Research Agenda for Performance Studies on Solid Waste Management Equipment

[1]Khant Shah [2]Dr. Devanshu Pandit
[1]Student [2]Professor
[1,2]CEPT University, Ahmedabad, Gujarat, India

Abstract

Since launch of Swachh Bharat Mission (SBM) in 2014, government has allocated huge budget to modernized solid waste management especially the equipment. However, Indian industry relies heavily on the experience of managers or data provided by the Original Equipment Manufacturer (OEM). This data when used in the estimates of a project resource gives a virtual or ideal scenario which doesn't consider the efficiencies, and factors which might affect the performance of the equipment under analysis. There is lack of research on performance of equipment productivity. This state of the art paper discusses the research carried out on equipment productivity and identifies the research needs for SWM equipment productivity.
Keyword- SWM Equipment, Productivity, Factors, Optimization

I. Introduction

In India, currently municipal solid waste management is one of the major issues and thus for the same, attempts are being made to organize and develop a comprehensive model for its management. This being said, it is also an important component of the Government of India's "Swachh Bharat Mission" (SBM). Various studies are carried out pertaining to the generation, collection and transportation, disposal and treatment technologies of MSW which might result in successful implementation of an integrated solid waste management program for the city.

Studies with the aim to find solutions for numerous issues such as reduction of waste at source, reduction of littering after collection, labour and resource management, working conditions, innovative techniques and systems, finding scientific methods for treatment and disposal of refuse etc. are being carried out for achieving better and sustainable model (Hazra & Goel, 2009).

With the innovations in various sectors, the equipment used for collecting and transportation of the refuse have also evolved. At the same time, managers' ability to understand the economics and performance of resources especially equipment has also gained firm grounds. The availability of various accurate and advanced computing and data collection techniques will boost the management's ability to understand the nuances of performance driving factors and their significance. On the other hand, Indian industry have long relied on the experience of managers or data provided by the Original Equipment Manufacturer (OEM). This data when used in the estimates of a project resource gives a virtual or ideal scenario which doesn't consider the efficiencies, and factors which might affect the performance of the equipment under analysis (Kannan, 2011).

Mechanization and equipment to certain extent reduce the dependency on human and at the same time increase the efficiency. This increase might be in terms of cost savings, time savings or quality of the output. Ahmedabad Municipal Corporation in its area has a road network of 2399 Km whereas that of Surat is 1914 Km (MoUD, 2011). Street sweeping by manual labour becomes either time consuming or requires abundant labour force to accomplish the task during the assigned hours. Mechanical sweeping machines mounted on truck or pulled by tractors prove to be really useful as far as time saving is concerned. Similarly, the importance of compacting equipment is also known when it comes to compaction of refuse in thousands of tons. Mobile compactors become useful in reducing the load on the stationary compactors placed at the transfer stations. This is also helpful in reducing the number of vehicles required for collection as the mobile compactors can carry more refuse than the normal waste collecting vehicles which carry slack waste. The paper reviews literature related to equipment to understand the productivities associated with the equipment used in solid waste management and the methodology applied. The research aims to address the issue where the project managers rely too much on the OEM data or their experience or gut feeling to find out the resource requirements. The need is to develop understanding of the performance of various solid waste management equipment pertaining to collection, transfer and sweeping activities, the environment under which the performance may vary and their influence level on the performance.

Ok & Sinha (2006) in their research has discussed impacts of changeable environment, the influences of job and management factors on operation productivity. Hazra & Goel (2009) brought out impacts of false prediction and assumptions of the SWM equipment productivity on the operation cost through case study of Kolkata Municipal Corporation. They further noted that the collection process was deficient in terms of manpower and vehicle availability along with lack of demand analysis of the collecting vehicles. Overestimated performance parameters led to a paralysed management which resulted in severe cost burdens.

II. LITERATURE REVIEW

A. Productivity

The term "productivity" is generally used to analyse the performance from the relationship of the output and associated inputs. Generally, in field practice by the engineers, productivity is calculated based on the dominating resource input such as labour in construction activities, or excavator and hauling truck in excavation works. This is known as partial factor productivity where only limited factors are taken in to consideration. Researchers generally try to create a holistic model to estimate productivity which considers all the variables affecting it, hence called Total Factor Productivity (Yi & Chan, 2014). Chao & Skibniewski (1994) defined productivity as the output of the system per unit of time. Productivity as defined by Kannan (2011) is the amount of work done by the individual or a group of equipment in a given time period. In general terms, it can be simply illustrated from the following formula given by Panas & Pantouvakis (2010),

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

Productivity as defined by economists and accountants is the ratio of total resource inputs to the total output product (Hanna et al, 2005). For a compactor, it can be defined based on the compaction achieved. As for mechanical sweeper it can be estimated from the length of road swept per unit time. This relationship of the input parameters and output will be arrived at during the study for the equipment under study.

B. Prior Studies on Equipment Productivity & Methodology

Productivity studies on construction equipment has been explored in past by the researchers. Studies on earthmoving system productivity (Han et al, 2005; Smith, 1999), excavator productivity (Chao et al, 1994; Edwards et al, 2000; Tam et al, 2002), dozer productivity (Ok & Sinha, 2006; Rashidi et al, 2014) and auger productivity in piling process (Zayed & Halpin, 2004) are available for reference.

According to Zayed & Halpin (2004) productivity assessment techniques can be divided into two major heads : Process Oriented Techniques (POT) and Data Oriented Techniques(DOT). They argue that POT deals with the process involved in the activity whereas, DOT deals with the data without giving any thought to the processes involved. The comparison of the four methods used shows DOT to be more accurate. POT was found to be carrying high deviations and optimistic too. In terms of methodology, rank reversal technique suggests that ANN is the superior technique followed by regression analysis (Zayed & Halpin, 2004).

Deterministic model focuses on the utilization of durations that are fixed and any variation in task duration is assumed to be ignored. Deterministic model often over-estimates the actual productivity (Han & Halpin, 2005). They used simulation to generate data for further analysis. Multiple Regression analysis was performed on the data. The actual collected data however has some limitations such as: a) smaller volume of data, b) variance is more in small data set, c) difficult to obtain actual field data. These limitations can be addressed with the use of simulation. The author used WebCYCLONE as the simulation program to generate data sets which were then analysed by multiple regression. Although the research has been done keeping earthmoving operations in focus yet, it can be treated as a framework for further research.

Contractors largely rely on deterministic approach to estimate productivity to a satisfactory degree of accuracy but these attempts will not take conditions into consideration and hence prove to be less reliable (Rashidi et al., 2014). In the recent decades, numerous researchers have taken up the task of developing reliable models to determine equipment productivity and the variables involved in the determination. The most of the models used in these research were found to be based on Linear Regression (LR) models and Artificial Neural Networks (ANN). Linear regression models were found in early researches (Edwards & Holt, 2000; Smith, 1999). Recent studies found to be based on mixed models or ANN approach (Chao & Skibniewski, 1994; Ezeldin & Sharara, 2006; Ok & Sinha, 2006; Rashidi et al, 2014; Tam et al, 2002; Zayed & Halpin, 2004).

LR models are not the most accurate owing to the fact that productivity assessment is a very complex process and involves number of independent variables. On the other hand, ANN is found to be adaptive method for the determination. ANN requires huge data sets to train, validate and assess the model. It is considered to be extremely complex and time consuming when actual productivity is to be calculated (Rashidi et al, 2014). Rashidi et al., (2014) used Generalized Linear Mixed Model (GLMM) is found to be more accurate than LR and does not require large datasets as required in ANN method.

C. Factors Affecting Productivity

From a thorough study of literature available, a list of factors influencing productivity rate is prepared and the same is summarized in the "Appendix 1 Equipment Productivity Factors identified from Literature Review." It was found that the most influencing factors are,

- Management skills- Ability to manage the job
- Planning- Sequencing and logistic planning, routing etc.
- Equipment Breakdown- Irregular maintenance and repairs, downtime
- Weather- Humidity, temperature, rainfall
- Job complexity- The method adopted for the job, complexity of the task.
- Operator skills & experience

- Equipment specification and capacity- The technology, capacity and other influencing parameters
- Site conditions- Spaciousness, soil/terrain conditions etc.

Other factors like repetitive work, non-payment, lack of instructions and clarity, motivation, working days, age of equipment, supervision, traffic, quantum of work & Idling/waiting. All the coefficients and corrections need to be analysed from the factors driving change in productivity to obtain accurate equipment efficiency. This coefficients arrive from the various parameters such as environment, operator's experience and job specific details. Thomas & Yiakoumis (1987) observed the effect of weather and temperature on productivity using multiple regression & sensitivity analysis. Effect of various other factors were also seen and a smooth discounted curve was obtained. The study was done on limited factors and projects and hence author insists on validation of the model by subsequent studies.

D. Prior Studies on Solid Waste Operations

On account of industrialization and population explosion, urbanization has increased from 28% to 32% as per Census of India data of 2001 and 2011 respectively. Thus the provision of basic amenities especially to the urban poor has become of great importance in urban development agenda. This development includes livelihood, access to resources, clean environment and public health. Solid waste management has become a service getting lot of attention in India with the initiation of Swachh Bharat Mission in the year 2014.

The increase in attention is evident from the budget that has been allotted to SBM and SWM in last five years. Budget released for SBM-Urban 2018-19 has increased to Rs 2,500 crores from Rs 1,600 crores in 2014-15 and that for SWM has gone up from 33% of SBM-U in 2014-15 to 46% in 2018-19 (Deshpande & Kapur, 2018). Despite this budgets, there have been debates on the current scenarios of SWM and shortcomings. Shekdar et al, (1991) had suggested the use of superior technology and optimal usage of resources long back but still if we look at the recent case studies these issues still exist which indicates the ignorance that the sector has received so far. Debates on Under-utilization of resources, collection efficiency and treatment failures have been there for a long time now. Shekdar et al, (1991) had also blamed inadequate or improper planning for the issues faced in implementation of SWM system and insists on long term planning of the system. The same issues have been found in many other research also. Goel (2008) criticized the failures in various packages of SWM.

Collection capacity which is often less than the actual generated waste is one of the biggest problems. This deficiency is mainly caused due to shortfall of resources or irregular transportation of waste (Goel, 2008; Shekdar et al, 1991). The research data (Goel, 2008; Sharholy et al, 2008) showed that only 50-70% of available fleet is available at any given time in most of the megacities which was mainly due to breakdowns, driver unavailability, inadequate capacity and numbers of vehicles.

The fact that collection and transportation processes are deficient has been discussed in various research papers (Goel, 2008; Gupta et al., 2015; Hazra & Goel, 2009; Joshi & Ahmed, 2016; Sunil et al., 2017). Hazra & Goel (2008) discussed about the issue in Kolkata (India) where collection efficiency is found to be in the range of 60-70% for registered residents and a mere 20% for slum dwellers.

Collection and transportation are the costliest activities in MSWM at approximately 70-80% of the total budget thus making them crucial components when it comes to determination of economic parameters of the entire system (Sharholy et al., 2008). Although these activities get huge share of the ULB's budget for SWM, yet they are the most inefficient due to various reasons. Tools like remote sensing and GPS, mathematical techniques and better planning approach are need of the hour. The applicability of GIS for better operation and management of collection systems -the most expensive and deficient activity of SWM, can yield heavy savings (Chang et al, 1997).

The observation about low collection efficiency is further asserted by Sudhir et al. (1996). According to the author, most cities have only 60-70% resources available and hence that is the maximum efficiency they reach in collection. Author proposed a goal based planning of SWM and covered all aspects of SWM in those goals. One of them being "minimization of deviations of available vehicles from the planned number. This can be only done if the planning approach is correct and has given you a realistic number of fleet required. Interactive resource planning by exploring available options would yield better results.

III. CONCLUSION

The fact that performance indicators remain crucial in design of a system such as solid waste management, where collection efficiency is dependent on performance of collection vehicles and where road cleanliness is dependent on mechanical or human sweepers. A failure in estimation of resources required to match the cities' requirement might lead to collapse of the entire solid waste management system of the city leading to disasters in terms of health, environment, economy and social well-being of the city. Current practice on field is from the two major approaches. One is based on the historical data available and personal experiences of the site personnel whereas other uses manufacturers' instruction manual and performance charts (Rashidi et al., 2014). However, Lambropoulos et al. (1996) has criticized the data available in the handbooks as marketing tools rather than a reliable source. When government announces the schemes such as SBM, it is one time opportunity for the sector in many years that ULBs have to take up, but in absence of reliable data, the detailed project reports submitted for funding and internal fund allocation proves inadequate. Hence it is clearly evident that there is need to have a model for productivity assessment in solid waste management systems especially for India.

APPENDIX 1 EQUIPMENT PRODUCTIVITY FACTORS IDENTIFIED FROM LITERATURE REVIEW

Factors	*Management Skills*	*Planning*	*Repair & Maintenance*	*Weather*	*Repeating Job*	*Non-Payment*	*Job Methods & Complexity*	*Lack of Instructions*	*Motivation*	*Operator Skills & Experience*	*Equipment Specs & Capacity*	*Age of Equipment*	*Supervision*	*Site conditions*	*Idling or Waiting*	*Traffic*	*Quantum of Work*
Thomas & Yiakoumis				●	●												
Amirkhanian & Baker (1992)	●						●				●			●			
Chao & Skibniewski (1994)							●				●			●			
Christian & Hachey (1995)															●		
Smith (1999)				●			●			●	●	●		●		●	
Edwards & Holt (2000)							●			●	●			●			
Abourizk et al. (2001)							●							●			
El-Rayes & Moselhi (2001)				●			●							●			
Thomas et al. (2002)		●	●	●			●										
Tam et al. (2002)							●			●	●			●			
Adrian (2002)		●	●					●	●								
Rojas & Aramvareekul (2003)	●	●	●														
Pan (2005)				●			●							●			
O'Connor & Huh (2005)							●										●
Chang (2005)							●							●		●	●
Kadir et al. (2005)	●	●	●	●		●			●				●	●			
Han & Halpin (2005)	●		●										●				
Ok & Sinha (2006)	●		●	●			●					●		●			
Faridi & El Sayegh (2006)	●		●										●	●			
Lee & Ibbs (2007)		●					●									●	
Mojahed, Aghazadeh (2008)	●	●							●	●							
Dai et al. (2009)	●							●		●	●						
Rashidi et al. (2014)	●		●	●			●		●	●	●	●		●			

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