EFFECT OF COST INCREMENT DISTRIBUTION PATTERNS ON THE PERFORMANCE OF JIT SUPPLY CHAIN

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ABSTRACT

Cost is an important consideration in supply chain (SC) optimisation. This is due to emphasis placed on cost reduction in order to optimise profit. Some researchers use cost as one of their performance measures and others propose ways of accurately calculating cost. As product moves across SC, the product cost also increases. This paper studied the effect of cost increment distribution patterns on the performance of a JIT Supply Chain. In particular, it is necessary to know if inventory allocation across SC needs to be modified to accommodate different cost increment distribution patterns. It was found that funnel is still the best card distribution pattern for JIT-SC regardless the cost increment distribution patterns used.

Keywords: supply chain management, cost increment distribution Patterns, JIT-hybrid supply chain.

1. INTRODUCTION

Similar to production floor, Supply Chain Management (SCM) places greater emphasised on profit optimisation. The usual way to optimise profit is by minimising total cost (Shapiro, 2001). Considering this, various researches in supply chain operation research integrate cost as one of their performance measures such as Gullu (1997), Sabri and Beamon (2000), Petrovic *et al.* (1998), Omar and Shaharoun (2000), Larson *et al.* (1999) and Van Der Vost *et al.* (2000), while Lin *et al.* (2001) propose ways of accurately calculating cost by implementing activity-based costing (ABC) in managing logistics. Lin *et al.* (2001) suggested that the cost should be assigned to the resources for each logistics activities. Aggregating the cost into departments or sections will not represent true cost occurred at the corresponding sections. They claim that using ABC may provide accurate output of optimisation. Ingene and Parry (2000) reviewed the literature, which led them to conclude that product price is similar for each player at every echelon in a supply chain. Price discrimination is infeasible due to administrative, bargaining and contract development costs.

As a product moves across a supply chain, the product cost also increases. However, most literature such those mention previously assumes equal cost per part at every echelon or in other words zero increment of costs. This hardly represents a real SC. There exist differences in cost increment per part at each echelon across a SC (Omar, 2000 and Lin, 2001). For instance the cost might be incremented equally as we move downstream of the SC yielding a uniform cost increment distribution pattern or the increment might increases as we move downstream of the SC forming a funnel cost increment distribution pattern. How such increments of cost are distributed along a supply chain may affect the performance of JIT Supply Chain is still unknown. In particular, it is necessary to know if inventory allocation across a supply chain needs to be modified to accommodate different cost increments.

2. THE SUPPLY CHAIN

A SC studied by Closs *et al.* (1998) is selected as the hypothetical SC for this research. The supply chain was selected because it fulfilled all four requirement of basic SC structure and had extensive input and output data. Mohd Lair *et al.* (2003) present model selection and building in detail. The SC selected consists of a supplier (S), a manufacturer (M), two distributors (D) and three retailers (R) as shown in Figure 1. There is unlimited supply of raw material at the supplier. Tables 1 through 3 provide additional information of the SC (Mohd Lair *et al.*, 2003).

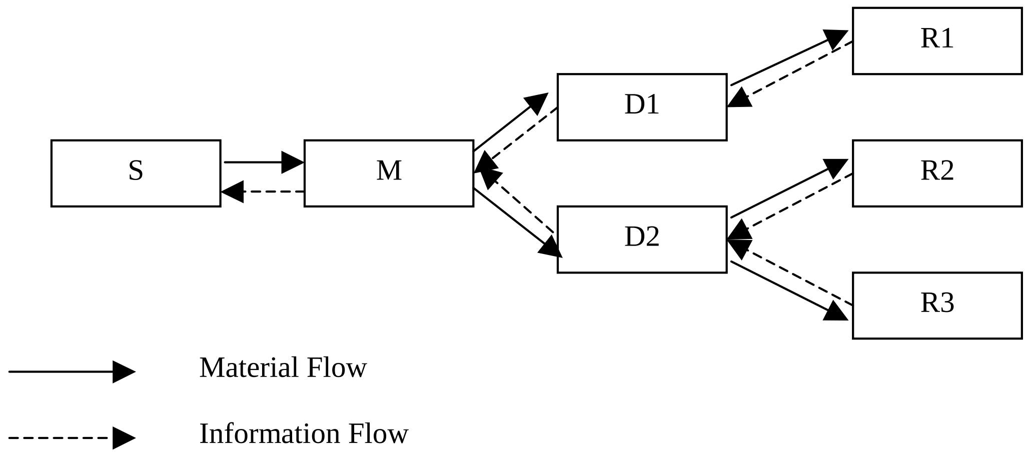


Figure 1. Supply chain layout (adapted from Closs *et al.*,1998)

Table 1. Cycle time (in days)

Parameter	Mean	Distribution
Processing time supplier	1.0	Normal (std dev. = 0.3)
Processing time manufacturer	0.08	Triangular(min=0.02, max=0.2)
Processing time distributor	0.3	Triangular (min = 0.1, max=1.0)
Processing time retailer	0.5	Triangular (min =0.2, max = 2.0
All transit times	5.0	(std dev. = 5)
Total lead time	21.9	

Table 2. Transportation schedule and truckload

Transporters	Schedule	*Load*
To supplier	Once per week	
To manufacturer	Once per week	Truck capacity 24 units
To distributor	Twice per week	partial loads allowed
To retailer	Twice per week	

Table 3. Customer arrival pattern distributions

Customer arrival (demand pattern)	Distribution
Low variability of demand	Uniform (0.8,1.2)
High variability of demand	Uniform (0.2,1.8)

3. MODELLING AND EXPERIMENTATION

A model was developed using WITNESS® simulation software. The benefits of simulation were recognised and documented by Chisman (1992), Law and Mc. Gomas (1994) and Witness user's Manual – Release 7.0 (1995). The selection criteria of the simulation Software was discussed in Law (1990), i.e. animation, computing time, model building time, customer support, minimum programming, customised report etc. After considering the criteria mentioned in Law and Mc. Gomas (1994), WITNESS® simulation software fulfilled the requirements. WITNESS® simulation software would be employed as the modelling tool. The model JIT Supply Chain was presented by Mohd Lair *et al.* (2003). The models are used to find means of determining the parameters for each card distribution pattern and cost increment distribution pattern strategy investigated. The models serve as initial testbed to analyse and evaluate the performance of JIT Supply Chain.

Most input data was as given by Closs *et al.* (1998) and additional necessary data was set based on extensive preliminary experiments. Before determining the warm-up period, a preliminary run was conducted to check whether the values of input parameters would deliver the expected performance of JIT SC that closely resembled to the Closs experiment. The simulation models developed were then run. Output data were analysed. The program was easily debugged using stepwise approach, i.e. change a few elements, run the model, verify it and then proceed on making changes. Validation was conducted by comparing the findings concluded from the simulation run with findings given by Closs *et al.* (1998). Detail discussions on model validation were presented in Mohd Lair *et al*. (2003).

The JIT-Hybrid model identified as the best JIT strategy in Mohd Lair *et al*. (2003) was used as the based for experimentation. Two parameters involved in this experiment were card distribution patterns and cost increment distribution patterns. The card distribution patterns referred to bowl, inverted bowl, funnel, reversed funnel and uniform. Figure 2 illustrated the distribution patterns. Both cards and cost increment patterns were arranged according to the illustrated patterns.

In order to simplify study on four echelons SC, 20 cost objects with the smallest cost of 0.1 and biggest cost of 2.0 were selected. These values were selected as they can be distributed easily among the four echelons. Andijani (1997) provided formulas to calculate the total number of feasible allocation sets for the cost,

$$A = C_{m-1}^{n-1} = \frac{(n-1)!}{(m-1)!(n-m)!} \qquad (1)$$

where,

A : feasible allocation sets.

n : costs objects

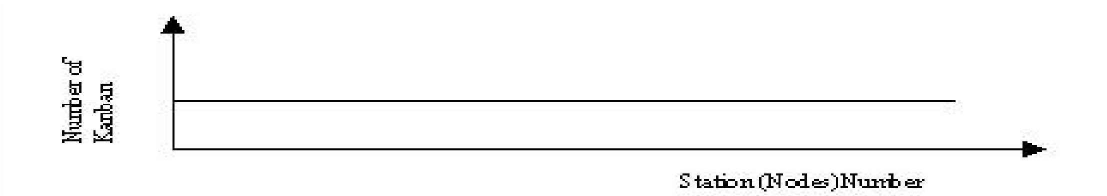
m : number of nodes

Using Formula 1, the feasible cost allocation sets for 4 echelons and 20 costs objects were:

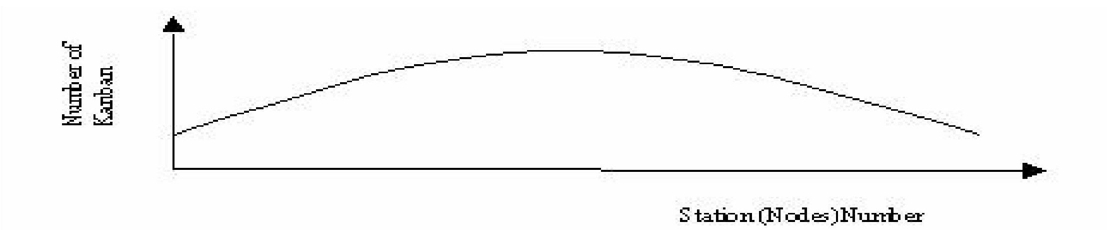
$$A = \frac{(20-1)!}{(4-1)!(20-4)!}$$

$$= 969 \text{ sets}$$

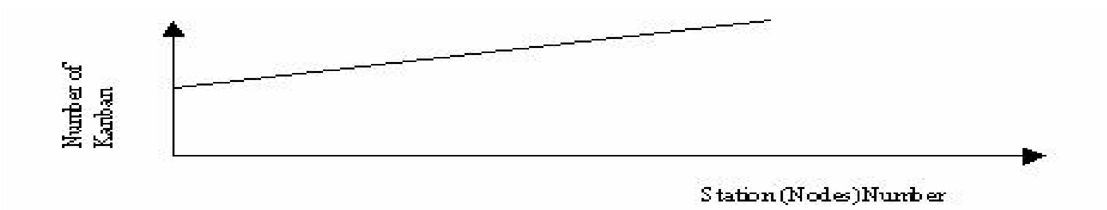
The identified feasible cost allocation sets were then grouped into six groups; five groups each representing one of the five cost increment distribution patterns and a group of allocation sets that did not belong to any of the distribution patterns. Based on this, there was one allocation set for uniform, 63 sets for funnel and reversed funnel, 264 sets for bowl and 236 sets for inverted bowl. The remaining 342 allocation sets were unidentified. The identified and grouped allocation sets represented the five cost increment distribution patterns.



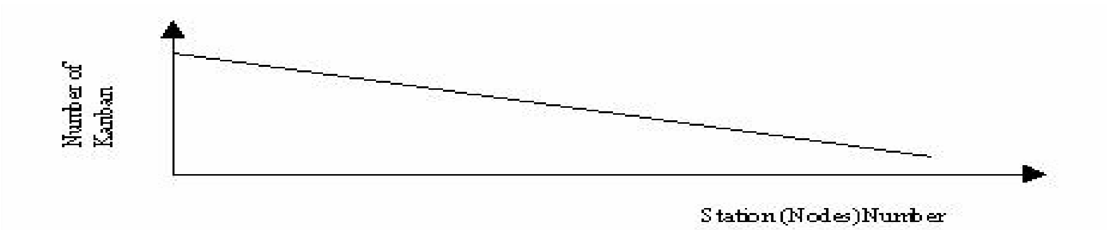
a) Uniform distribution pattern



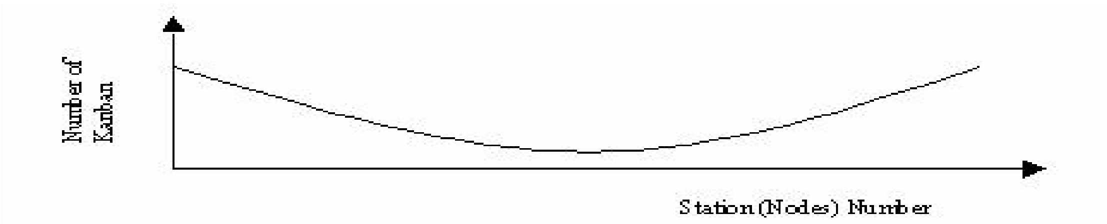
b) Bowl distribution pattern



c) Funnel distribution pattern



d) Reverse funnel distribution pattern



e) Inverted bowl distribution pattern

Figure 2. The distribution patterns (adapted from Mohd Lair *et al.*, 2003)

The cost increment distribution patterns were then implemented on the models along with the corresponding card distribution patterns. The models are then modified to simulate different cost increment distribution patterns. The experiments on the models are conducted and analysed. The simulation results show the next section in detail.

4. RESULTS

Table 4 presents the means and ANOVA results comparing each card distribution pattern under cost increment distribution pattern. Based on the results presented, it is concluded that funnel card distribution pattern produced significant different for lowest inventory cost and bowl card distribution pattern produced significant different highest for total inventory cost.

Table 4. Comparing the means of total system inventory cost for bowl cost increment distribution pattern under five card distribution patterns

	Total system inventory cost		
Card pattern	**Mean (std. dev)**	**Mean diff. (lowest)** [a]	**Mean diff. (highest)** [b]
Bowl	126.73 (13.806)	**-10.156***	-
Inverted bowl	122.54 (14.182)	**-5.972***	**4.184***
Funnel	116.57 (13.105)	-	**10.156***
Reversed funnel	123.46 (13.591)	**-6.886***	**3.270***
Uniform	122.48 (13.688)	**-5.906***	**4.250***

- [a] Comparing the lowest mean (row)against other means. Tested using ANOVA.
- [b] Comparing the highest mean (row) against other means. Tested using ANOVA.
- * Indicates the mean difference is significant at $\alpha = 0.05$.
- ▢ Shaded indicates pattern (row) with either the lowest or highest mean.

Table 5 presents the means and ANOVA results comparing each card distribution pattern under inverted bowl cost increment distribution pattern. Based on the results presented, it is concluded that funnel, inverted bowl, reversed funnel and uniform card distribution patterns produced significant lowest inventory cost and bowl, inverted bowl, reversed funnel and uniform produced significant highest total inventory cost.

Table 5. Comparing the means of total system inventory cost for inverted bowl cost increment distribution pattern under five card distribution patterns

	Total system inventory cost		
Card pattern	**Mean (std. dev)**	**Mean diff. (lowest)** [a]	**Mean diff. (highest)** [b]
Bowl	123.20 (21.494)	**-7.458***	-
Inverted bowl	120.37 (21.052)	**-4.636**	**2.822**
Funnel	115.74 (19.813)	-	**7.458***
Reversed funnel	120.56 (20.848)	**-4.825**	**2.633**
Uniform	120.09 (20.829)	**-4.348**	**3.110**

- [a] Comparing the lowest mean (row)against other means. Tested using ANOVA.
- [b] Comparing the highest mean (row) against other means. Tested using ANOVA.
- * Indicates the mean difference is significant at $\alpha = 0.05$.
- ▢ Shaded indicates pattern (row) with either the lowest or highest mean.

Table 6 presents the means and ANOVA results comparing each card distribution pattern under funnel cost increment distribution pattern. Based on the results presented, it is concluded that inverted bowl, funnel, reversed funnel and uniform card distribution patterns produced significant lowest inventory cost and bowl, inverted bowl, reversed funnel and uniform patterns produced significant highest total inventory cost.

Table 6. Comparing the means of total system inventory cost for funnel cost increment distribution pattern under five card distribution patterns

	Total system inventory cost		
Card pattern	**Mean (std. dev)**	**Mean diff. (lowest)[a]**	**Mean diff. (highest)[b]**
Bowl	94.27 (12.04)	**-5.997***	-
Inverted bowl	91.58 (11.49)	**-3.046**	**2.691**
Funnel	88.27 (10.59)	-	**5.997***
Reversed funnel	92.32 (11.56)	**-4.046**	**1.951**
Uniform	91.70 (11.44)	**-3.426**	**2.571**

- [a] Comparing the lowest mean (row)against other means. Tested using ANOVA.
- [b] Comparing the highest mean (row) against other means. Tested using ANOVA.
- * Indicates the mean difference is significant at $\alpha = 0.05$
- Shaded indicates pattern (row) with either the lowest or highest mean.

Table 7 presents the means and ANOVA results comparing each card distribution pattern under reversed funnel cost increment distribution pattern. Based on the results presented, it is concluded that funnel card distribution pattern produced significant lowest inventory cost and bowl, inverted bowl, reversed funnel and uniform patterns produced significant highest total inventory cost.

Table 7. Comparing the means of total system inventory cost for reversed funnel cost increment distribution pattern under five card distribution patterns

	Total system inventory cost		
Card pattern	**Mean (std. dev)**	**Mean diff. (lowest)[a]**	**Mean diff. (highest)[b]**
Bowl	154.38 (10.60)	**-10.604***	-
Inverted bowl	150.58 (10.60)	**-6.802***	**3.802**
Funnel	143.78 (10.22)	-	**10.604***
Reversed funnel	150.67 (10.38)	**-6.891***	**3.713**
Uniform	150.02 (10.47)	**-6.235***	**4.369**

- [a] Comparing the lowest mean (row)against other means.
- [d] Comparing the highest mean (row) against other means.
- * Indicates the mean difference is significant at $\alpha = 0.05$
- Tested using ANOVA.
- Shaded indicates pattern (row) with either the lowest or highest mean.

Table 8 presents the means and ANOVA results comparing each card distribution pattern under uniform cost increment distribution pattern. Based on the results presented, it is concluded that funnel card distribution pattern produced significant lowest inventory cost and bowl produced significant highest total inventory cost.

Table 9 summarizes all discussion above. The table shows that funnel card distribution pattern is still the best when various cost increment distribution patterns are applied. Moreover, arranging the card in bowl distribution pattern may cause the total system inventory cost to be higher than necessary, as more inventories are needed to operate this system.

Table 8. Comparing the means of total system inventory cost for uniform cost increment distribution pattern under five card distribution patterns

	Total system inventory cost		
Card pattern	**Mean (std. dev)**	**Mean diff. (lowest)** [a]	**Mean diff. (highest)** [b]
Bowl	125.02 (1.03)	**-8.821***	-
Inverted bowl	121.52 (0.47)	**-5.312***	**3.509***
Funnel	116.20 (0.84)	-	**8.821***
Reversed funnel	122.07 (0.72)	**-5.866***	**2.954***
Uniform	121.34 (0.63)	**-5.135***	**3.686***

- [a] Comparing the lowest mean (row)against other means. Tested using ANOVA
- [d] Comparing the highest mean (row) against other means. Tested using ANOVA
- * Indicates the mean difference is significant at $\alpha = 0.05$
- ☐ Shaded indicates pattern (row) with either the lowest or highest mean.

Table 9. Card distribution patterns representing the lowest and highest system inventory cost for each cost increment distribution pattern

	Card distribution pattern/s	
Cost increment distribution pattern	**Lowest total inventory cost**	**Highest total inventory cost**
Bowl	Funnel	Bowl
Inverted bowl	Inverted bowl, funnel, reversed funnel and uniform	Bowl, inverted bowl, reversed funnel and uniform
Funnel	Inverted bowl, funnel, reversed funnel and uniform	Bowl, inverted bowl, reversed funnel and uniform
Reversed funnel	Funnel	Bowl, inverted bowl, reversed funnel and uniform
Uniform	Funnel	Bowl

5. CONCLUSION

Many research study on supply chain inventory management so far used counts or units in inventory without regard to cost. For inventory cost minimization, this is tantamount to assuming that the costs of inventory remain constant across a supply chain. In reality, costs increase as the product moves along the supply chain. In this study, various patterns of incrementing cost were investigated. The results show that the selection of supply chain parameters for a supply chain is not sensitive to how the costs are incremented as the product moves along the supply chain and the funnel card distribution pattern is still the best and preferable to store inventory at the downstream nodes, even when the cost of inventories is much higher at these downstream nodes.

Therefore, the current practice of using units of inventory as performance measure is without regard to the cost increments along the JIT supply chain is justified. Recommendation for future work is to modify the generic models developed in this study and investigate other specific objectives and also expand the model of the actual system.

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