Supply Chain Approach & Performance: An OEM (Case Study)

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Abstract- The disruptions in the supply chain occur due to several factors like a global tender, local tender or the vendor's failure to deliver in time (Berger et al 2004). There are a number of original equipment manufacturers (OEM) who have been traditionally producing all the required parts in house. This problem has, therefore, given way to outsourcing of major producing activities instead of producing all the items in house. This has led to the problem of having a number of vendors for an efficient functioning of the organization. The improvement in vendor performance and vendor-producer relationships has provided number of opportunities for cost reduction and the performance of supply chain. The key to the problem lies in having long term relationships with reliable vendors as any failure of vendor in fulfilling the commitment may have serious repercussions on production schedule.
IndexTerms- distruptions, original equipment manufacturer, producing activities etc

I. INTRODUCTION & LITERATURE REVIEW

The disruptions in supply may occur not only due to individual vendor failure but also due to natural disasters (Berger et al 4004). Although, it may be mainly due to the failure of the individual vendor or a global basis, the local events too play role. Berger et al (2004) have used the mean value approach and deterministic failure cost (assuming that the cost can be determined with certainty) to determine the ultimate number of vendors. The cost includes the operational cost of all the vendors and the cost associated with the loss due the failure of all suppliers. A model is proposed for the determination of ultimate number of vendors for a diesel engine taking into consideration various factors which affect the supply chain.

II. PROBLEM DESCRIPTION

We take the case of a diesel engine producer which has grown from producing 100 odd diesel engines in the year 2010 to about 275 in the year 2018. It is now focusing on producing a new generation of 450-550 Horse Power diesel engine called Horse Power (HP) diesel engine. The number of HP diesel engine produced by this OEM in the financial year 2016-2017 was 199 and it now aims to increase this number to 260 in the financial year 2017-18. Even though profit making is not a major consideration, the cost reduction is certainly a matter of concern especially for the activities where capacity has not been built up .Therefore, a properly designed and managed supply chain may help in reducing the cost significantly. The OEM depends heavily on outsourcing of fully finished items as well as of semi finished items. This is also a typical organization which on one hand has to deal with growing demands of outsourcing and on the other hand has to follow strict rules of public procurement.

There are some critical issues faced by this OEM in the procurement process .In- sufficient supply of material and the quality of material is also a matter of concern. At present the setup is very resource intensive. There are cases, where more than ten vendors are operating for the same class of items. Since the vendor does not get the advantage of volumes, the cost of item increases which is nothing but a direct loss to OEM. Sometimes the supplies have been disrupted or completely failed. Determining number of vendors in an objective manner in such a situation is a major challenge. It is therefore focusing on the determination of ultimate number of suppliers by taking into consideration various factors including the probability of supply disruptions, both at the global basis as well as local basis. The issues being faced by OEM are: few vendors for the costly and complex items, no objectivity in vendor evaluation and the supply disruptions in case of low value items. In the present work we have attempted to develop a model by taking into consideration various factors outlined earlier. This model has then been applied to the typical case of a diesel engine producer to help it in the decision making process.

The description of the product, the number of items to be purchased for a particular product and the number of vendors in a typical case of a manufacturer of the diesel engine is given in Table 4.1. It can be seen from Table 4.1 that there are products for which there are no vendors meaning in- house producer. The model will now be developed to find an ultimate number of vendors under supply chain disruptions, quantity discount and the operational cost of the vendors This is to assist the diesel engine producer (OEM) in its decision making process and for the smooth functioning.

III. THE MODEL DEVELOPMENT

A model, based upon the cost of the item, quantity discount, operation cost of vendors and the probability of supply chain disruptions due to various events is being developed. The present model takes into consideration the events discussed by Berger et al (2004). However, for the sake of simplicity, we take into account only two events which can disrupt the supply chain:

(i) Global basis
(ii) Local basis

The Global basis affects all vendors whereas local events affect only some suppliers. A very important factor which must be taken into consideration is the quantity discount offered by vendors for bulk orders. It is known that as the number of vendors increases the advantage of discount decreases. Although modelling the discount is a difficult problem, taking into account the relation between the number of vendors and discount may be the solution to the problem. Under normal circumstances for 100% order to a single vendor, the discount offered is about 5%. The discount reduces with the reduction in the quantity ordered by the producer. It must be stated that the effective cost will depend upon the discount given by the suppliers. It is possible to express the quantity discount (D) as an exponential function:

$$D = A\{\theta e^{-\lambda(n-1)}\}$$

Where, A is the cost of item
θ is a parameter and is estimated as 0.05 for present study
λ is a variable parameter ; n is the number of vendors

3.1 Modeling the probability

One very important aspect is to model the probability of the occurrence of the events under consideration. For this we define the following parameters:
Pg the probability of Global event
Si the probability of Local event (for vendor i)
Further it is assumed that the probabilities of local events for the different vendors are independent. The probabilities of global event and local event are also not dependent on each other
Si and Sj are independent for i≠j,
Pg, Si are independent events.
The probability that supplies from supplier i are disrupted or fail (f) is,

$$P_i(f) = P_g + (1 - P_g)S_i \quad (4.1)$$

The probability that the supplies from both the vendors are disrupted or fail (f) is,

$$P_2(f) = P_g + (1 - P_g)S_2S_1 \quad (4.2)$$

It is clear that having number of vendors reduces the risk of supply disruption. It must be kept in mind that with each additional vendor, operational cost increases.
We now undertake the analysis. Analysis is first done by taking a case where the quantity of discounts offered by suppliers is not accounted for as adopted by Berger et al (2004) .The analysis has to be performed under the following conditions:
The number of vendors is chosen from i= 1 to n.
There are two conditions, all vendors fail, or some fail.
If all the vendors fail, there is a loss to the company denoted by Lt
The cost of operating a vendor, i, is denoted by C(i), i=1,2…n.
The Expected Total Cost (E) from the system in case of only one vendor is:

$$E(1) = P_1(f)[L_t + C(1)] + [1 - P_1(f)]C(1)$$

$$= C(1) + L_t[P_g + (1 - P_g)S_1]$$

Thus for n vendors,

$$E(n) = P_n(f)[L_t + C(n)] + [1 - P_n(f)]C(n)$$
$$= C(n) + L_t[P_g + (1 - P_g)S_1S_2S_3 \ldots . S_n] \quad (4.3)$$

In order to simplify the Eq.(4.3) it is assumed that probability of local event for each vendor is same, i.e. S1=S2=…………Sn =S

The equation (4.3) can be expressed as,

$$E(n) = C(n) + L_t[P_g + (1 - P_g)S^n] \quad (4.4)$$

If multi- vendor option is to be less expensive, the condition E (n) < E (1) must be satisfied. Substituting S1=S2=S3 to Sn=S

One gets the following condition:

$$C(n) - C(1) < L_t(1 - P_g)S - L_t(1 - P_g)S^n$$

$$\frac{\{C(n) - C(1)\}}{L_t} < (1 - P_g)S(1 - S^{n-1}) \quad (4.5)$$

The term on the left hand side of the inequality (4.5) is defined as “Critical Ratio” (CR) by Berger et al (2004). The inequality (4.5) also indicates that the right hand side decreases with increasing Pg.

For determining the optimal size of vendors, we have to compare (n+1) vendors to n vendors. It is obvious that we must have E (n+1) <E (n), Under this condition having n+1 vendors will be more advantageous than having n vendors.

To find the ultimate number of vendors for a given set of conditions, n has to be increased till the condition, E(n+1)-E(n)>0 is satisfied. The value of n thus determined would be the ultimate number of vendors.

From Eq. (4.5) it can be seen that

$$E(n+1) - E(n) = [C(n+1) + L_t\{P_g + (1 - P_g)S^{n+1}\}] -$$
$$[C(n) + L_t\{P_g + (1 - P_g)S^n\}] \quad (4.6)$$

We now proceed to take into account the cost of maintaining the vendor.

Consider that the cost of maintaining a vendor is a linear function of n,

Then C(n) is given by the following expression: C (n) =u+v (n)

Where, u is the fixed component and v is the variable component. Therefore

$$E(n+1) - E(n) = v + L_t(1 - P_g)(S^{n+1} - S^n) \quad (4.7)$$

Finally the quantity discount (D), a very important factor will be incorporated in this model. The exponential function defined earlier for D will be introduced in Eq. 4.7 to take care of quantity discount. The final equation is obtained as following:

$$E(n+1) - E(n) = -A\theta[e^{-\lambda n} - e^{-\lambda(n-1)}] + v + L_t(1 - P_g)(S^{n+1} - S^n) \quad (4.8)$$

This is the mathematical representation of the present model.

The Eq. 4.8 obtained above will now be used for making the calculations. The procedure is to increase, n till E (n+1)- E (n) >0 ,which means that it is costlier to operate (n + 1) vendors than n. The number n thus obtained will be the ultimate number of vendors’ n*.

3.2 Discussion and application of model

We now consider the case of a diesel engine producer and apply the present model to arrive at the ultimate number of vendors. The parameters for the calculations to be used for Eq. 4.8 in case of this producer have either been assumed or estimated on the basis of past experience.

In case of the diesel engine producer the cost of item A varies from Rs 500 to about Rs 200 ,000/-. However, the cost of the critical items to be purchased is in the range of Rs 100,000 to Rs 250,000. Therefore the ultimate number of vendors, n* will be calculated for a range of values of A.

The discount offered by vendors for 100 % order is of the order of 5%.Therefore for the present study, the discount parameter θ; is estimated at 0.05.

With each increase in vendor the discount reduces by ~ 1% to 1.5%. However, we have to determine a suitable value of parameter λ.

We proceed as follows:

(i) First determine the % discount by varying n

(ii) Estimate the suitable parameter λ from these calculations

Using D= $A\left\{\theta e^{-\lambda(n-1)}\right\}$

Keep θ= 0.05, and vary λ, find the % discount and use the value of λ which best compares with empirical values.

Table **Error! No text of specified style in document.**.1 The value of percent discount for two values of λ

Θ	0.05		θ	0.05
Λ	0.6		λ	0.4
N	% discount		n	% discount
1	5.000		1	5.000
2	2.744		2	3.352
3	1.506		3	2.247
4	0.826		4	1.506
5	0.454		5	1.009

The quantity (D/A) x100 is the percent discount in Table-4.1. It is seen that λ=0.4 gives % discount value very near to actual one. Hence λ=0.4 is the estimated value to be used in further calculations.

The calculations for the optimal number of vendor will be done for both, the present model as well as for Model-B.

3.2.1 Calculation of optimal number for Model-B:

The optimal values, n* are calculated by taking into consideration the following values for different parameters:

Pg the probability of Global event is ~ 5%.Hence, the estimated value is taken as Pg =0.05, which is kept on higher side for safe working.

Si the probability of Local event for vendor i is 10% It is assumed same for all vendors (S=0.1).This has been the average failure rate for multiple vendors of various class of items.

Lt, the loss to company due to vendor’s failure is being estimated as Rs 200,000 per day as that is the earning potential of diesel engine per day for the firms.

v, the variable, is the cost of operating vendor and is estimated as Rs 2000. This cost is not very significant as it can be managed by same set of people.

It is to be noted that A, θ and λ appearing in Eq. 4.8 (of present model) have no role to play in model-B

Therefore we have only v, Pg, S and Lt

V	Pg	S	Lt
2000	0.05	0.1	300000

Substituting the values of parameters in equation (4.7), we get optimal number of vendors, n* = 3. This value of n* is the value of ultimate number of vendors corresponding to Model –B.

3.2.1.1 Calculation of ultimate number for present Model

The present model which has been developed here accounts for vendor’s discount and will have a direct bearing on the ultimate number. Eq (4.8) will be used to estimate the ultimate number of vendors, n*. The ultimate number n* will depend upon the value of A which will have a direct role to play in the present Model. The value of λ, as estimated earlier, has been taken as 0.4. All other parameters are the same as used in Model-B.

Table **Error! No text of specified style in document.**.2 ultimate number of vendors for various values of A

v	θ	λ	Pg	S	Lt
2000	0.05	0.4	0.05	0.1	300000
Result					
A, cost of item in Rs			n*, optimal number of suppliers		
5000			3		
10000			3		
50000			3		
100000			2		
200000			2		
250000			2		
500000			2		
1000000			1		

In case of items having price less than Rs 100,000 the ultimate number of vendors, n*=3. It is suggested that for these items three vendors may be the ultimate number for the Diesel Engine producer in order to maintain proper supply of items and production in OEM. Although n* =1 for higher values of A, it may not be feasible, therefore, it is suggested, on practical considerations, to have two vendors.

The present model has been successful in determining the ultimate number of vendors based upon the parameters of Eq. 4.8 for different cost of items.

We now proceed to do the sensitivity analysis.

3.3 Sensitivity Analysis

In order to test the authenticity of this model by the sensitivity test must be carried out. This is done to see whether the model is following natural rules or not. There are two situations:

Parameters common to Model-B and the present model: compare n*

Parameters unique to the present model: no comparison

3.3.1 The Ultimate number of vendors, n: Variation in the value of Probability of Global failure, Pg*

Table **Error! No text of specified style in document.**.3: n* with variation in Probability of Global failure Pg

V	A	θ	Λ	S	Lt
2000	100000	0.05	0.4	0.1	300000
Pg		n*		n*(Berger)	
0.005		2		3	
0.01		2		3	
0.025		2		3	
0.05		2		3	
0.075		2		3	
0.1		2		3	

It can be seen, Pg does not have a significant role in determining the ultimate number of vendors. The only difference in Model-B and present model is that n* = 3 in former and n*=2 in the present model. This difference is due to the fact that in the present model, the discount is taken into consideration which is likely to be more for less number of vendors.

3.3.2 The optimal number of vendors n: Variation in the value of Probability of Individual vendor's failure, S*

Table **Error! No text of specified style in document.**.4: n* with variation in the value of Probability of Individual vendor's failure, S

V	A	Θ	λ	Pg	Lt
2000	100000	0.05	0.4	0.05	300000
S	n*	n*(Berger)			
0.05	2	2			

0.10	2	3
0.15	3	3
0.20	3	3
0.25	4	4
0.30	4	4

It can be seen that the value of S has direct impact on n*.The value of n* is almost same in both the models for varying values of S. More the probability of vendor failure, larger should be the number of vendors.

3.3.3 The optimal number of vendors n: Variation in the value of Loss due to supply disruption, Lt*

Table **Error! No text of specified style in document.**.5: n* with variation in the value of Loss due to supply disruption, Lt

V	A	θ	λ	Pg	S
2000	100000	0.05	0.4	0.05	0.1

Lt	n*	n*(Berger)
10000	1	1
50000	2	2
100000	2	2
200000	2	2
300000	2	3
500000	3	3
1500000	3	3
2500000	3	4
3500000	4	4
4500000	4	4
5500000	4	4

It is seen that with increasing loss due to supply disruptions, the value of n* increases. More number of reliable vendors will, therefore, be required in such a situation, which authenticates the model. Although, the value of n* in the present model is same as in Model-B , n* will be effectively less in the present model because of quantity discount available.

3.3.4 The optimal number of vendors n: Variation in the value of cost of maintaining a vendor, v*

Table **Error! No text of specified style in document.**.6 : n* with variation in the value of cost of maintaining a vendorr, v

A	θ	λ	Pg	S	Lt
100000	0.05	0.4	0.05	0.1	300000

V	n*	n*(Berger)
500	3	3
1000	3	3
2000	2	3
5000	2	2
10000	2	2
50000	1	1

The parameter v has a significant impact on n*, since higher cost of operating/maintaining a vendor will tend to reduce n*. In one case the Model-B gives n*, which is more than the value in present model, which may be due to the quantity discount available in present model.

In the following calculations the cost of item and discount parameters are varied which are unique to the present model.

The parameter, λ denotes the rate of decrease of discount with increasing number of vendors. For the value of λ ranging from 0.2 to 1.0, there is no change in n*, indicating that λ does not have any significant role to play in determining n*.

IV. RECOMMENDATIONS

The results show that the optimal number of vendors varies mainly on the cost of operating the vendor, cost of item and the probability of vendor's failure. In the present case, it is recommended that the OEM should have different number of vendors depending upon the cost of item under consideration. The optimality has been estimated for various values of the main costs, like rate of item and loss associated with supply disruption. This will be the optimal size of vendor base for the conditions enumerated. It is expected that the present study will assist the diesel engine producer to decide on the optimal vendor base using a mathematical model, with practical value as well. The study recommends 2 vendors for most items and 3 vendors for low value items.

Further studies may be required by including cost of vendor development, limited capacity of vendor, trade off between vendor management cost and risk .It may be mentioned here that this work has assumed constant lead times but it may be extended for the case of stochastic lead times.

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