x_i} \tag{5}$$

Where:

E(x): Expected demand during lead time,
r: Reorder point,
k: Safety factor,
σ_x: Standard deviation of lead time demand.

Chopra & Meindl (2016) calculated the safety stock for a single SKU as per (6).

$$SS = F_s^{-1}(CSL)\sigma_x \tag{6}$$

Where:

CSL: Cycle service level,

F_s^{-1}: The inverse of the cumulative standard normal distribution.

Using equations (5) and (6), it can be concluded that the optimal safety factor should equal the inverse of the cumulative standard normal distribution of optimal cycle service level:

$$\therefore k = F_s^{-1}(CSL) \tag{7}$$

CSL is equal to the probability of having no stock out in a replenishment cycle(Chopra & Meindl, 2016) and the optimal CSL can be calculated as:

$$CSL^* = \frac{C_u}{C_u + C_o} \tag{8}$$

Where:

C_u: Under-stock cost,

C_o: Over-stock cost.

The cost of under-stocking is the margin lost by a firm for each lost sale (lost profit) because there is no inventory on hand (Chopra & Meindl, 2016).

$$\therefore C_u = sales\ price - purchasing\ cost = S_p - C_p \tag{9}$$

Where:

S_p: Selling price of one sold unit.

As previously mentioned, the purchasing cost should be multiplied with suppliers' share factor to calculate the total weighted average purchasing cost for the available suppliers. Then, the under-stock cost is calculated per (10).

$$\therefore C_u = S_p - \sum_{j=1}^{m} C_{p_j} \vartheta_j \tag{10}$$

The cost of over-stock is the loss occurred by a firm for each unsold unit at the end of the selling cycle (Chopra & Meindl, 2016).

$$\therefore C_o = holding\ cost\ on\ reprenshment\ cycles = \frac{annual\ holding}{number\ of\ orders} = \frac{C_h}{N} \tag{11}$$

Where:

N: Total number of orders per cycle time.

The number of orders from each supplier (j) (N_j) of a single SKU per the cycle time can be calculated per (12).

$$N_j = \frac{D_j}{Q_j} \tag{12}$$

The total number of orders for a single SKU from multi suppliers can be calculated per (13).

$$\because N = \sum_{j=1}^{m} N_j \tag{13}$$

From (12) and (13), the total number of orders as a function of D and Q is calculated per (17).

$$\therefore N = \sum_{j=1}^{m} \frac{D_j}{Q_j} \tag{15}$$

$$\because D_j = D * \vartheta_j \tag{16}$$

$$\therefore N = D \sum_{j=1}^{m} \frac{\vartheta_j}{Q_j} \tag{17}$$

Equation (17) is substituted in (11) to calculate the appropriate over-stock cost for the proposed model

$$\therefore C_o = \frac{C_h}{D} \sum_{j=1}^{m} \frac{Q_j}{\vartheta_j} \tag{18}$$

Equations (10) and (18) are substituted in (8) to calculate the optimal cycle service level.

$$\therefore CSL^* = \frac{C_u}{C_u + C_o} = \frac{S_p - \sum_{j=1}^{m} C_{p_j} \vartheta_j}{S_p - \sum_{j=1}^{m} C_{p_j} \vartheta_j + \frac{C_h}{D} \sum_{j=1}^{m} \frac{Q_j}{\vartheta_j}} \tag{19}$$

Subsequently, the safety factor can be calculated per (20) after substituting by (19) in (7).

$$k = F_s^{-1}(CSL^*) = F_s^{-1}\left(\frac{S_p - \sum_{j=1}^{m} C_{p_j} \vartheta_j}{S_p - \sum_{j=1}^{m} C_{p_j} \vartheta_j + \frac{C_h}{D} \sum_{j=1}^{m} \frac{Q_j}{\vartheta_j}} \right) \tag{20}$$

The standard deviation of lead-time demand was calculated per (21) (Chopra & Meindl, 2016).

$$\sigma_x = \sqrt{L_j \sigma^2 + D^2 \sigma_{L_j}^2} \tag{21}$$

Where:

L_j: Lead time of supplier j,

σ^2: Variance of demand,

$\sigma_{L_i}^2$: Variance of lead time.

The lead-time is multiplied with suppliers' share factor to get the total weighted lead time of all the available suppliers to supply the same SKU.

$$\sigma_x = \sqrt{\sigma^2 \sum_{j=1}^{m} \vartheta_j L_j + D^2 \sum_{j=1}^{m} \sigma_{L_j}^2} \tag{22}$$

Equations (20) and (22) are substituted in (6) to calculate the safety stock for a single SKU from multi suppliers.

$$\therefore SS = F_s^{-1}\left(\frac{S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j}{S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j + \frac{C_h}{D}\sum_{j=1}^{m}\frac{Q_j}{\vartheta_j}}\right)\sqrt{\sigma^2 \sum_{j=1}^{m} \vartheta_j L_j + D^2 \sum_{j=1}^{m} \sigma_{L_j}^2} \tag{23}$$

The expected shortage quantity at the end of the cycle was calculated as a function of safety factor per (24) (Annadurai & Uthayakumar, 2009; C. Chang & Lo, 2009; Chopra & Meindl, 2016; Yang et al., 2005).

$$E(X-r)^+ = \sigma_x [f_s(k)] - SS[1 - F_s(k)] \tag{24}$$

Where:

f_s *and* F_s, are the standard normal probability density function (pdf) and the cumulative distribution function (CDF) respectively. Those are originated in the standard normal distribution tables.

Then, equations (22), (20) and (23) are substituted in (24) to be appropriate in the proposed model.

$$E(X-r)^+ = \sqrt{\sigma^2 \sum_{j=1}^{m} \vartheta_j L_j + D^2 \sum_{j=1}^{m} \sigma_{L_j}^2}\; f_s\left\{F_s^{-1}\left(\frac{S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j}{S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j + \frac{C_h}{D}\sum_{j=1}^{m}\frac{Q_j}{\vartheta_j}}\right)\right\}$$
$$-\left\{F_s^{-1}\left(\frac{S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j}{S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j + \frac{C_h}{D}\sum_{j=1}^{m}\frac{Q_j}{\vartheta_j}}\right)\right\}\sqrt{\sigma^2 \sum_{j=1}^{m} \vartheta_j L_j + D^2 \sum_{j=1}^{m} \sigma_{L_j}^2}\left[1 - \left(\frac{S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j}{S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j + \frac{C_h}{D}\sum_{j=1}^{m}\frac{Q_j}{\vartheta_j}}\right)\right] \tag{25}$$

The order cost is the cost of dealing with replenishing the inventory stock. It is typically evaluated as the dollar amount per order. The order cost also depends on the number of orders per cycle (H.-C. Chang et al., 2006; H. Chang et al., 2004; Ouyang & Yao, 2002; Varnas et al., 2009).

$$OC = C_k \frac{D}{Q} \tag{26}$$

Where:

OC: Total ordering cost,

C_k: Ordering cost per order.

To accommodate multi suppliers, equation (26) is reformulated as:

$$\therefore OC = D \sum_{j=1}^{m} C_{k_j}\vartheta_j / Q_j \tag{27}$$

Some of the demand will not be satisfied due to insufficient inventory and intolerant customers. Therefore, shortage cost or stock-out cost is the total of all costs associated with shortage units. The effect of backorder, lost sales, and shortage penalty costs are considered by several researchers. They calculated the shortage cost per (30) (H.-C. Chang et al., 2006; H. Chang et al., 2004; Lin, 2008; Ouyang & Yao, 2002).

$$SC = \frac{D}{Q}[C_S + \pi(1-\alpha)]E(X-r)^+ \tag{28}$$

Where:

SC: Total shortage cost,

C_S: Penalty cost,

π: Lost profit.

To consider multi suppliers sourcing, equation (28) is reformulated as follows:

$$SC = \sum_{j=1}^{m} \frac{D\vartheta_j}{Q_j}[C_S + \pi(1-\alpha)]E(X-r)^+ \tag{29}$$

$$\because \pi = S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j$$

$$\therefore SC = D\left[C_S + \left(S_p - \sum_{j=1}^{m} C_{p_j}\vartheta_j\right)(1-\alpha)\right]\sum_{j=1}^{m}\frac{\vartheta_j}{Q_j}\; E(X-r)^+ \tag{30}$$

The proposed model split the orders between the available suppliers. Moreover, it accumulates the percentage of quantities that are taken from the available suppliers for the same SKU per the cycle time. Therefore, the total suppliers share factor for a single SKU during the cycle time must be equal to 1.

$$\sum_{j=1}^{m} \vartheta_j = 1 \tag{31}$$

To keep the supplier active, some orders should be assigned to him during the cycle. Therefore, an arbitrary lower limit should be assigned to suppliers' share factor, which should satisfy (32) to keep a feasible solution.

$$\sum_{j=1}^{m} \vartheta_{l_j} < 1 \tag{32}$$

Where:

ϑ_l: Lower-bound of suppliers' share factor.

According to Bera et al. (2009), the budget constraint was formulated in which the total purchasing cost was less than or equal to the available budget.

$$\left[BC = \sum_{i=1}^{n} C_{p_i}(Q_i + r_i - E(x_i))\right] \le B \tag{33}$$

Where:

BC: Budget constraint,

B: Available budget.

Equation (33) is reformulated to consider multiple suppliers, defective goods return, sales during credit time, backorder and lost sales as follows:

$$\left[BC = C_{p_j}\left[Q_j(1 - p_j) - E\left(Y(t_j)\right) - \alpha E(X - r)^+ + SS\right]\right] \le B \quad \forall j \tag{34}$$

Therefore, the total cost can be minimized using (3), (4), (23), (25), (27), (30), (31), (32) and (34) as per the below model

$$Min\ TC (= PC + HC + OC + SC)$$

S.T.

$$\sum_{j=1}^{m} \vartheta_j = 1 \qquad \forall j$$
$$\sum_{j=1}^{m} \vartheta_{l_j} < 1 \qquad \forall j$$
$$BC \le B \qquad \forall j$$
$$Q_i \ge 0 \qquad \forall j \qquad and\ integer$$
$$\vartheta_j \in \left[\vartheta_{l_j}, 1\right] \qquad \forall j$$

Based on the above model, a three-stage algorithm shown in figures (2) and (3) is used to find the needed decisions variables. The first phase is to address the selected suppliers' list. During the second phase, the selected suppliers' list is queried to assign shares to the selected suppliers. After that, the total cost is calculated. During this phase, the optimum orders quantity and the suppliers' share factor are calculated to minimize the total cost under the given conditions.

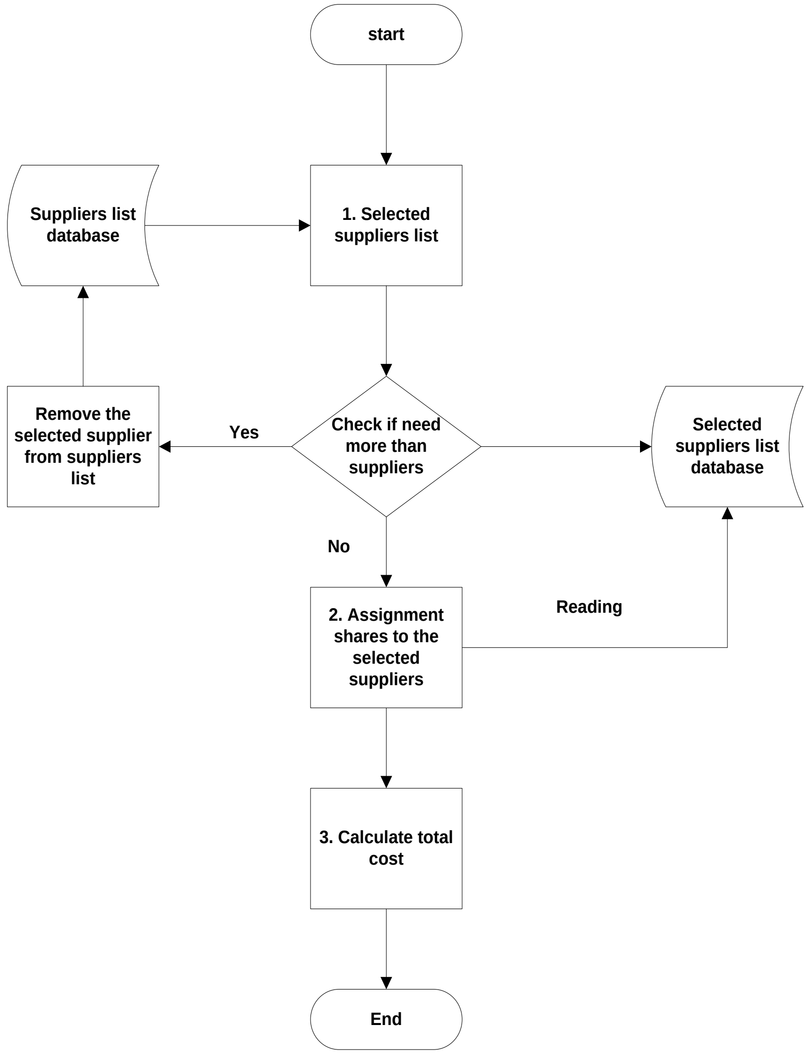

Figure 2: Flowchart of the proposed model algorithm.

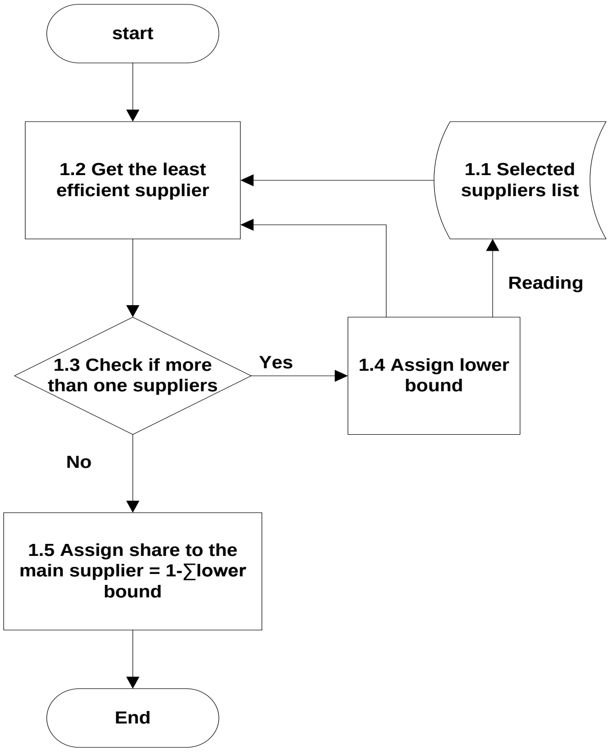

Figure 3: Flowchart of assigning shares to the selected suppliers.

5. Case Study

To validate the proposed model, a set of MATLAB functions is developed to simulate the proposed model using MINLP (mixed integer nonlinear programming) and FMINCON solver. The model is tested using data obtained from a food manufacturer in Cairo, Egypt. The company uses 17 main raw material items supplied by 24 suppliers. The company policy is to keep two active suppliers for each of its main raw material items. The company-planning manager chooses 10% as the minimum order share a supplier can have to be considered as an active supplier for an item.

Based on final product bill of material (BOM) (as shown in figure 4), the shortage in any raw material of the company results in a shortage of the final product due to the below two assumptions:

- There is no replacement of raw material.
- There is no significant stock in the final product due to its short shelf time.

Therefore, the raw material lost profit is calculated based on the lost profit of the final products. Data obtained from the company is used to run the MATLAB functions to get the optimal supplier share and the optimal order cost of each of the 17 items, as shown in table III. The model successfully selected the most economical suppliers and assigned them the largest feasible share of the item demand, while assigning the forced minimum share to the backup supplier. Then the system calculated the optimal order quantity, the optimal reorder point, the optimal safety stock, and the optimal cycle service level. Comparing the actual costs in 2013 to the costs that would occur if the company used the data from the model revealed that the company would save 17.45% of its total inventory cost in 2013 by using the proposed model.

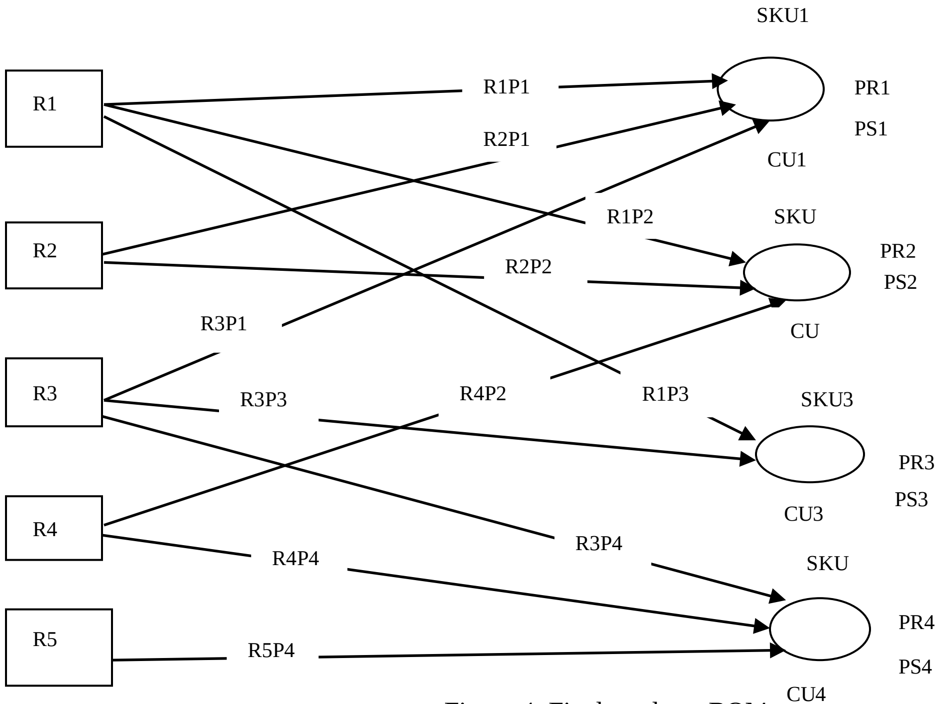

Figure 4: Final products BOM.

A second case study is created by doubling the lead-time of the main supplier while keeping the lead-time of the backup supplier unchanged. The new data is re-used with the MATLAB functions to get the optimal procurement policies for each of the 17 items as shown in table IV. Comparing Table (1) and Table (2) shows that the model responded logically by getting higher optimal total cost when the lead-time lead was increased. Moreover, the model was able to alternate its selection of the main supplier when he became less economical than the backup one (items number 5, 6, and 12).

Table1. The optimal solution of the default data for the system.

	Main supplier			Backup supplier			Optimal total cost
	Code	Q*	0.9	#	Q*	%	235,800
1	A	4,791	0.9	B	1,996	0.1	235,800
2	A	4,218	0.9	C	1,821	0.1	81,900
3	A	3,634	0.9	D	1,651	0.1	116,800
4	A	1,470	0.9	C	900	0.1	24,800
5	E	95,380	0.9	F	15,870	0.1	1,307,300
6	G	30,274	0.9	H	6,806	0.1	318,100
7	J	9,042	0.9	M	2,054	0.1	331,800
8	J	9,002	0.9	N	2,031	0. 1	58,400
9	J	2,835	0.9	O	1,082	0.1	90,400
10	L	2,516	0. 9	O	819	0. 1	12,700
11	I	1,774	0.9	Q	940	0.1	90,100
12	I	936	0.9	R	934	0.1	41,900
13	S	15,559	0.9	T	5,555	0.1	650,600
14	U	17,853	0.9	V	4,718	0.1	187,100
15	W	3,613	0.9	X	1,621	0.1	110,600
16	Y	299	0.9	Z	243	0.1	26,900
17	Y	1,025	0.9	Z	656	0.1	9,600

Table 2. The optimal solution after changing the lead time.

	Main supplier	Backup supplier	Optimal total cost

	Code	Q*	0.9	#	Q*	%	235,800
1	A	5,110	0.9	B	1,660	0.1	236,400
2	A	4,480	0.9	C	1,510	0.1	82,400
3	A	3,840	0.9	D	1,370	0.1	117,100
4	A	1,520	0.9	C	740	0.1	24,900
5	E	15,890	0.1	F	140,460	0.9	1,378,300
6	G	6,880	0.1	H	29,470	0.9	329,900
7	J	12,470	0.9	M	3,050	0.1	336,800
8	J	11,430	0.9	N	2,110	0.1	63,100
9	J	1,850	0.9	O	320	0.1	91,100
10	L	2,820	0.9	O	700	0.1	13,300
11	I	790	0.9	Q	600	0.1	91,100
12	I	230	0. 1	R	940	0. 9	49,900
13	S	16,900	0.9	T	4,750	0.1	653,700
14	U	20,880	0.9	V	4,450	0.1	196,400
15	W	3,840	0.9	X	1,340	0.1	111,200
16	Y	230	0.9	Z	180	0.1	27,100
17	Y	1,060	0.9	Z	550	0.1	9,700

6. Conclusion

Suppliers' selection and orders' quantity models based on continuous inventory review were heavily addressed by procurement literature. Eighteen different factors have been identified to characterize procurement models. A questionnaire with procurement specialists of thirty-two manufacturing companies has been used to select the critical factors for them. The questionnaire has illustrated that procurement specialists need a model that can handle orders splitting of the same item among multi suppliers while considering the quality and the lead-time of those suppliers. Having different holding cost for different items and different prices for the same items at different prices are considered critical aspects of their desired model. On the other hand, payment term, minimum order quantity, ordering cost, and long-term contracts have not been critically requested by the respondents.

The proposed model is tailored to small and medium-sized manufacturing companies. Therefore, characterizing the procurement model needed for non-manufacturing and large enterprises may be research-worthy.

References

Annadurai, K., & Uthayakumar, R. (2009). Controlling setup cost in (Q, r, L) inventory model with defective items. *Applied Mathematical Modelling*, *34*, 1418–1427. https://doi.org/10.1016/j.apm.2009.04.010

Arabsheybani, A., Paydar, M. M., & Safaei, A. S. (2018). An integrated fuzzy MOORA method and FMEA technique for sustainable supplier selection considering quantity discounts and supplier’s risk. *Journal of Cleaner Production*, *190*, 577–591. https://doi.org/10.1016/J.JCLEPRO.2018.04.167

Babbar, C., & Amin, S. H. (2018). A multi-objective mathematical model integrating environmental concerns for supplier selection and order allocation based on fuzzy QFD in beverages industry. *Expert Systems with Applications*, *92*, 27–38. https://doi.org/10.1016/J.ESWA.2017.09.041

Bera, U. K., Rong, M., Mahapatra, N. K., & Maiti, M. (2009). A multi-item mixture inventory model involving random lead time and demand with budget constraint and surprise function. *Applied Mathematical Modelling*, *33*(12), 4337–4344. https://doi.org/10.1016/j.apm.2009.03.025

Chandra, C., & Grabis, J. (2008). Inventory management with variable lead-time dependent procurement cost . *Omega*, *36*(5), 877–887. https://doi.org/10.1016/j.omega.2006.04.009

Chang, C., & Lo, T. Y. (2009). On the inventory model with continuous and discrete lead time , backorders and lost sales. *Applied Mathematical Modelling*, *33*(5), 2196–2206. https://doi.org/10.1016/j.apm.2008.05.028

Chang, H.-C. (2011). A comprehensive note on: An economic order quantity with imperfect quality and quantity discounts. *Applied Mathematical Modelling*, *35*, 5208–5216. https://doi.org/10.1016/j.apm.2011.03.039

Chang, H.-C., Yao, J.-S., & Ouyang, L.-Y. (2006). Fuzzy mixture inventory model involving fuzzy random variable lead time demand and fuzzy total demand. *European Journal of Operational Research*, *169*(1), 65–80. https://doi.org/10.1016/J.EJOR.2004.04.044

Chang, H., Yao, J., & Ouyang, L. (2004). Fuzzy Mixture Inventory Model with Variable Lead-Time Based on

Probabilistic Fuzzy Set and Triangular Fuzzy Number. *Mathematical and Computer Modelling*, *39*, 287–304. https://doi.org/https://doi.org/10.1016/S0895-7177(04)90012-X

Chopra, S., & Meindl, P. (2016). *Supply Chain Management* (6th ed.). Upper Saddle River: New Jersey: Pearson.

Chou, S., Julian, P. C., & Hung, K. (2009). A note on fuzzy inventory model with storage space and budget constraints. *Applied Mathematical Modelling*, *33*(11), 4069–4077. https://doi.org/10.1016/j.apm.2009.02.001

Gören, H. G. (2018). A decision framework for sustainable supplier selection and order allocation with lost sales. *Journal of Cleaner Production*, *183*, 1156–1169. https://doi.org/10.1016/J.JCLEPRO.2018.02.211

Hamdan, S., & Cheaitou, A. (2017a). Dynamic green supplier selection and order allocation with quantity discounts and varying supplier availability. *Computers & Industrial Engineering*, *110*, 573–589. https://doi.org/10.1016/J.CIE.2017.03.028

Hamdan, S., & Cheaitou, A. (2017b). Supplier selection and order allocation with green criteria: An MCDM and multi-objective optimization approach. *Computers & Operations Research*, *81*, 282–304. https://doi.org/10.1016/J.COR.2016.11.005

Hazra, J., & Mahadevan, B. (2009). A procurement model using capacity reservation. *European Journal of Operational Research*, *193*, 303–316. https://doi.org/10.1016/j.ejor.2007.10.039

He, Z., Wen Jiang, B., & Felix S Chan, B. T. (2017). Evidential Supplier Selection Based on Interval Data Fusion. *Int. J. Fuzzy Syst*, *20*(4), 1159–1171. https://doi.org/10.1007/s40815-017-0426-7

Hlioui, R., Gharbi, A., & Hajji, A. (2017). Joint supplier selection, production and replenishment of an unreliable manufacturing-oriented supply chain. *International Journal of Production Economics*, *187*, 53–67. https://doi.org/10.1016/J.IJPE.2017.02.004

Huang, B., Bai, L., Roy, A., & Ma, N. (2018). A multi-criterion partner selection problem for virtual manufacturing enterprises under uncertainty. *International Journal of Production Economics*, *196*, 68–81. https://doi.org/10.1016/J.IJPE.2017.08.024

Huang, C. (2010). An integrated inventory model under conditions of order processing cost reduction and permissible delay in payments. *Applied Mathematical Modelling*, *34*(5), 1352–1359. https://doi.org/10.1016/j.apm.2009.08.015

Kawtummachai, R., & Hop, N. Van. (2005). Order Allocation in a Multiple-Supplier Environment Fuzzy Stochastic optimization and Supply Chain Management View project Multi-Criteria Process Planning for PCB Asembly View project Order allocation in a multiple-supplier environment. *Int. J. Production Economics*, *9394*, 231–238. https://doi.org/10.1016/j.ijpe.2004.06.022

Keshavarz Ghorabaee, M., Amiri, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2017). A new multi-criteria model based on interval type-2 fuzzy sets and EDAS method for supplier evaluation and order allocation with environmental considerations. *Computers & Industrial Engineering*, *112*, 156–174. https://doi.org/10.1016/J.CIE.2017.08.017

Kumar, N., Kumar, T., & Maiti, M. (2005). Multi-objective fuzzy inventory model with three constraints : a geometric programming approach. *Fuzzy Sets and Systems*, *150*, 87–106. https://doi.org/10.1016/j.fss.2004.07.020

Lamba, K., Singh, S. P., & Mishra, N. (2018). Integrated decisions for supplier selection and lot-sizing considering different carbon emission regulations in Big Data environment. *Computers & Industrial Engineering*. https://doi.org/10.1016/J.CIE.2018.04.028

Liao, Z., & Rittscher, J. (2007). Integration of supplier selection , procurement lot sizing and carrier selection under dynamic demand conditions. *Int. J. Production Economics*, *107*, 502–510. https://doi.org/10.1016/j.ijpe.2006.10.003

Lin, Y. (2008). A periodic review inventory model involving fuzzy expected demand short and fuzzy backorder rate. *Computers & Industrial Engineering*, *54*, 666–676. https://doi.org/10.1016/j.cie.2007.10.002

Lo, H.-W., Liou, J. J. H., Wang, H.-S., & Tsai, Y.-S. (2018). An integrated model for solving problems in green supplier selection and order allocation. *Journal of Cleaner Production*, *190*, 339–352. https://doi.org/10.1016/J.JCLEPRO.2018.04.105

Manerba, D., Mansini, R., & Perboli, G. (2018). The Capacitated Supplier Selection problem with Total Quantity Discount policy and Activation Costs under uncertainty. *International Journal of Production Economics*, *198*, 119–132. https://doi.org/10.1016/J.IJPE.2018.01.035

Minner, S. (2003). Multiple-supplier inventory models in supply chain management: A review. *Int. J. Production Economics*, *81–82*, 265–279. https://doi.org/https://doi.org/10.1016/S0925-5273(02)00288-8

Mirzaee, H., Naderi, B., & Pasandideh, S. H. R. (2018). A preemptive fuzzy goal programming model for generalized supplier selection and order allocation with incremental discount. *Computers & Industrial Engineering*, *122*, 292–302. https://doi.org/10.1016/J.CIE.2018.05.042

Mohammadivojdan, R., & Geunes, J. (2018). The newsvendor problem with capacitated suppliers and quantity discounts. *European Journal of Operational Research*, *271*(1), 109–119. https://doi.org/10.1016/J.EJOR.2018.05.015

Moheb-Alizadeh, H., & Handfield, R. (2017). An integrated chance-constrained stochastic model for efficient and sustainable supplier selection and order allocation. *International Journal of Production Research*, 1–27. https://doi.org/10.1080/00207543.2017.1413258

Mousakhani, S., Nazari-Shirkouhi, S., & Bozorgi-Amiri, A. (2017). A novel interval type-2 fuzzy evaluation model based group decision analysis for green supplier selection problems: A case study of battery industry. *Journal of Cleaner Production*, *168*, 205–218. https://doi.org/10.1016/J.JCLEPRO.2017.08.154

Ouyang, L., & Yao, J. (2002). A minimax distribution free procedure for mixed inventory model involving variable lead time with fuzzy demand. *Computers & Operations Research*, *29*, 471–487.

Qi, X. (2007). Order splitting with multiple capacitated suppliers. *European Journal of Operational Research*, *178*(2), 421–432. https://doi.org/10.1016/J.EJOR.2006.02.004

Rezaei, J., & Davoodi, M. (2008). A deterministic, multi-item inventory model with supplier selection and imperfect quality. *Applied Mathematical Modelling*, *32*, 2106–2116. https://doi.org/10.1016/j.apm.2007.07.009

Rezaei, J., & Salimi, N. (2012). Economic order quantity and purchasing price for items with imperfect quality when inspection shifts from buyer to supplier. *Int. J. Production Economics*, *137*, 11–18. https://doi.org/10.1016/j.ijpe.2012.01.005

Tassabehji, R., & Moorhouse, A. (2008). The changing role of procurement : Developing professional effectiveness. *Journal of Purchasing & Supply Management*, *14*, 55–68. https://doi.org/10.1016/j.pursup.2008.01.005

Tatsis, V., Mena, C., Wassenhove, L. N. Van, & Whicker, L. (2006). E-procurement in the Greek food and drink industry : Drivers and impediments. *Journal of Purchasing & Supply Management*, *12*, 63–74. https://doi.org/10.1016/j.pursup.2006.04.003

Varnas, A., Balfors, B., & Faith-ell, C. (2009). Environmental consideration in procurement of construction contracts : current practice , problems and opportunities in green procurement in the Swedish construction industry. *Journal of Cleaner Production Journal*, *17*, 1214–1222. https://doi.org/10.1016/j.jclepro.2009.04.001

Wahab, M. I. M., & Jaber, M. Y. (2010). Economic order quantity model for items with imperfect quality, different holding costs, and learning effects: A note. *Computers & Industrial Engineering*, *58*(1), 186–190. https://doi.org/10.1016/J.CIE.2009.07.007

Yang, G., Ronald, R. J., & Chu, P. (2005). Inventory models with variable lead time and present value. *European Journal of Operational Research*, *164*(2), 358–366. https://doi.org/10.1016/j.ejor.2003.09.030

Yu, F., Yang, Y., & Chang, D. (2018). Carbon footprint based green supplier selection under dynamic environment. *Journal of Cleaner Production*, *170*, 880–889. https://doi.org/10.1016/J.JCLEPRO.2017.09.165

Zhang, J.-L., & Zhang, M.-Y. (2011). Supplier selection and purchase problem with fixed cost and constrained order quantities under stochastic demand. *Int. J. Production Economics*, *129*, 1–7. https://doi.org/https://doi.org/10.1016/j.ijpe.2010.08.003

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