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CONCEPT TO POSITION AND ENHANCE AUTOMATION TECHNOLOGIES IN EMERGING CONSTRUCTION MARKETS

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ABSTRACT

Construction has conventionally been a labour intensive process. Until recently, automation of construction processes was not considered to be economically and technologically sustainable in emerging economies. In recent times, the demanding construction requirements and shortage of skilled labour has made automation a viable alternative. However, there are different levels of automation that can be employed and there is no structured approach to assess what is the best level of automation technology which can be used for a given field situation. This paper presents a Technology Positioning Map (TPM) to position the current practice and assess the technological viability to make the process more automated. The usage of TPM is illustrated with technologies in use today from Indian and global construction sites. This approach will enable decision makers to make a more structured and rational decisions on technological scaling to be used for a given situation.

KEY WORDS

Construction Automation, Technology Position Map, Indian Construction, Robotics

1. INTRODUCTION

Automation has been an indicator of technological and developmental progress of society. The primary objectives of any automation have been to improve the quality of a product or service as well as liberate humans from tedious and hazardous tasks in order to improve the quality of life [1]. While early steps in automation focused on physical functions, modern technology addresses the automation of cognitive and sensory functions also.

Developed countries have been the front-runners in developing and implementing automation technologies as the demand for automation is higher. In developing countries such as India and China, where labour has been easily available, the justification to implement automation has been less. However, in today's global economy, where emerging countries such as India and China are experiencing large volumes of work and a shortage of skilled workers, there is a strong demand for automating construction processes.

Automation of construction activities has always been a challenge. The key challenge arises from the fact that construction, unlike manufacturing is usually done in an unstructured fashion. There are numerous variables for each process and method statement may vary from site to site. Until recently, automation technology available has not been adequate to meet the needs of such unstructured environments. The rapid advancement of technology in recent times in conjunction with the demanding requirements of modern construction projects has prompted equipment manufacturers to adopt automation and robotics in their equipments. The level of automation in particular equipment is usually decided by the country of utilization.

Although, technology required for automation is available, the level of automation utilised to execute different construction activities varies widely. For example, excavation can be done manually with a shovel, mechanized using a back-hoe, further automated using GPS/Laser mounted excavators and fully automated or robotised by incorporating sensors and decision making algorithms which ensure no human intervention is required at the operational level. What is the appropriate level of automation for a specific situation given the technology available, costs and local conditions? This is an important issue, especially in emerging nations such as India and there is a need for a structured approach to answer these questions.

The primary objective of this paper is to propose a structured approach to audit and identify the position of a construction activity using the TPM. Based on the position on the TPM, the feasibility to move to a higher level of automation can be assessed. This paper also discusses the construction environment in India and identifies key technologies used in the rapidly changing Indian construction environment, positions the technology and discuses the potential for further automation from a technology sustainability and cost-effectiveness perspective.

2. TECHNOLOGY POSITIONING MAP

From a fundamental perspective, automation can be defined as the reduction of physical, cognitive and sensory effort for executing a designated activity. The reduction of physical human effort implies more mechanization of the activity. For example, the use of a power trowel significantly reduces the physical human effort required but decision making on the trowelling pattern and force applied are still required to be made by the operator.

The reduction of human cognition implies use of algorithms, expert systems and other decision support tools to reduce the cognitive effort to plan and execute the task. For example, an optimization algorithm can determine the best cut-fill pattern for a golf course project. When mounted on a GPS/LASER controlled motor grader it minimises the need for tedious calculations and human decisions during the operation.

In unstructured environments sensing is an important requirement for feedback on an operation. For physical tasks, sensing provides inputs for cognition, and the decisions taken by the cognitive process are translated to physical actions. Sensing and positioning are critical for construction tasks. Imaging sensors which can acquire surface level information during a grading operation can send feedback to the graders to make dynamic field based readjustments. Today numerous types of sensors are available and with the advent of wireless technologies to communicate, the information can be processed for decision making and actions. An imaging sensor

The proposed approach utilizes these three dimensions as a basis for the technology positioning map. Figure 1 illustrates the map. The axes represent the physical, cognitive and sensory dimensions. The scale along each axis represents the level of automation along that dimension. On this map, a manual execution of a task is represented by the origin and a completely automated/robotic execution is represented by the extreme corner.

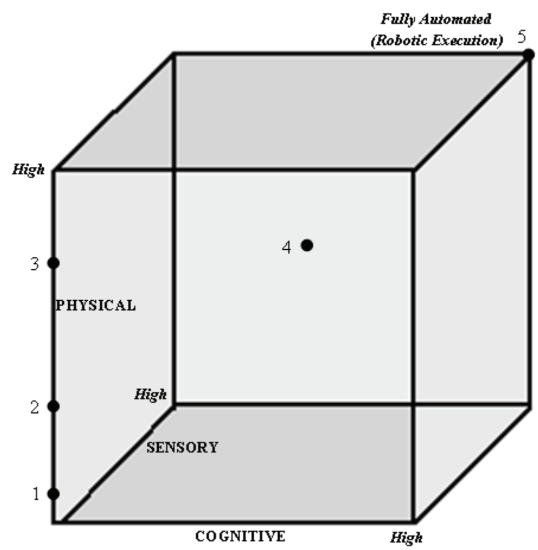

Figure 1 Technology Positioning Map (TPM)

This map can be used to position the technology used for a particular task. Table 1 shows the alternate methods by which soil compaction can be done and the position of the method on the automation technology map is also indicated by the corresponding number.

Table 1 Compaction Technologies

	Technology Used	Automation Level		
		Physical	Cognition	Sensory
1	Manual- using rudimentary hand tools	Low	Low	Low
2	Manually- using Rammer (Figure 2)	Medium	Low	Low
3	Operator guided ride on compactor (Figure 3)	Med-High	Low	Low
4	Operator Guided, Radio remote controlled compactors with compaction sensors (Figure 4)	Med-High	Medium	Medium
5	Autonomous compactor, GPS guided with obstacle and compaction sensors	High	High	High

Figure 2 Compaction using Rammer

Figure 3 Ride on Compactor

3. INDIAN CONSTRUCTION SCENARIO

India has the four the largest economy in the world [2] with a Gross Domestic Product (GDP) of 3.6 trillion US Dollars as shown in Figure 5. The construction industry in India contributes to about 6% of the GDP and is the second largest contributor to the GDP after agriculture. The level of investment in infrastructure construction is expected to rise dramatically in the next few years. The total investment in infrastructure is expected to be in the order of 800 billion dollars over the next five years. The level of investment expected in specific sectors is shown in Figure 6 and Figure 7. As a result of these investments in infrastructure, the turnover of construction companies in India has been growing exponentially each year and the growth is expected to rise in the next few years.

Figure 4 GPS-Controlled Compactor

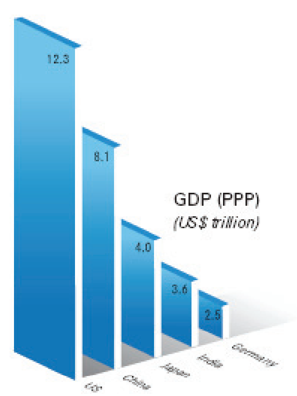

Figure 5 Highest National GDP [2]

3.1 Need for Automation

It is evident from the above data that volume of construction scheduled in India over the next few years is enormous. Not only is the volume of construction increasing rapidly, but to ensure better returns on investment, the owners are demanding projects of higher technical complexity, meeting stringent quality requirements in shorter durations. Using conventional techniques, the demanding requirements of these projects cannot be achieved. Further, there is an acute shortage of skilled labour in the country and the level of shortage is expected to increase projects which don't adapt automation technologies will not be successful.

US $125 Bil

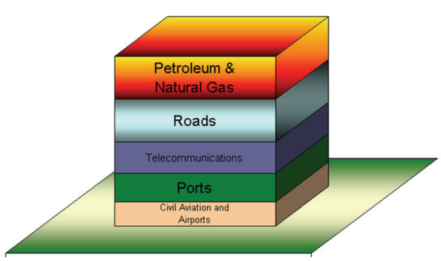

Figure 6 Investment in Infrastructure [2]

US $ 700 Bil.

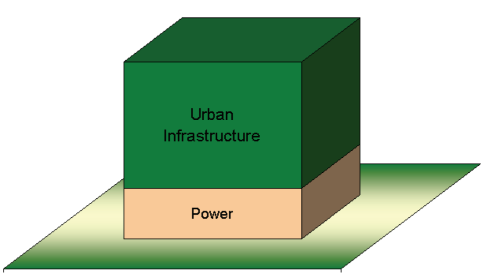

Figure 7 Investment in Power and Urban Infrastructure [2], [3]

In addition to gains in productivity, construction automation technology is essential for undertaking hazardous tasks as well as deployment in disaster situations. Both situations are common in India. Hazardous tasks include situations such as the decommissioning of nuclear power plants, working at heights and enclosed spaces. Disaster situations include search and rescue in the aftermath of earthquakes, hurricanes or floods. Both situations involve unstructured environments and technology applicable to construction sites can be utilised effectively for the benefit of society. However, the strategy to utilize the technology should be to adapt the technology to local requirements and not directly adopt the technology as it is used elsewhere. The technology positioning map enables the appropriate assessment of technology for adoption.

4. EXAMPLES

4.1 Excavation

Excavation is a common construction activity. The technologies used for excavation in India vary widely as shown in the Table 2 and positioned in Figure 8. Until recently manual excavation was considered to be the most cost-effective approach. With increased labour costs and shortage of labour, mechanised excavation has become popular. This indicates that the move from point 2 to point 3 on the map was driven by the availability of sustainable technology for local conditions. In certain situations, automation level 4 is also used in India. Level 5 is not yet sustainable in India.

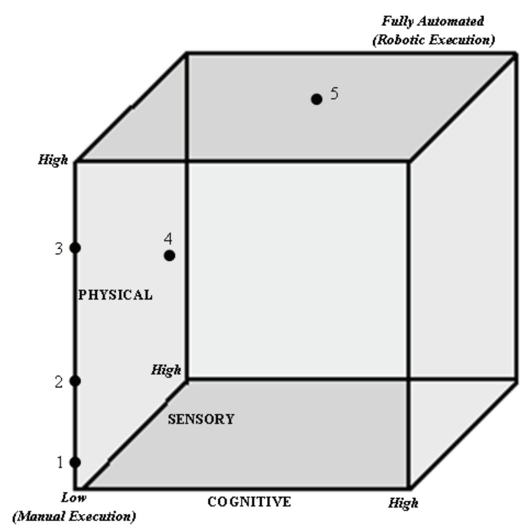

Figure 8 Position of Excavation Technologies

Table 2 Excavation Technologies

Technology Used		Automation Level		
		Physical	Cognition	Sensory
1	Manual- using rudimentary tools (spade/crowbar and basket)	Low	Low	Low
2	Moving earth using wheel barrow	Medium	Low	Low
3	Mid-sized on-road excavators with bucket attachment (JCB)	Med-High	Low	Low
4	Operator friendly Wheeled Hydraulic Excavators with force control	Med-High	Low	Medium
5	Robotic excavation (Figure 9)	High	Medium	High

Figure 9 Robotic Excavation

4.2 Demolition

Demolition is a specialized activity which has not been widely used in India. As schedule and safety requirements for demolition jobs were not demanding, manual labour using hammers and chisels were commonly used. The surge in real-estate values has resulted in a corresponding surge in old dilapidated building being replaced by new complexes. The demolition of these buildings faces many complex constraints and hence technology levels used for demolition work have been steadily increasing. As shown in Table 3 and positioned in Figure 10, there are various levels of automation which can be implemented. Level 3 has become popular in urban demolition projects. The robotic demolition equipment is also under consideration on specialized demolition projects in constraint spaces.

Table 3 Demolition Technologies

Technology Used		Automation Level		
		Physical	Cognition	Sensory
1	Manual- using rudimentary tools (Hammer & Chisel)	Low	Low	Low
2	Hand-held Pneumatic Hammers	Medium	Low	Low
3	Hand-held Electric Chippers/ Breakers (Figure 11)	Med-High	Low	Low
4	Excavator Mounted, Hydraulic Crushers (Figure 12)	High	Low	Low
5	Robotic Demolition using Brokk with breaker	High	Med	Med

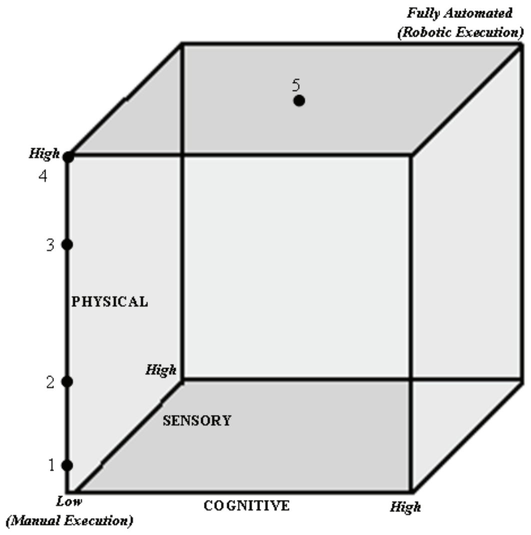

Figure 10 Position of Demolition Technologies

Figure 11 Demolition using Electric Chipper

5. SUMMARY

This paper has presented a novel 3-D concept map for positioning the technology used on a construction activity and demonstrated how the map can be used to assess the current level of automation used for an activity. Once the position of the automation level is assessed, the technology available to increase the level automation along the physical, cognitive and sensory dimensions can be evaluated. The position map can be extended by incorporating the region based economic and technological sustainability of each level of automation. In order to assess the region based sustainability, there is a critical need for establishing a proving ground to assess the overall performance of the technology in a selected local region. Presently the engineering curriculum does not address this area and there is a need to form inter-disciplinary program with industry support to identify and solve challenging problems.

Figure 12 Demolition using Hydraulic Crusher

6. REFERENCES

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