USE OF STATISTICAL TECHNIQUES IN CONSTRUCTION MANAGEMENT

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Abstract: While manufacturing industry has generally been capable to apply new concepts successfully, construction industry still appears failing to apply them. Although these two industries differ significantly from each other, there is no obvious reason why construction industry should not be able to take advantage applying new concepts, and reject its denounced traditionalism. The new trends have been represented by concepts like mathematical modeling, operations research, lean production techniques, total quality management and just-in-time production. This paper is thus intended to highlight the various scenarios in the life-cycle of construction projects, where statistical methods can be used to overcome the drawbacks of traditional construction. Time studies have been conducted on various grades of manpower and equipments in Indian construction to measure their actual productivity. The application of statistical methods in construction provides construction managers and other decision makers the opportunity of experiencing and responding to various factors which are responsible for loss of productivity, and hence eliminating them.

Objectives of the Study

The aim of the research is to apply statistical methods available at various stages during the life-cycle of construction projects. Hence, highlighting the advantages of applying statistical methods to construction is the prime objective. As a first step in applying such methods to construction, quantifying the significance of statistical parameters and their interactions.
and benchmarking the standard times obtained from time-studies is important.

- The prime objective is to measure productivity and hence identify and measure non-value adding items, their impact, study their probable causes, and find out methods of eliminating these.

- Time-motion studies need to be carried out to determine the productivity of the system under study. Waiting line models need to be applied to find out the most optimum solution or method which will give highest productivity.

- Vendors must be rated based on their past performance for punctuality, quality and reliability, and hence a Vendor Rating Index (V.R.I) should be given to vendors, which would help assessing them for present or future assignments.

- Vogel’s Approximation Method must be applied to a Transportation Matrix for finding Initial Basic Feasible Solution (IBFS).

- Subsequently, method of multiplexes is applied to the Transportation Matrix to balance between supply and demand and hence find out the optimal units that need to be supplied from a particular site to a particular destination, minimum cost of transportation is obtained.

- In essence, the focus is to apply various statistical tools to the observation data-sets generated for various construction processes and compare the results with traditional methods for savings in time and cost, due to their application.

**Data Collection**

The discrepancy between productivity in construction with that in other industries, such as manufacturing, prompted the statement that construction productivity lags behind that of manufacturing. With the advent of new technologies and fast-track construction, it becomes utmost essential to make optimum utilization of resources. Hence data needs to be collected to measure productivity and hence take corrective action to improve the process.

Statistical Models need to be applied to the life-cycle of a construction project to achieve maximum benefit. Hence data right from the conceptual phase to the operations
and maintenance phase needs to be collected and statistical methods should be employed for continuous improvement.

Data was collected from the Gowalkot-Kaluste river bridge project site in Chiplun, Ratnagiri where cycle times of machine and manual loader were measured in order to determine their operational productivity.

The following data-set was generated:

- Capacity of 1 truck: 2 brass
  
  \[= 2.83 \times 2 = 5.66 \text{ cum.} \]

- Bucket Capacity of loader = 1 cum

- Rate of machine loader = Rs. 80/brass

- Rate of labor gang = Rs. 70/brass

- Waiting cost for Dumper = Rs. 300/hour

**Fig 1: Kaluste Bridge site**

*(during construction)*

Hourly cost of loaders (manual and machine) and dumpers were established in order to find out the optimal matching and sizing of these units. Further, past performances of sand suppliers were studied, and the on-site rates proposed by different vendors for the site were noted down.

**Loading of Dumper using human loading and machine loading**

The times taken for labor gangs (4 members each) to load sand into a 2 brass dumper and the times taken by a machine loader for the same work were measured.

The emphasis here was to first of all measure and compare the productivity of the two systems, with respect to their cost; find out and reduce the waiting times (or rather ‘waste’) in the systems, by applying Mathematical models.
Table 1: Time taken for Machine Loading

Table 2: Time taken for Labor Loading

From the set of observations generated in Table 1 and Table 2 and its subsequent analysis, it was found that average time taken by machine loader to fill up a 2 brass dumper with sand was 297.625 sec. and the average time taken by a group of labor loaders (4members) to fill up a 2 brass dumper with sand was 1169.25 sec.

It can be further interpreted that, the average time actually required to fill a dumper (297.625 sec.) is much more than the expected normal time (216 sec.), about 82 sec. more. Although, this time is not by any means a very large one, but its effect on the waiting time of the dumpers is quite a considerable one. This is because the effect is not linear but an exponential one, because the lesser servicing rate can lead to more number of dumpers waiting simultaneously.

Economical analysis was done for all permutations and combinations of machine loaders and labor loaders for total hourly operating cost and it was found that 3 labor gangs were the most economical combination for optimally loading the dumper.

Past performance of Sand Suppliers

For the construction of a section of the river portion of the bridge, 3 sand suppliers; viz. Falcon Sand Suppliers, Surve Sand Company and Katmale Traders, supplied sand during the construction.

Falcon Sand Suppliers had delivered 244 brass of sand, out of which 12 brass was found to be reddish in color and hence was not used for the intended purpose. Rate at which they supplied sand was Rs. 1700/ brass. Out of the
244 brass received, 210 brass was received as promised.

Surve Sand Company, who furnished with 30 brass, during the same period, charged Rs. 1750/brass. No defect whatsoever was found in their sand quality, however, due to lack of manpower, they could not supply 10 brass out of the 30 promised on time.

Katmale Traders, who supplied 183 brass, were the lowest price suppliers at Rs. 1625/brass. However, 21 brass of the total supplied was too coarse than desired and 24 brass was reddish sand, which contained high amounts of salts and minerals, and was not suitable for construction. Katmale Traders were late with 17 deliveries of 2 brass each (i.e. in total 34 brass).

The past performance of sand supplier can be handful in rating the supplier and determining the most likely performance for future works.

Since price is most volatile factor and constantly increases at a very fast rate, it should be given maximum weightage. Hence, following weight factors are assigned.

- Price – 40%
- Quality – 30%
- Delivery on Time – 30%

Subsequent analysis after assigning the above weight factors reveal that Falcon Sand Suppliers had a Vendor Rating Index (V.R.I.) of 0.926, Surve& Co. had a V.R.I. of 0.872 and Katmale Traders had a V.R.I. of 0.879. This suggests that Falcon Sand Suppliers can be more trusted for future supplies.

Varying prices of sand and inventory carrying cost

When the construction of bridge first started in 2006, the cost of sand was estimated to be Rs. 1100/brass in 2010, i.e. in the final stages of construction. But due to increase in royalties to be paid by sand suppliers, the sand prices went up abruptly.

Hence, the actual sand prices in 2010 far exceeded the estimated prices. The contractor had to shell out Rs. 1700/brass on an average and this itself lead to a tremendous increase in cost. Moreover, due to increase in diesel and petrol prices, the inventory carrying cost which was estimated to be 15%, actually turned out to be 18%.

The ordering cost which was estimated to be Rs. 25/truck (i.e. 2 brass), increased to Rs 50/truck. The annual consumption of sand in
the Year 2010 was estimated to be 640 brass, but in actual due to pilferage, bulking of sand, and defective supply, 672 brass was required.

% increase in total cost based on these variations

\[
\text{\% increase in total cost} = \left( \frac{\alpha \beta + \gamma \delta}{2(\alpha \beta \gamma \delta)^{1/2}} - 1 \right) \times 100
\]

Where,
\begin{align*}
\alpha &\text{ represents estimated value of capital consumption} \\
\beta &\text{ represents estimated value of ordering price} \\
\gamma &\text{ represents estimated value of unit price} \\
\delta &\text{ represents estimated value of inventory carrying cost.}
\end{align*}

Hence, from the data observed, it is found out that rate of sand, inventory carrying cost, ordering cost and sand consumption have all been under-estimated.

**Table 3: Rates and supply capacities of sand vendors**

Therefore, % increase in total cost based on these variations = 7.87%

**Supply v/s demand**

In 2011, the construction was in its final stages and the contractor was searching for continuous supply of construction materials. As such, the contractor wanted to finish maximum work in the month of May and hence had asked for on-site sand rates from local sand suppliers for that particular month.

The sand suppliers quoted following rates and their daily supply capacities.

There were two places where side berms need to be constructed on either side of the river and hence the bridge to be zeroed. Sand was also needed for plastering of bridge portion over the river and building fence for the bridge. The Gowalkot end of the bridge was well connected to the city and hence easy transportation of sand, cements and other
construction materials is possible; however, transportation of construction materials to the Kaluste end was expensive, as there was just one route available, which joined it to the city and it was about 13 kilometers from the city.

Hence, this transportation problem had to be solved to arrive at the optimum cost. The objective here was to determine the sources from which the sand should be procured and the amount that should be procured from each source, that will minimize the total cost of transportation while satisfying all the supply and demand restrictions.

Hence, using Vogel’s Approximation Method (V.A.M.), the initial basic feasible solution (IBFS) was found out.

<table>
<thead>
<tr>
<th>Name of Supplier</th>
<th>Amount of Sand to be supplied (in brass)</th>
<th>Daily Supply Capacity (in Brass)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falcon Sand Suppliers</td>
<td>Gowalkot end 2, Kaluste end 8, River Portion 2, Dummy 8</td>
<td>20</td>
</tr>
<tr>
<td>Surve Sand Company</td>
<td>Gowalkot end 0, Kaluste end 0, River Portion 4, Dummy 0</td>
<td>4</td>
</tr>
<tr>
<td>Katmale Traders</td>
<td>Gowalkot end 14, Kaluste end 0, River Portion 0, Dummy 14</td>
<td></td>
</tr>
<tr>
<td>Daily Demand (in Brass)</td>
<td>Gowalkot 16, Kaluste 8, River Portion 6, Dummy 8</td>
<td>38</td>
</tr>
</tbody>
</table>

Hence, initially it was determined that, daily for the Gowalkot end, 2 brass should be obtained from Surve Sand Company and rest 14 brass should be procured from Katmale Traders; for the Kaluste end, daily 8 brass should be procured from Falcon sand suppliers; and for the bridge over the river portion, daily 4 brass should be procured from Falcon Sand Suppliers and rest 2 brass should be procured from Surve Sand Company. In doing so, the daily cost would be just Rs. 55,150. However, this was just the initial basic feasible solution and the optimal solution was found out by further optimizing.

**Table 4: IBFS using VAM**

Using u-v method or method of multiplexes, and subsequent optimizing, it was ascertained that, daily for the Gowalkot end, 2 brass should be obtained from Falcon Sand Suppliers and rest 14 brass should be procured from Katmale Traders; for the Kaluste end, daily 8 brass should be procured from Falcon sand suppliers; and for the bridge over the river portion, daily 4 brass should be procured from Falcon Sand Suppliers and rest 4 brass should be procured from Surve Sand Company. In doing so, the daily cost would be reduced to Rs. 55,100.
Table 5: Optimal Solution or Solution of Transportation Matrix

<table>
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</tr>
<tr>
<td>Katmale Traders</td>
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<td></td>
</tr>
</tbody>
</table>

Conclusions

From the various scenarios observed and detailed above, it can be concluded that, using statistics to enhance construction activities is not a difficult preposition; it is something which is very simple, aimed at reducing wastes and improving productivity. Although, statistics is used as a tool to make business strategy decisions by contracting firms at the top level of management, it is inevitable that construction planners realize the importance of implementing statistical techniques in day-to-day construction activities.

References

5. www.answers.com
6. www.wikipedia.in