PROCUREMENT OF CENTRALISED ITEMS AT GUJARAT WATER SUPPLY AND SEWERAGE BOARD (GWSSB)

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Abstract

The problem is concerned with effective inventory control of materials for water supply of the Gujarat Water Supply and Sewerage Board (GWSSB) in Gujarat State in India. The objectives of this study are to identify the minimum and maximum quantity of materials to be maintained, that for a given service level minimise the cost of the system and to identify areas where improvements can be made. Also, to formulate approaches in the purchasing and inventory management areas in order to meet the uncertain demand more effectively and efficiently.

The method, which has been used to tackle this problem, is simulation modelling. The purpose of the model is to capture the uncertainty of demand and lead time of the inventory system at GWSSB and identify the relationship between the reorder and fill point and the service level of the system, as well as the total cost.

Data problems meant that a number of assumptions about demand and lead-time distributions needed to be made. Four different types of pumps were chosen among the water supply items and were independently tested. The results for service level and total system cost showed a dependence on the reorder and fill point.

By experimenting with the model, we identified the minimum and maximum quantity to maintain for a range of service levels and the minimum cost, that correspond to the current policies of the organisation. It was also identified that, by keeping a fixed fill point, as used by the organisation, although it contradicts the reorder quantity used in most inventory systems, it proved to be not only cost effective, but also gave satisfactory service levels. After experimentation with the model, it was observed that the current inventory policies at GWSSB don’t yield a satisfactory service level, while they give increased total cost. We proved that by reducing the inter-order period, GWSSB can achieve a higher level of customer service, and at the same time keep the cost at the same levels, and in some cases decrease the total cost of system.

1. Introduction

1.1 Problem outline

Gujarat Water Supply and Sewerage Board (GWSSB) is a non-profit government organisation located in Gandhinagar, the capital of Gujarat state in India. GWSSB is engaged in providing water for household purposes to the towns and villages of Gujarat. Its main activity is procuring from manufacturers and providing various materials needed for the purposes of drilling deep tubewells and drawing water from the ground. These materials include various types of handpumps, pipes, panel boards, submersible pumps and cables. For the purpose of providing the materials needed for drawing water from the ground, GWSSB has divided the state of Gujarat into 3 main zones (Gandhinagar, Baroda and Rajkot). In our analysis of inventory system we will be concerned only with the Gandhinagar store that provides materials to the Gandhinagar zone. As we are concerned with the Gandhinagar store only, we assume that there is one single stocking point. Also, we will consider only 4 types of submersible pumps, which are the most important for the organisation and which account for approximately 16% of the total money-usage of pumps. These pumps all fall in the A category. This study has aimed to achieve effective inventory control of the materials mentioned.

The year in India is divided into three main seasons, namely the rainy, winter and summer season. In Gujarat state the rainy season is from July to October, the winter season is from November to March and the summer season is from April to June. The rainy season is the only period of the year which is characterised by rainfalls (monsoons), while during the winter and summer season it hardly rains at all.

The water, which is used for household purposes, is obtained either from the ground surface (75-80%) or from underground (20-25%), depending on the rainfalls of the year. For example, if there is much rain during the previous rain season, then a greater percentage of the surface water will be used, while if there is little rain, more water from the ground needs to be drawn. In general, the demand for the materials peaks during the summer season. In the following diagrams, we can see the demand per month for the 4 different types of pumps used in the analysis for the 36 months preceding the analysis.

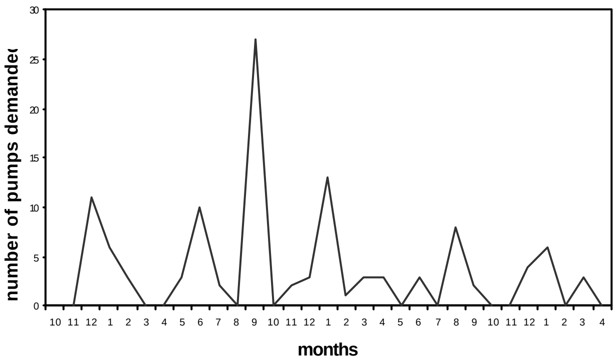

Figure 1.1: Demand of pump type 3.0

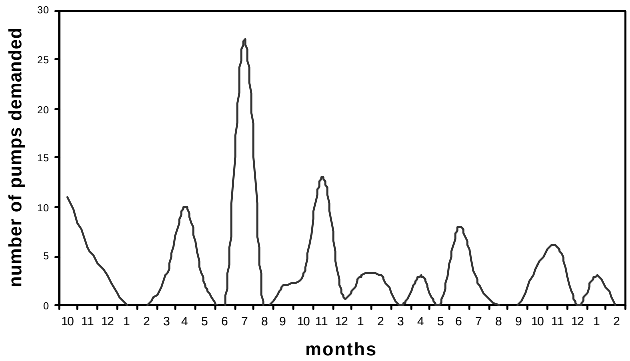

Figure 1.2: Demand of pump type 4.0

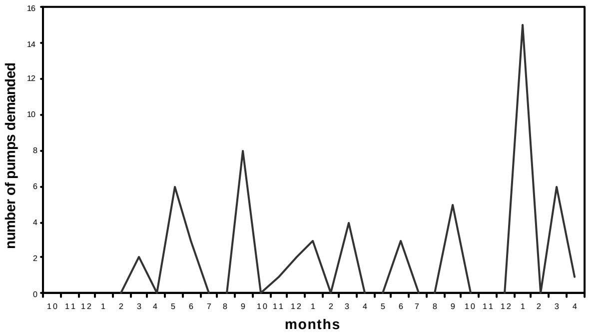

Figure 1.3: Demand of pump type 7.2

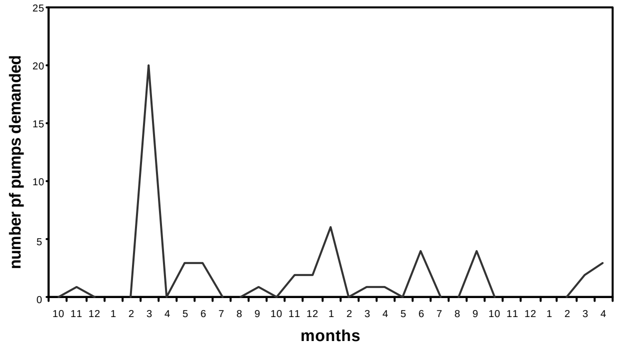

Figure 1.4: Demand of pump type 8.1

This uncertainty of demand causes one main problem. GWSSB is either unable to provide the materials demanded due to non-availability or is forced to maintain a large number of materials to meet the demand whenever it is created. GWSSB's major concern is the inventory maintenance throughout the whole year. The procurement of materials is based on material requirements, which is in turn based on water requirement. Because there is continuous demand during the whole year and because some of the materials need replacement, due to the fact that they become obsolete, GWSSB is mainly concerned with the establishment of the minimum and maximum quantity of materials it has to maintain throughout the three seasons.

1.2 Inventory policies at GWSSB

Detailed records of issued and quantity demanded as per item are maintained by GWSSB. Based on these records, GWSSB makes an estimation of the demand for the following year as follows: The actual consumption of materials is considered on a three-year basis (for the previous three years). The average of the three years is taken as a rough estimate of the demand for the following year. This figure is only the basis for the procurement of the materials but on these grounds GWSSB will procure 50% of the quantity at the beginning of each year. The rest of the quantity will be purchased gradually according to the requirements. In the programme used, we have considered this policy and whenever the programme runs the first month of each year, the inventory is updated by this amount of inventory.

GWSSB's practice of material ordering is the maintenance of a number of suppliers located in different parts of the country. GWSSB will place sequential orders with the manufacturers based on the quantity demanded sent to the organisation. As with all inventory systems there is an inter-order period, which determines the minimum amount of time before which the company does not place an order. In the case of GWSSB this inter-order period is 2 months, which means that no orders are placed before 2 months have passed from the previous order. This figure is also used in the programme.

2. SIMULATION MODELLING OF PROCUREMENT SYSTEM

2.1 DEMAND AND LEAD TIME DATA

For each of the four pumps demand is forecasted individually. As Daellenbach et al. [1] mention, probability distributions of demand of items of A category are either based on the empirically observed distribution or approximated by normal distributions. We assume a normal distribution for the demand of the pumps as per month and this distribution will have a different mean and standard deviation for each month.

As far as the lead-time for the materials is concerned, for the submersible pumps, the average total time for receipt of material at the stores after the materials are required is approximately 3 months. This figure can vary from 1.5 to 4.5 months. The assumption made here is that the lead-time is normally distributed with a mean of 3 months and a standard deviation of 0.3 months.

Random numbers for the demand and lead-time for every month are generated in the model using the polar method.

2.2 COST OF THE SYSTEM

Table 2.1 shows the cost of the four types of pumps as recorded in the weekly balance statement at GWSSB's main store in Gandhinagar.

PUMP TYPE	COST OF ONE ITEM (Rupees)
3.0	11,068
4.0	12,111
7.2	25,786
8.1	28,828

Table 2.1: The cost of each pump type considered in the analysis

Further, we attempted to identify the costs that vary as the operating doctrine varies and that influence the selection of the operating doctrine. The total cost of the system is divided into two types. The two types of cost are incorporated in the model. The first of these costs is the cost of ordering. In general, the cost of ordering can be divided in two categories, as Hadley and Whitney [2] mention: those which are dependent on the quantity ordered and those which are not dependent on the quantity ordered. An equation was formulated to account for these two types of ordering costs.

The first type is:

$$\text{Dependent cost of ordering} = C_1 \times (\text{number of items ordered})$$

The second type is:

$$\text{Independent cost of ordering} = C_2 \times (\text{number of orders})$$

It should be noted here that the values of C_1 and C_2 were taken to be 0.01 times the cost of one item.

The second type of cost is the cost of holding inventory. The holding or storage cost is usually related to the maximum or average level of inventory or excess of supply in relation to demand during a particular time period. In our analysis the carrying cost is taken as equal to the average level of inventory multiplied by the cost of one item and furthermore multiplied by the interest rate of 0.1. Thus the equation that was used for estimating the cost of holding can be expressed as:

$$\text{Cost of holding} = (\text{average inventory}) \times (\text{cost of one item}) \times 0.1$$

There is a third type of cost, the stockout or shortage cost, which occurs when the demand for an item exceeds its supply. In the classical inventory systems, this cost varies depending on whether the exceeded demand is lost or backordered. In the case of GWSSB the demand that is not satisfied is not lost. GWSSB is the only supplier of the materials to the villages and towns of Gujarat. Demand for the back-ordered items is satisfied when the items next become available. The best that can be done to measure the stockout cost is to translate it into service level.

For the purposes of this study, its value was taken as the percentage of demand that is satisfied as opposed to the demand that is not satisfied. The equation used to calculate the service level is:

$$\text{Service level} = [1 - (\text{average unsatisfied demand} / \text{total demand})] \times 100$$

The unsatisfied demand was calculated by estimating the number of items that were demanded and not been delivered at the end of a fixed time period, which was taken to be six months. The average unsatisfied demand was then calculated at the end of the six years. In the model, unsatisfied demand enters a queuing system to ensure that it will be satisfied, as soon as the quantity requested becomes available.

3. RESULTS AND DISCUSSION

The simulation model was run for 6 years (72 months). Experimentation with the model involved various combinations of the reorder and the fill point in order to identify their values that minimise the cost of the system for a service level that the company specifies.

In an attempt to prevent extreme values from influencing the results, each combination was run for approximately 20 times. Then, the average total cost and service level were calculated and these were the final figures used in the analysis and the figures presented in the tables below.

The programme was run for a range of reorder point and a range of fill level. These ranges were inferred after considering the monthly values of the demand for each type of pump. The model was run for each of the four types of pumps individually. Approximately 4,000 runs were made in total.

3.1 ANALYSIS OF OUTPUT

This section presents the analysis of output made after experimenting with the model. Results from the analysis are presented for each type of pump individually. A minimum acceptable service level was taken as 86% for all pumps and a maximum acceptable cost was taken for each pump differently. Because there has been an upper limit for the cost, it has not been possible to achieve service levels of more than approximately 93%. Thus, the range of service level that appears in the analysis is 86% to 93%. Numbers were rounded up to the nearest integer.

For pump type 3.0 the range of values for the fill level varied between 15 and 25 and for the reorder point the values varied between 2 and 15. Various combinations were tested. For every fixed value of service level, ranging from 86% to 93%, the optimum combination of reorder point and fill level was chosen according to cost minimisation. Table 3.1 gives the final results for pump type 3.0. The table shows the combinations of reorder and fill point that were chosen as having the minimum cost for the different service levels. The maximum acceptable cost was taken to be Rs. 600,000. The corresponding results obtained for cost at various service levels for pump type 4.0 are given in Table 3.2. For this pump the range of reorder point has been 2 to 6 and for the fill point it was taken as 15-25. The cost restriction for pump 4.0 was also taken to be Rs. 600,000.

Table 3.3 shows the comparison of cost and service level for pump 7.2. In this case, the maximum acceptable cost was taken to be Rs. 650,000. The value range for the reorder point and the fill level for this pump have been 2-6 and 8-15 respectively.

Finally, table 3.4 shows the results for pump type 8.1. In the case of pump type 8.1, the maximum acceptable cost was taken to be Rs. 800,000. The range of value for the reorder point has been 2 to 6 and for the fill level 7 to 15.

Service level (%)	Reorder Point	Fill Point	Minimum Total Cost (Rs.)
86	4	19	300,837
87	2	22	302,264
88	2	24	325,645
89	3	24	394,759
90	6	21	391,848
91	4	24	443,563
92	5	23	490,165
93	10	21	546,253

Table 3.1: Combinations of reorder and fill point that give the minimum costs for every service level for pump type 3.0.

Service level (%)	Reorder Point	Fill Point	Minimum Total Cost (Rs.)
86	2	19	285,387
87	2	22	353,153
88	3	20	378,501
89	5	17	366,821
90	3	21	391,866
91	4	19	402,554
92	4	20	419,134
93	5	20	506,902

Table 3.2: Combinations of reorder and fill point that give the minimum costs for every service level for pump type 4.0.

Service level (%)	Reorder Point	Fill Point	Minimum Total Cost (Rs.)
86	2	11	400,316
87	2	12	436,674
88	2	13	482,612
89	4	8	427,984
90	5	8	491,895
91	4	9	506,361
92	3	12	572,309
93	4	10	599,707

Table 3.3: Combinations of reorder and fill point that give the minimum costs for every service level for pump type 7.2.

Service level (%)	Reorder Point	Fill Point	Minimum Total Cost (Rs.)
86	2	10	543,899
87	2	11	616,545
88	4	9	611,746
89	3	10	619,962
90	3	11	664,775
91	2	12	671,744
92	2	14	767,244
93	4	12	784,353

Table 3.4: Combinations of reorder and fill point that give the minimum costs for every service level for pump type 8.1.

The tables show which combination of reorder and fill point should be chosen for minimising the cost for a desired service level. For all types of pumps, and according to the cost restriction, the optimum combinations of reorder and fill point are presented in the tables above.

The conclusion that can be drawn is that similar patterns can be observed for all pump types. The following give the main observations from the experiments carried out.

As one would expect normally, for a fixed value of reorder point, an increase in the value of fill point would result in an increase in service level and an increase in minimum total cost. Furthermore, for a fixed value of fill point, an increase in the value of reorder point results in an increase in service level and a consequent increase in minimum total cost.

For all pump types, the tables show that, in general, an increase in the value of reorder point and a decrease in the value of fill point, increases the service level and decreases the minimum total cost. There is an exception to this general observation, which occurs for high values of service level, where an increase of reorder point and a simultaneous decrease of fill level, increases the service level and the total cost. This can be observed for all pump types and can be explained by the increase in the reorder point and the high service level, which results in a decrease in the fill level, in order to keep the cost to its minimum level. However, the need to keep the reorder point at high values increases this minimum total cost. For pump type 3.0, the value of service level where the behaviour of the system starts to change is 91%, while for the other pump types this value of service level is 92%. Finally, in all cases of decreasing the reorder point and increasing the service level, the fill point and the minimum total cost is increasing.

We can observe that the behaviour of the fill point is the same as the behaviour of the total cost, (except for high values of service level, where the behaviour of the total cost follows that of the reorder point) and this can be attributed to the fact that the total cost is mainly influenced by the cost of holding. This occurs because the cost of ordering is made up of two components, which have exactly the opposite behaviour. The dependent cost of ordering depends on the number of items ordered, which increases as the difference between the two variables increases, while the independent cost of ordering depends on the number of times the orders are made and increases when the difference between the two variables decreases.

If we look at the reorder point and the fill point as functions of the service level, we identify that the need to keep a minimum total cost results in opposite signs in the first derivatives of the above functions.
The difference between the fill and the reorder point reaches its minimum value for 90% service level for pump type 3.0 and 7.2, for 89% service level for pump type 4.0 and for 88% level of customer service for pump type 8.1 and this results in a local minimum in the minimum total cost.

3.2 SENSITIVITY ANALYSIS

A sensitivity analysis was performed on the inter-order period, which initially was taken to be 2 months. An acceptable level of 1.5 months was used in the sensitivity analysis for pump type 3.0, as smaller inter-order period gave unacceptable high levels of total cost, due to the increased cost of ordering and the increased holding cost. The model was run for 72 months and for service levels between 86% and 93%. The following diagram shows the relationship between the minimum total cost and the service level for inter-order periods of 2 and 1.5 months.

As we can see from the diagram, the same levels of customer service, in all cases give lower or equal total cost, when the inter-order period was taken to be 1.5 months, as compared to the value of 2 months. The experimentation with the other pump types gave similar results and the behaviour of the total cost as related to the service level was the same.

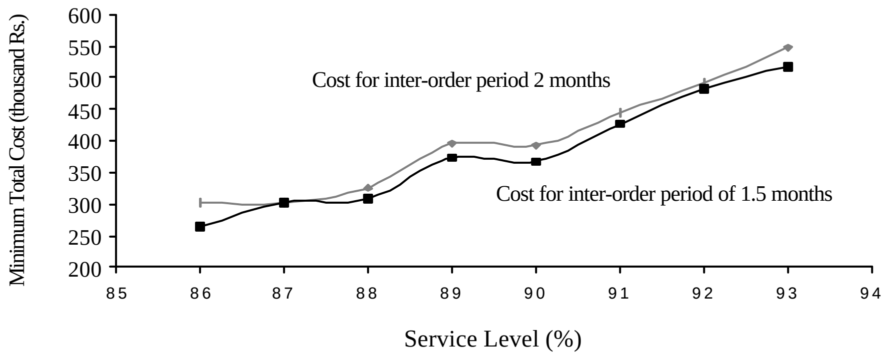

Figure 3.1: The relationship between service level and cost for inter-order period of 2 and 1.5 months for pump type 3.0

4. CONCLUSIONS

This project has been triggered by interest in effective inventory control of the materials procured by the Gujarat Water Supply and Sewerage Board of India. The major concern has been the establishment of the minimum and maximum quantity of materials for water supply for various levels of customer service and minimum total cost. From the materials procured by GWSSB, four types of pumps were chosen as a basis for exploring inventory control. For each pump type the same procedure was followed in order to identify relationships between the reorder and fill point and the service level, as well as the corresponding costs. All of the different types of pumps showed similar patterns.

The analysis showed that as a function of the service level, the first derivative of the reorder and fill point have opposite signs, and this can be attributed to the goal seeking behaviour of the model towards the minimum total cost. Moreover, for values of service level between 86% and 91%, the curve of the minimum total cost and the fill point have the same behaviour, while for service levels between 91% and 93%, the curve of the minimum total cost follows the behaviour of the reorder point.

Finally, a sensitivity analysis in the inter-order period showed that if this period is reduced by 0.5 months, then for the same levels of customer service, the total cost of the system decreases, and in some cases remains virtually unchanged.

References

[1] Daellenbach, H.G., George, J.A., McNickle, D.C.: *Introduction to Operations Research Techniques*, Allyn and Bacon, Inc., London, 1983.

[2] Hadley, G. and Whitney, T.M.: *Analysis of Inventory Systems,* Prentice-Hall, inc. international, Englewood Cliffs, N.J., 1963.