Use of Statistical Methods in Construction Industry

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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.

Introduction: With the continuous decline in profit margins and increased competition in construction projects, construction contractors are finding ways of eliminating waste and increasing profit. Although numerous approaches have been developed to improve efficiency and effectiveness of construction processes, mathematical modeling techniques offer the promise to minimize, if not eliminate non value-adding work.

Time study is the study carried out to assess human effectiveness by improved planning and sound incentive scheme to its employees. It is employed in the assessment of human efforts in all its aspects to lead systematically to all the factors which ultimately affect efficiency and economy of the situation under study in realizing the objectives of bringing about improvements.

The objective of this paper is to highlight the benefits of use of statistical methods in construction. Statistical methods are employed to find out the best sizing-matching of operations for arriving at the optimum cost. Time-motion study has been employed to measure the productivity of the operations and hence find out non-value added items.

It is expected that employing statistical concepts to construction will help in increasing productivity and reduce risks. Mathematical models will help in selecting the most suitable combination of machines/labor gangs for a
particular operation. Time-motion study will help in benchmarking operations for a construction firm.

With the advent of new technologies and fast-track construction, it becomes utmost essential to make optimum utilization of resources. Previous Scheduling Models need to be replaced by Realistic Repetitive Scheduling Models, wherein concepts such as same crew working in multiple activities, varied production rates, work quantities, activities having multiple predecessors, activities skipping units, custom progress direction and work sequence, ability to specify space buffer or time buffer between activities, etc. are being accounted for.

Why theories are essential in construction?

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. According to Koskela(2000), there is lack of theoretical foundation in construction production. Construction peculiarities {on-site, one-of-a-kind (i.e. unique product production or prototype nature), and temporary organization} are also determining factors for this lag in productivity. Carassus (2004) further elaborates the characteristics of construction:

- Products are static on-site (immobile) : a trait of construction
- Structure are prototypes adapted to each site and environment
- Structures have a very long life (relative to other manufactured products)
- Structures are adapted to evolving demands.
- Institutional rules play an essential role.

Construction, as practiced is broader than just a theory of production, and involves many other disciplines. Several studies have highlighted the similarities and differences between construction and the ship-building, electronics, aerospace and the automobile industries.

Various theories such as the project management theory, transformation theories, flow value theory, etc. can be judiciously applied to construction. A deep study in the theories of project and the theories of management by Koskela and Howell(2002) for lean construction techniques has enabled them to prepare a guide – PMBOK (Project Management Body Of Knowledge). Koskela analyses the anomalies (deviations from assumptions and outcomes) between theory and practice to conclude that a wider and more powerful theoretical base is needed.

However, special care should be taken for applying theories to construction, because construction is an industry of industries, a complex meta-industry, rather than an industry. This is the prime reason why it is normally difficult to apply
theories to construction rather than in case for other sectors.

**Time Studies:**
This relates to the study to assess human effectiveness by improved planning and sound incentive scheme to its employees. This technique, along with method study, is employed in the assessment of human efforts in all its aspects to lead systematically to all the factors which ultimately affect efficiency and economy of the situation under study in realizing the objectives of bringing about improvements. It is a major tool for carrying out productivity analysis.

The credit to this particular concept of scientific management goes to F.W. Taylor. Time study is defined as the application of techniques with which the time required for a qualified worker (not academic qualification but skilled or semi-skilled or unskilled worker) to execute a specified work at a defined level of performance is determined. In case of time study, the work study officer has to consider following factors in detail:

- Qualified worker for a particular job.
- Specified job to be performed by a person qualified to perform the job.
- Defined level of performance to be achieved by qualified worker.

These three factors determine the standard time which is required to be established.

**Objectives of Time Study:** The aim and objectives of time study are:

- To find the optimum number of machines a worker can handle or optimum number of persons required to handle, operate and maintain a machine.
- To avoid delays in the work process.
- To find the optimum number of persons required to perform a specified job efficiently.
- To prepare accurate planning schedule for effective progress of work.

The sole objective of time study is to find out normal standard and to establish a unit of measurement. It helps in determining days work.

**Case Studies:**
Keeping in mind the requirements of the work, data was collected from two construction sites. The first set of data was collected from a bridge site in Chiplun, Ratnagiri, India where times of machine and manual loader were measured in order to determine their operational productivity. Hourly cost of loaders (manual and machine) and dumpers were established in order to find out the optimal matching and sizing of these units. The second set of data was collected from a 7-storeyed residential building site in Bhawani Peth, Pune to measure labor productivity of various grades of labor in various construction activities. Labors were observed for a sufficiently long period for each activity to get a reasonably reliable data-set.
Special care has been taken with regard to time of measurement while measuring productivity; as it is not advisable to do so during the first or the last half hour of a workday or closely before or after lunchtime. The data was collected between 10 am - 12.30 pm and after 2.30 pm to 5 pm on both the sites. Care has been taken to avoid identification by those performing the work, as it is a well-known fact that people tend to alter their behavior when they know they are being observed.

Findings, discussion:
A visit was made to the Gowalkot-Kaluste bridge project site in Chiplun, Ratnagiri and there the times taken for labor gangs 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.

The following data-set was generated:

- Capacity of 1 truck: 2 brass = 2.83 * 2 = 5.66 cum.
- Bucket Capacity of loader = 1 cum
- Rate of machine loader = Rs. 80/brass
- Rate of labour gang = Rs. 70/brass
- Waiting cost for Dumper = Rs. 300/hour

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<th>Dumper Sr. No.</th>
<th>Time taken(sec.)</th>
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Table 1: Details of time taken by Machine Loader to fill up a 2 brass dumpers

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Table 2: Details of times taken by labour gang of 4 members to fill up a 2 brass dumper

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 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.

Time study was performed on labors of various grades for different works. As shown in Table 3, where transporting bricks for 15m distance was observed, the activity was broken into 5 sub-activities viz. (i) putting bricks in vessel (ghamela); (ii) loading vessel, lifting and getting ready to move; (iii) transportation of bricks; (iv) unloading/emptying the vessel removing the bricks; (v) returning back and hence the cycle time was recorded.

Statistical analysis showed that sub-activities (i), (ii), (iii) were executed without too much variations as their standard deviation(σ) values were 7.32 sec., 9.97 sec. and 4.03 sec. respectively, while their coefficient of range (C.R.) values 0.42, 0.45 and 0.3 respectively and their coefficient of variation (C.V.) values were 24.73%, 26.45% and 17.99% respectively. The sub-activities (iv) and (v) had much higher values of measures of dispersion. Sub-activity (iv) had σ = 30.64, C.R.= 0.58 and C.V.= 40.26%, whereas sub-activity (v) had σ = 34.24, C.R.= 0.82 and C.V.= 100.41%. The activity as a whole had σ = 41.86 sec., C.R.= 0.33 and C.V.= 20.95%. This in essence indicates that the activity as a whole was executed properly, as C.R. and C.V. values are reasonably low.

Time study was performed on the brickwork activity in a 7-storeyed residential building in Bhawani Peth, Pune, where English bond pattern of laying bricks was observed. The whole activity ‘brickwork’ was broken into sub-activities, viz., (i) laying mortar over previous layer; (ii) lifting bricks and laying them in sequence; (iii) laying mortar in

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Table 3: Details of time required for horizontal transportation of bricks, about 9 bricks in 1 go by a single male labor

and C.V.= 20.95%. This in essence indicates that the activity as a whole was executed properly, as C.R. and C.V. values are reasonably low.
between bricks; and (iv) checking with line-dori and plumb bob and adjusting. Time in seconds for each sub-activity was recorded. The total cycle times for entire activity recorded were normally in proportion to quantity of brickwork. However, statistical analysis on different types of brickwork, varied number of rows in a layer and varied number of layers in a brick-wall was done and the measures of dispersion revealed that at least one sub-activity was under performed in some capacity in each observation. Various factors which lead to under-performance were presence of kids of female laborers on-site, scattering of waste leading to either diversion or blockage of normal working procedure. Construction managers can take a leaf out of these studies to get to the root-cause of loss of productivity and hence eliminate such non-value adding items (i.e. wastes).

Simple co-relation analysis was done on the time studies analyzed for two female labors working together for same activity, viz., transporting of sand bags (wt. about 30 kg.) horizontally for a distance of 30 m. this activity was sub-divided into two sub-activities, viz., (i) traveling towards dumping place, inverting and hence emptying the bags; and (ii) coming back to loading place, lift bag, get loaded & ready to leave. Examination and analysis of these times showed that there was a good positive co-relation [+0.641] for sub-activity (i) between the two labors and an almost perfectly linear co-relation [+0.962] for sub-activity (ii) between the two labors. The co-relation between the two labors for the whole activity was +0.976. All these findings suggest that as one labor slows down or is disrupted, it has a contagious effect on the other labor and her processes follow the same pace as the former ones’. Project managers need to take such studies into account while planning their processes.

Time studies were also carried to determine the idle times of units working in association. While times of different units responsible for the vertical transport of sand bags using pulley were recorded, analysis showed that the pulley operator and the ones on ground horizontally transporting these bags to pulley location from sand yard and loading them to pulley were busy; the one filling these bags and the ones responsible for unloading them on 6th floor often wasted much of their time just because of unavailability of products to execute their works. Using the results of these studies, planners can reshuffle their man-power so that idle time of each unit is minimized; or else put in some more labor for the critical sub-activities.

Time studies were also carried out on the process of shuttering of columns on a particular floor and the results of statistical analysis showed a large variation. Measures of dispersion suggested that coefficient of range and coefficient of variation were on the higher side (C.R. generally between 0.45 to 0.7 & C.V generally between 30 to 90%). Time was wasted due to rework, unavailability of
proper working material, lack of safe working practices, etc. Operations Research in such activities and their sub-parts is essential and construction managers need to understand where possibly the flaw lies; in the construction process or in the human inadequacy or in machine inefficiency. These studies are also essential in finding out the idle time of a particular type of resource and possible measures can be taken to eliminate these.

**Conclusion:**

The data collected and subsequent analysis done show that in each case the contractor is not concerned too much for enhancing operational productivity and the fact that time-motion studies were not previously done by them by proper benchmarking, support the hypothesis. The analysis done for matching and sizing of machine loaders/ labor gangs to obtain the optimum solution for that particular operation, i.e. loading 2 brass dumpers, suggest that 3 labor gangs of 4 labors each (hourly cost: Rs 1734.78) is the most optimum solution. But the contractor had provided a machine loader (hourly cost: Rs. 2184.78), which is about Rs. 450 more than the optimal solution. Hence, such models tell us where we can go wrong, if we just blindly employ traditional methods.

Hence, it can be concluded that statistical tools, which are very simple to use and give precise results should be incorporated in each and every major activities / operations, because construction activities / operations, are interdependent and delay in a critical activity delays the project itself.

**References:**