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A review on need of implementation of modern construction techniques and equipment in Indian construction sector

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Abstract
The contribution of Indian construction sector to the GDP is approximately 10%. A massive growth is taking place in the construction sectors due to the boom in IT sectors and other fast growing services in the country. With the rapid growth in infrastructure demand, several new challenges have emerged in various forms, like massive number of projects, strict time stipulations, quality and safety assurance, unexpected rise/jump in the prices of materials essentially required for the construction project development. Outdated methods and old equipment's that used in India are creating obstacles to that growth. This paper focuses on identifying the factors influencing selection of equipment and then discusses how productivity and safety at work place can be increased based on results from old researchers and available data's. It also focuses on kind of equipment's that are used and how applicability and selection criteria for equipment is done using a sample example. Furthermore, it highlights the applications and significance of interpretive structural modelling for construction sector.

Keywords: Construction equipment; interpretive structural modelling; modern construction techniques, construction sector

1. Introduction
India is a developing country and a massive growth is taking place in the construction sectors. From the year 2000, a growth at 9% per annum has been consistently recorded and it is expected to continue and grow even further. Currently, the role of Indian construction sector to the GDP is almost 10% and under new government policy, it is projected that $1000 billion share will be completed entirely in infrastructure segment alone within the following few years. (Prasad *et al*., 2016) [35]. The boom in IT sectors and other fast growing services in the country has contributed to this ever fast rising construction segment needs. The Planning Commission is all set to lay out a lions–share of the total budget allocations for the rural infrastructure along with large number of power plant projects and other important needs. With the growth in the field of infrastructure, several new challenges have emerged in various forms, like massive number of projects, strict time stipulations, quality and safety assurance, unexpected rise/jump in the prices of commodities (steel, cement, bricks, sand etc.) essentially required for the construction project development and outdated processes and looking at out of box solutions which have become the order of the day. Construction engineering is inter related complex of operations whereby civil engineering structures are constructed. Construction processes may be simple, complex/complicated, mechanized, semi-mechanized or none mechanized. Construction has been a part of the Indian tradition in ancient times, in the recent past, in present and in the near future. Significant constructions in India includes such as the city of Mohenjo-Daro, the historic monuments like Taj Mahal, temples and other religious places, forts and towers that reflect India's building ability and craftsmanship in the past as well high rise buildings of the present. With each passing decades, the construction materials to methods to equipment's – everything has been updated with construction suitability, need/type of the project and the construction sector has been divided into several sub-departments like structural development, irrigation, energy, transportation, communication, health, housing and so many other activities with the objectives of improving the quality of life of people and to avoid complexity in planning, processing and managing of labor, materials and equipment. Mainly, construction equipment

is a vital resource in the execution of every construction projects and success of a project within targeted times and budget constraint is greatly influenced by the selection of right kind of equipment for the tasks to be performed. All construction activities require equipment irrespective of type of construction and it requires utilization of heavy construction machinery (Gransberg *et al*., 2006) [1]. Although the initial investment is high, it is impossible to progress and achieve targets as projected in construction projects in absence of fitting equipment. Adding to that, selection of an equipment which will ensure safety for the people working is also equally important to eliminate accidents during construction stage of a project. Construction process is dangerous and creates considerable injury and ill-health, with a link between these, and poorly designed processes and tools (Haslam *et al*., 2005) [28]. In addition to safety assurance, the environmental impacts due to emissions while operation construction equipment is also a major concern for every party involved (Guggemos & Horvath, 2006) [2]. Factors like efficiency, productivity, cost, safety and environmental is given due attention during selection of construction equipment. Procurement of construction machinery is an essential decision making process and planning is required to weigh necessity of equipment at several stages of construction. The role of management is vital concerning decisions relating to procurement of equipment (Tatari & Skibniewski 2006) [4]. The selection criteria of construction equipment such as site conditions, maintenance, cost, safety, ease of acquisition and technology are critical factors in the standpoint of contractors (Samee & Pongpeng 2016) [6]. The effective selection of construction equipment for operation in a construction project depends on mechanical efficiency, economic feasibility and obtainability. A survey conducted in Malaysian construction industry stated that health, safety and environmental aspects were not prioritized while selection of equipment (Waris *et al*., 2013) [5]. Sometimes equipment are selected due to similar settings of operation in other project sites elsewhere and past success records influences in equipment selection decision making process (Chinchore, 2014) [7]. Multi criteria decision making methods were proved to be useful to embrace the selection of equipment necessary for construction of roads in hilly terrain areas in India and authenticated the results by considering a case study (Singh & Singh, 2013) [21]. From the literature review, it is observed that prior to 2000, the selection of equipment is mostly circle around on aspects such as useful life, cost of maintenance and operating cost. Nowadays the paradigm had shifted towards influences like reliability, safety and sustainable equipment selection (Siddharth & Pitroda, 2014) [8].

2. Equipment Selection

2.1 Influencing Factors: The factors that influences the selection of construction equipment in Indian construction scenario were identified by Prasad *et al*. (2016) [35] by piloting wide-ranging literature review and they were based on the experts' opinions in the domain of equipment management and from both real estate and infrastructure sectors of Indian construction industry. The observations/results of that study are represented in Table 1 with the source of the information's.

Table 1: Factors influencing selection of construction equipment

S.no	Factor	Observations / comments	Source
1	Productivity	Higher productivity and operational flexibility is	Tatari & Skibniewski, 2006 [4];
		crucial in selection process.	Chan *et al*., 2001
2	Safety	Safety controls are to be incorporated to	Goldenberg & Shapira, 2007 [10][; Idoro,
		safeguard occupational health and safety of	2011; Arslan, 2004
		employees.	
		Mechanization of equipment shall not create	
		new hazards.	
3	Cost	Acquisition of equipment contributes 36% of	Yeo & Ning, 2006; Arditi *et al*., 1997;
		the total project cost.	Tavakoli *et al*., 1990; Ameh *et al*., 2010;
		Investment on the equipment management and	Azhar *et al*., 2008; Creedy 2005
		policy has impact on the profit.	
		Investment and equipment policy has a great	
		impact on the income/ profitability of the project.	
4	Availability of spares	Standard and interchangability of spares is	Prasertrungruang & Hadikusumo, 2007;
		vital.	Warisa *et al*., 2014 [5]
		Keeping the equipment idle due to non	
		availability of spares is cost to the project.	
5	Reliability and maintainability	Cost of maintenance is approximately 40% of	Schexnayder & Hancher, 2009;
		the total project cost.	Gransberg *et al*., 2006 [1]; Robert *et al*.,
		Easy maintenance, service and repair	2006; Arslan, 2004; Eldin & Mayfield,
		Maintenance is to be viewed as investment but	2005
		not as cost	
		Equipment must be available always with	
		optimum utilization.	
6	Capacity	Estimation of production capacity is important	Oglesby *et al*., 2005; Gunduz *et al*.,
		to save time and cost.	2012
7	Average life	Better operating conditions and timely	Goldenberg & Shapira, 2007[10]; Valli &
		maintenance increases life	Jeyasehar, 2012; Eldin & Mayfield,
			2005; Haidar *et al*., 1999
8	Job requirements	Matching of equipment to the type of	Gransberg *et al*., 2006 [1]
		construction activity is important.	

9	Operating		Site conditions have effect on life of	Eldin & Mayfield, 2005; Haidar *et al*.,
	conditions		equipment as well as wear and tear of rotating	1999
			parts.	
10	Training needs		Regular training to operators on safe	Mackenzie *et al*., 2000; Idoro, 2011
	for operator		operation/safety and health is important as	
			majority of the accidents due to construction	
			machinery are due to faulty operation.	
11	Environmental		Age, horsepower and fuel used, can affect rate of	Avetisyan *et al*., 2012; Koo &
	impacts		emissions.	Ariaratnam, 2008; Hajji, 2013
			Noise and vibration from equipment shall be	
			controlled at source.	
			Emission of particulate matter shall be within	
			prescribed limits.	
12	Versatility		Act as a catalyst for the advancement of a	Arditi *et al*., 1997
			construction industry.	

2.2 Productivity, Safety and Health Issues: The construction industry has a high frequency of sick leave among workers, and consequently a great percentage of work-related illness (Vedder and Siemers, 2003; Müller *et al*., 2003) [29, 30]. In the European Union, just 7% of the work force works in construction, yet this sector accounts for 15% of all accidents and 20% of all fatalities (Riese, 1995) [31]. In United States, the fatality rate in construction is 15.2 per 100,000 workers compared to 4.2 in manufacturing, and with an injury rate of 7.9 per 100 workers. In the past, rate of accident and work related sickness were more in both US and Europe countries, but with each passing decades the rate of safety hazard issues have been decreasing due to task and tools being used accordingly. Particularly in the application of power tools, it is vital that any potentially improper or dangerous use be prohibited by the design of the tool. For example- the electrical power tools, the electrical isolation of any part of the tool with which the user could come into contact reduces the risk of being electrified and be injured. Design for health means the elimination or reduction of exposure of the worker to physical agents. In the construction industry, they are mostly noise, vibration and dust. The reduction of tool vibration needs a sophisticated technical design of the tool. An active vibration reduction system implemented in a breaker tool can reduce the vibration transmitted to the operator by up to 50%, radically reducing the impact on the hand–arm system. Fig. 1 shows an example of a heavy electric breaker tool with an active vibration reduction system.

Fig 1: Breaker tool with active vibration reduction

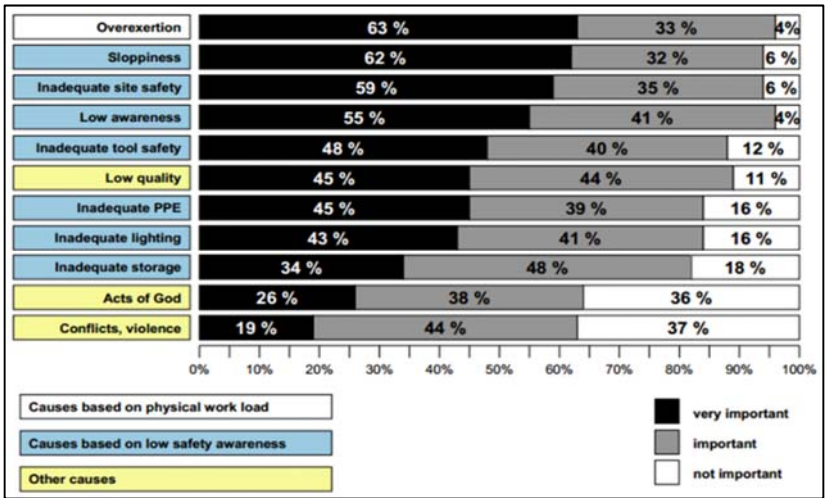

Fig 2: Root causes for accidents and occupational diseases in construction and their relative importance; Moser *et al*. (1999) [32].

Buying a customized or user friendly equipment to perform a single or specific task may cost a high compared to old equipment that was being used but in a long run it avoids many unpleasant accidents which may lead to great problems to the project because of delay, budget jump etc. Moreover, productivity studies in construction have revealed that the value-added time in construction is reasonably low. A field study of mechanical installation work has exposed that over 50% of the total time observed on construction sites is non-value-adding time due to interruption, disturbance, communication and preparation (Müller *et al*., 2003) [30], as shown in Fig. 3. Many products which decrease the load on the workers also lead to a higher level of productivity (de Looze *et al*., 2001) [33].

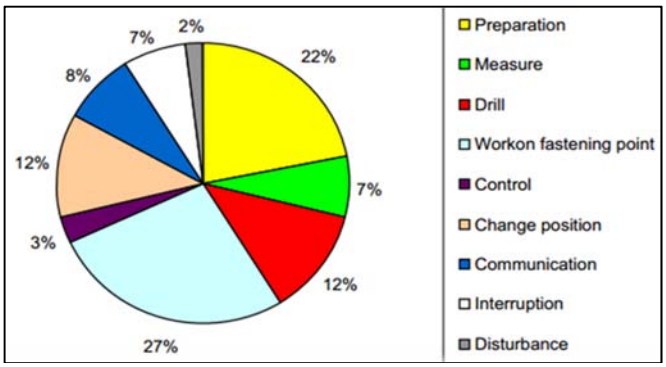

Fig 3: Breakdown of working times for installation work activities; Müller *et al*. (2003) [30]

Fig. 4 compares the overall productivity of the construction industry and the automotive industry. In the construction industry, the main productivity enhancements have been attained from the introduction of mechanized equipment, such as vehicles and chiefly cranes. With regard to manual tasks, productivity in construction has remained constant for many years (Al-Arja, 1997) [34].

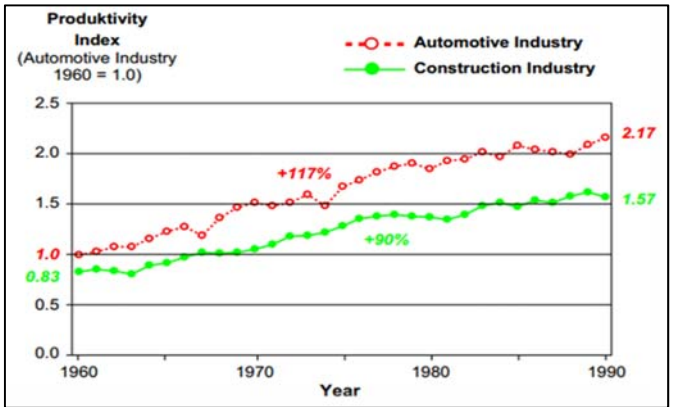

Fig 4: Productivity in construction and automotive industry; Al-Arja (1997) [34]

2.3 Use of Modern Equipment to Save Time: One of the benefits of using modern construction equipment is that one can save time; thus it reduces the risk of project delay, decreases the unpredictability nature of project budget rise/jump and few other benefits. Modern equipment have proved to reduce time, number of required labors over time in the fields of excavation, lifting heavy weights, transferring materials from one place to another, batching, mixing of materials, soil compaction etc.

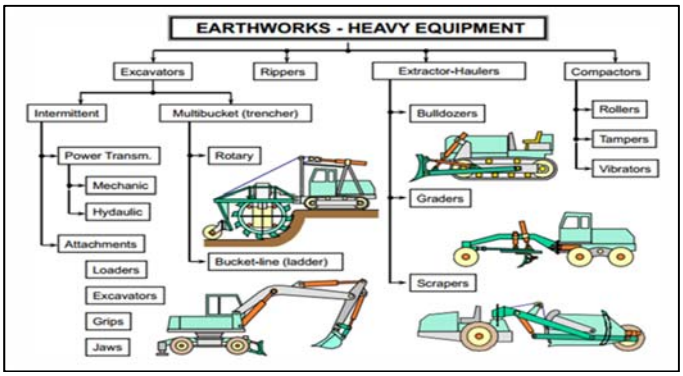

Fig 5: List of heavy equipment used in earthworks

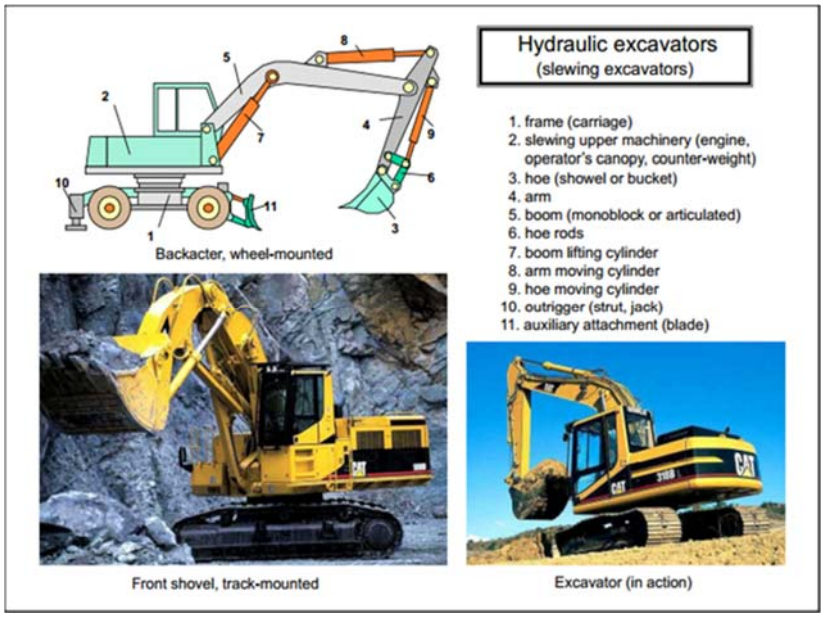

Fig 6: Excavators doing field works

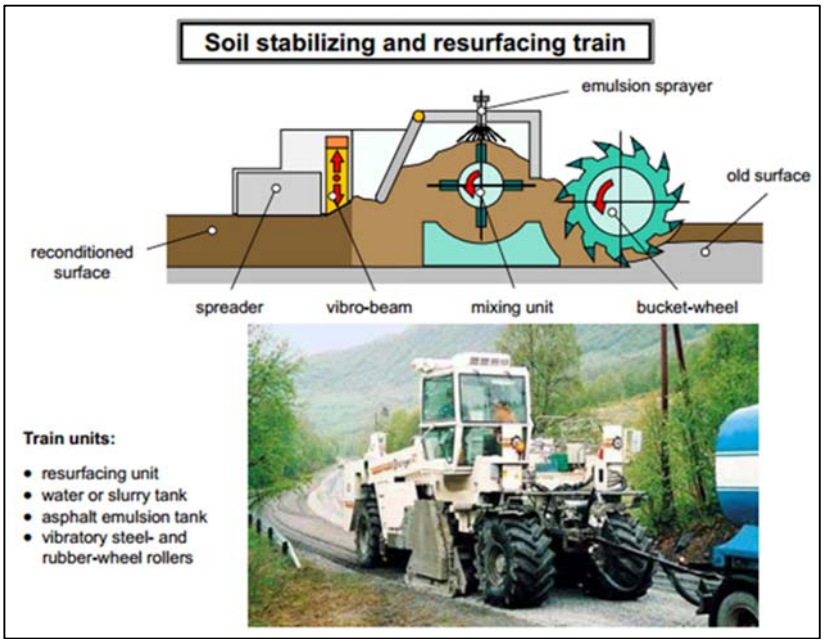

Fig 7: Soil stabilizing and resurfacing train

2.3 Applicability and Selection Criteria for Equipment: Although there are several equipment available in the market to purchase, not all of the equipment are useful for every type of project. Depending upon the work, several cutting-edge tools can be used and in future for similar type of work they may be used again. For example (source-Mechanisation in Construction Scope, Applicability & Value – CMAC), there are concrete mixing and batching equipment in market with capacity ranging between batching units from one bag mixers 3CuM/hr up to 120CuM /hr. Depending on the work value and volume, we have to decide which equipment has to be chosen and installed to suit for particular project.

Volume of work: 3.2 million sq.ft Area; Nature of work: Apartment – 6 Blocks (G-2 & G+14) and commercial single block (350x280 ft.) complex (G-3 & G+12). Project completion time deadlines: 30 months from the time of start. Requirement of concrete: 180Cum/per day; peak requirement: 240Cum 3 times a week. In this project, concrete production have been designed for the peak requirements. One unit of 30CuM batching plant and one unit of 18CuM batching have been finalized. This arrangement had to be adopted keeping in view of the peak and low requirements and also to have a standby arrangement in case of any unforeseen breakdown circumstances.

Based on direction of movements, material handling can be divided into two separate categories - Horizontal and Vertical movement. These can be determined by Structure sizes: Area of floor, Height of the structure, Layout of the structures and limitations at the given site.

The usual horizontal movement of equipment on the site are Tractors with attachments, Loaders, Dumpers, Site trucks/Tough riders and various types of trolleys and Wheel Barrows. There are various techniques and methods for horizontal movement on the floors, during carpentry, fixing and fitting of steel and also for concreting of columns. Horizontal movements have to be designed for input to the batching plant. The steel movement from the yard to the respective structures, Bricks from the yard to the respective structures, Tiles, doors, windows, Bathrooms etc. to reach the respective structures, and of–course movement of small equipment like vibrator, compactors, plastering machines etc.

The suggested equipment are as follows:

Front end dumper : 4
Tractor loaders : 3
JCB : 2
Tractors : 2
Wheel barrows and trolleys 24 approx.

The vertical movements are generally structure specific. The equipment generally used in terms of vertical material handling would be winches, Tower hoists, Passenger & Material hoists, Tower cranes etc. The vertical material handling depends on many features: 1. Size of the structures, 2. Location of the structures, 3. Approach to construction (planning), and 4. Completion time frames. Selection criteria should be considered after enlisting: 1. Capability of the equipment, 2. Limitations of the equipment like power need, size weight etc., 3.Limitations of the site for the usage of this equipment, and 4. Various applications due to be performed by the said equipment.

2.4 Interpretive Structural Modelling (ISM): Interpretive structural modelling is a great method for establishing relationships among related factors. A number of factors may be associated with a complex problem and ISM methodology is useful to identify direct and indirect relationship among factors. ISM methodology develops a model considering into mutual understandings of relation between factors. ISM technique starts with an identification of factors influencing a specific issue and then proceeds with a group solving process (Attri *et al*., 2013) [36]. ISM methodology has been adopted by several researchers in various way and some of its applications are described in Table 2.

Table 2: Areas of application of ISM

Area of application	References
A decision support tool in identification and ranking of performance measures in automobile supply chain	Susana *et al*., 2013
To understand the relationships among total quality management practices	Talib *et al*., 2011
To identify and relationships among factors affect labour productivity in India	Sayali & Rohan, 2014
For modelling complex interaction among factors responsible for cost overruns in construction projects in Oman	Alzebdeh *et al*., 2015
To examine relationship among elements of relating to lean manufacturing in India.	Kumar & Kumar, 2016
To ascertain variables to implement lean manufacturing in Indian automobile industry	Naveen *et al*., 2013
To find relationships among criteria influencing solid waste management practices	Ming- Lang & Yuan Hsu, 2011
In risk assessment process to identify weak drivers in infrastructure projects in India	Iyer & Sagheer, 2010
To identify barriers in implementation of green supply chain management in Indian industries.	Arvind & Azhar, 2014

ISM is a useful technique to develop a hierarchy model for the factors influencing selection of construction equipment in Indian construction segments. The influential factors could be identified from widespread literature review and consultations with experts in the field of construction equipment management. The expert opinions are critical in developing this model.

3. Summery Conclusion & Discussion: This case study has attempted to look into various factor in which up gradation of modern equipment is needed so as to save time, decrease budget unreliability, increase safety at work place. Selecting the exact equipment is usually crucial for the success of a project; hence a model like ISM which is very useful in selection of construction equipment for Indian construction sectors. A separate para has been dedicated to discuss the applicability and selection criteria for equipment using a sample example. While, how productivity and safety can be increased at work place has been discussed taking results and data's from previous work of other researchers.

4. Notations

1. GDP = gross domestic product
2. IT = Information technology
3. US = United States
4. ISM = Interpretive Structural Modelling

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