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Preparedness of the Indian Construction Industry to Adapt to Robotics and Automation

Dr. Rajiv Gupta[1], Jaya Pradeep.S[2], Chiranjeev Mohota[3], Mainak Datta[4]
[1](Professor and Head ACM, National Institute of Construction Management and Research (NICMAR), India, [2, 3, 4] (Students, PGPACM, National Institute of Construction Management and Research (NICMAR), India)
Corresponding Author: Dr. Rajiv Gupta

Abstract: *The Indian construction sector plays a key role in India's economic development and nation-building through infrastructure projects and facilities and real estate development. Unlike the western world which is seeing an increasing utilization of robotics and automation in construction (RAC) India lags in the use of robotics and automation in construction. The objective of this research was to study the current awareness of robotics and automation in Indian construction industry and to determine the acceptability, and perception of adaptability and feasibility of robotics and automation in the construction industry. Primary data collected from 398 construction industry project engineers through a structured questionnaire was used to test the results through factor analysis and hypotheses testing. The findings reveal that the general perception is that robotics and automation are considered to be the same by the practicing construction industry professionals and that RAC is considered suitable for a developing country like India and that there is awareness about the benefits of adaptability and usage of robots in construction but at the same time several resistance factors emerge and these barriers will have to be overcome for successful adaption of RAC in India.*

Keywords: *Robots, Robotics, Automation, Construction Industry, Modern Technology.*

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I. Introduction

Robotics is an inter-disciplinary branch of engineering and science that includes mechanical, electrical and computer science engineering. Robotics deals with the design, construction, operation, and use of robots as well as computer technology for their control, sensory feedback and information processing. These technologies are used to develop machines that can substitute for humans and replicate human action. Automation is a creation of technologies and its application in order to control and monitor the production and delivery of various goods and services.

In its abbreviated form "Robotics and Automation in Construction" is referred to as RAC. In the construction field the motivation to introduce robots and automation stems from the hazardous nature of this industry. In Japan, construction site works are symbolized by 3Ks. Kiken meaning dangerous, Kitanai meaning dirty and Kitsui meaning Hard (laborious). This peculiar nature of the construction works prompted the Japanese to undertake development of more than 200 prototypes of construction robots in the 80s. The very nature of the construction industry makes the usage of RAC appealing but it has its own challenges too due to the non-repetitive nature of construction tasks and changing project sites. Even though application of RAC is witnessed in numerous construction activities the widespread usage of RAC is restricted due to sophisticated technology and high costs which make robots and automation commercially unviable for many lower scale projects and for many developing economies.

II. Review of Literature

A review of literature reveals that studies have supported and found several benefits in the usage of robotics and automation. Whilst some other studies have reported the barriers discerned regarding the usage of RAC.

Benefits

Elattar (2008) states that robotics and automation systems in construction industry can achieve the following advantages: Higher safety for both workers and the public through developing and deploying machines for dangerous jobs; uniform quality with higher accuracy than that provided by skilled workers; improving work environment as conventional manual work is reduced to a minimum so the workers are relieved from uncomfortable work positions, eliminating complaints about noise and dust concerning works such as removal, cleaning or preparation of surfaces, increasing productivity and work efficiency with reduced costs.

Skibniewski (1988) mentions the following advantages: a) improvement in work quality, b) reduction of labor costs, c) savings accrued on safety and health improvements, d) time savings, and e) improvement in productivity.

Barriers

Mahbub (2008) found seven barriers for using RAC. These are given in the order of their rank: (1) High initial costs/financial commitment from end-users (2) The fragmented character of the market (3) The difficulty to use and necessary adaptation process of the new technology (4) Incapability with the current processes and practices in the construction industry (5) Low technology literacy of the participants to the construction process, need for specific training and even for different skills and competencies (6) Unavailable locally and difficult to obtain (7) Not accepted by workers. Few other barriers identified by Mahbub (2008) but not ranked are: R&D innovation cost is very high as it includes an increase in capital intensity and highly qualified workplace; high costs for updating the existing technology to the latest state of the art; training costs for using technology and costs related to the tailoring of the construction operations; incompatibilities with current practices and operations; the needed technologies are either very difficult to find, either do not exist; psychological barriers referring the acceptance of the new technologies.

Applications

Slocum and Schena (1988) observed that prototype machines have been developed for shotcreting, fireproofing, concrete finishing, rebar placement, positioning of structural members, and tunnelling.

The International Association for Automation and Robotics in Construction (IAARC) (1998), in its publication gives details of specific robots and automation for: demolition, surveying, excavation and earthmoving, paving, tunnelling, concrete transportation and distribution, concrete slab screeding and finishing, cranes and autonomous trucks, welding and positioning of structural steel members, fire resisting and paint spraying, inspection and maintenance and integrated building construction.

Elattar (2008), found robots being used for: Concrete Works - laying, post laying levelling, removal of surface water, final floor finishing (robot receives floor plan as input); Road Paving – asphalt receiving, conveyance, spreading, automatic control (start/stop) of all paving functions based on artificial vision and laser range sensor. Remote controlled longitudinal crack sealing machine; Finishing Works – indoor plastering, window glass mounting, welding, tile setting, surface finishing in tunnelling, block laying, facade renewal; building management and security systems - surveillance, first line fault attendance, risk control by monitoring worker and machine positions.

Strukova (2012) mentions about robots for structural works (e.g. concrete placing, steelwork lifting and positioning), robots for finishing or completion works (e.g. exterior wall spraying, wall or ceiling panel handling and positioning), robots for inspection works (e.g. external wall inspection) and robots for maintenance works (e.g. window and floor cleaning). Intelligent or cognitive machines present the least developed category, most are still under research.

Holt (2018) states that construction robots are still in developmental stage. And they are still very costly to purchase. They have many limitations, and absolutely will not be replacing the need for labourers anytime soon, but the future certainly looks bright.

Gupta et al (2018) concluded that academic research in RAC has so far been limited to topics such as a futuristic vision for the justification of RAC, the likely barriers and challenges that RAC faces, applications which have either been experimental, proto type tests and limited scale mainstream commercial usage. Although it was the manufacturing sector in which early applications of robotics and automation are seen a review of academic literature reveals that in the construction sector robotics and automation find mention only since the early eighties that too in Japan, USA and a few European countries.

III. Need for The Study

The countries where RAC is used are the USA, Europe including the Eastern Bloc, Japan, Australia, Korea, Canada and India. It is observed that out of the 34 years of conducting the annual RAC symposiums by IAARC, in India its annual symposium was held only once in the year 2007. India's academic research contribution in these symposia peaked in 2007 when more 12 research papers were presented by Indian researchers out of the 152 papers presented. However, these papers approached the subject of robotics and automation in construction on the soft side of theoretical constructs, lab level model building, framework development or use of IT based platforms. We find that in the Indian context the study and reporting of usage of robots and automation in applications in the construction sites is so far minimal. (Gupta et al 2018).

Our research reveals that although the concept development and usage of robots and automation in construction began in the early eighties it has largely been restricted to the developed and industrialized countries of the world. The applications of robots and automation in construction are vast even in the face of numerous constraints present in the construction industry. In India the development and usage of robots and automation has been minimal so far and limited to concept development and model building and testing. Recent developments reveal that commercial usage on a limited scale is witnessed in a few projects and sites. At this stage we can state that Indian academic research has so far concentrated on the soft side of the development in this field of RAC. It is hoped that further research in this field of RAC to ascertain the mindset, awareness and acceptability of robotics and automation in construction by the construction industry professionals will better prepare us for embracing the world of robotics and automation in the future.

IV. Objectives

The purpose of this study is:

1. To assess the awareness of robotics and automation in Indian construction industry.
2. To identify the favourable factors that support acceptance of robotics and automation in Indian construction industry.
3. To identify the factors that resist the adaptation of robotics and automation in Indian construction industry more specifically in the Real Estate and Infrastructure sectors.
4. To determine the views of Indian Construction industry professionals about the suitability of robotics and automation.

V. Research Design, Sample Size & Data Collection

Primary data was collected through a questionnaire based survey of engineers, managers and supervisors working at various positions in leading construction organizations in India. The questionnaire consisted of two sections. Section-1 sought the demographic data of the respondents and Section-2 had 34 questions about individual perception and opinion of awareness, usage, benefits and constraints of robots and automation in the construction sector in India. A five point Likert scale was used to gauge responses ranging from strongly disagree, disagree, neither agree nor disagree, agree and strongly agree. Using convenience sampling, the questionnaire was circulated to 800 working executives in the construction field across various construction sectors in India during the period of five months from April 2018 to August 2018 and it generated 410 responses and after eliminating incomplete responses the sample had 398 valid responses.

VI. Characteristics of The Respondents

The demographic profile of the respondents was created across six characteristics viz. gender, age, education level, professional discipline, work experience and nature of the organisation (construction sector). The results are as given in Table No. 1:

Table No. 1: Demographic Characteristics of the Respondents (n=398)

1.	**Gender**	**Frequency**	**Percent***
	Male	375	94 %
	Female	23	6 %
	Total	**398**	**100 %**
2.	**Age**	**Frequency**	**Percent**
	under 30 years	229	58 %
	31- 40 years	120	30 %
	41-50 years	45	11 %
	51-60 years	4	1 %
	Total	**398**	**100 %**
3.	**Education**	**Frequency**	**Percent**
	Doctorate (Ph.D)	8	2 %
	Post Graduate	82	21 %
	Graduate	171	43 %
	Diploma	137	34 %
	Total	**398**	**100 %**
4.	**Discipline**	**Frequency**	**Percent**
	Civil Engineering/Diploma	260	65 %
	Architecture	29	7 %
	Mechanical	37	9 %
	IT	6	2 %
	Electrical	27	7 %
	Management	34	9 %
	Others	5	1 %
	Total	**398**	**100 %**
5.	**Work Experience**	**Frequency**	**Percent**

	Less than 5 years	187	47 %
	6-10 years	146	36 %
	11-15 years	47	12 %
	16-20 years	16	4 %
	Above 20 years	2	1 %
	Total	**398**	**100 %**
6.	**Construction Sector**	**Frequency**	**Percent**
	Infrastructure	119	30 %
	Real Estate	181	45 %
	Contracting	42	11 %
	Consultancy	17	4 %
	Equipment Suppliers	17	4 %
	Facility Management	10	2 %
	Academics	7	2 %
	Others	5	1 %
	Total	**398**	**100 %**

*rounded off to the nearest integer

VII. Data Analysis, Results and Discussion

The data was analyzed by using SPSS 24. To determine the internal consistency of the data collected reliability test was conducted. The Cronbach's alpha value was $\alpha = 0.888$, which is good considering that 0.70 is the cut off value for being acceptable (Yigit & Kurnaz 2010). The value shows that the data indicates a high level of internal consistency and that the questionnaire consistently measures what it purports to measure when properly administered.

Objective 1- Awareness about RAC in Indian Construction Industry

To test the awareness level about robotics and automation in construction we asked two questions. One was about the source of information and the second was regarding likely applications of RAC in different activities of construction. For the source our premise was that many of the respondents may not have first-hand experience of RAC in their workplace and their information and knowledge of RAC could be from secondary sources. Hence a question regarding source of information about RAC elicited the following responses (Table No. 2) for the six source options given. Many respondents chose more than one source of information thus the total response exceeds 100%.

Table No. 2: Source of Information about Robotics and Automation in Construction

Source (for each source n=398)	Frequency	Percent
Print & TV media	46	11.6 %
YouTube	148	37.2 %
Social Media	59	14.8 %
Face Book	107	26.9 %
Institutional Events and Studies	76	19.1 %
Workplace	56	14.1 %

This analysis reveals that the current exposure to RAC in the Indian workplace is low at 14.1% and most of the information garnered by the Indian construction industry is from online sources as given in Table No.3.

Table No. 3: Application of RAC in Different Construction Activities

Construction Activity (for each activity n =398)	Frequency	Percent
Earthwork	102	25.6 %
Concreting	147	36.9 %
Assembly works	75	18.8 %
Subsidiary works	41	10.3 %
Finishing works	141	35.4 %
Structural Engineering	46	11.6 %
Reconstruction works	34	8.5 %
Building and Facilities Management	42	10.6 %

For Objective 2 and 3, fifteen questions represented positive favourable variables supporting the usage of robots and automation in construction and eleven questions represented the barriers and negative variables against the usage of robots and automation in construction. For the fifteen questions the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .821, above the commonly recommended value of .6, and Bartlett's test of sphericity was significant ($\chi2$ (105) = 1848.112, $p < .05$) and for the 11 questions the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .811, above the commonly recommended value of .6, and Bartlett's test of sphericity was significant ($\chi2$ (55) = 1222.896, $p < .05$). Hence factor analysis was deemed to be suitable with all 26 items.

Objective 2 - To identify the favourable factors that support acceptance of robotics and automation in Indian construction industry.

Factor analysis was conducted to find out the underlying grouped favourable factors using Principal Component Analysis with Varimax rotation. Four factors having factor loading of 61.341 % as per initial Eigen Values were extracted and are given in Table No. 4.

Table No. 4: Favourable Factors Total Variance Explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.406	29.371	29.371	4.406	29.371	29.371	2.819	18.790	18.790
2	2.263	15.088	44.459	2.263	15.088	44.459	2.293	15.286	34.076
3	1.348	8.987	53.445	1.348	8.987	53.445	2.180	14.534	48.610
4	1.184	7.896	61.341	1.184	7.896	61.341	1.910	12.731	61.341
5	.777	5.178	66.519						
6	.709	4.728	71.247						
7	.660	4.400	75.647						
8	.649	4.330	79.977						
9	.572	3.813	83.790						
10	.492	3.280	87.070						
11	.465	3.100	90.170						
12	.426	2.838	93.009						
13	.383	2.554	95.562						
14	.345	2.299	97.862						
15	.321	2.138	100.000						

Extraction Method: Principal Component Analysis.

Table No. 5: Favourable Factors Rotated Component Matrix[a]

VARIABLE	Component			
	1	2	3	4
Give savings		.782		
Reduce labour requirement		.849		
Increase productivity		.735		
Save time		.547		
Improve project quality			.800	
Suitable for repetitive works			.814	
Reduce risk to human life			.607	
Robots is currently being used				.582
Financially feasible				.819
Easily available commercially				.719
Helpful for building and facility management	.656			
Increase user satisfaction	.686			
Adds value to the building projects	.792			
Helpful to building management professionals	.771			
Automation is currently being used	.639			

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Based on the factor loadings, four factors were extracted as per the Rotated Component matrix in Table 5. These extracted factors being in favour of supporting the usage of robotics and automation in construction were given factor labels as: Savings and efficiency Boosters, Suitability (to construction projects), Viability (financial and commercial), user satisfaction and value-add as given in Table No. 6.

Table No. 6: Factor Labels for 4 Favourable Factors Extracted

Factors Extracted	Favourable Factor Labels	Comprising of variables
Factor 1	Savings and Efficiency Boosters	give savings, reduce labour requirement, increase productivity, save time,
Factor 2	Suitability (to construction projects)	improve project quality, suitable for repetitive works, reduce risk to human life
Factor 3	Viability (financial and commercial)	currently being used, financially feasible, easily available commercially
Factor 4	User satisfaction and value-add.	helpful for building and facility management, helps increase user satisfaction, adds value to the building projects, helpful to building management professionals

Objective 3 - To identify the factors that resist the adaptation of robotics and automation in Indian construction industry more specifically in the Real Estate and Infrastructure sectors.

Factor analysis was conducted to find out the underlying grouped Resistance factors using Principal Component Analysis with Varimax rotation. Three factors having factor loading of 59.392 % as per initial Eigen Values were extracted and are given in Table No.7.

Table No. 7: Resistance Factors Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.937	35.790	35.790	3.937	35.790	35.790	2.973	27.029	27.029
2	1.422	12.923	48.713	1.422	12.923	48.713	1.907	17.337	44.366
3	1.175	10.678	59.392	1.175	10.678	59.392	1.653	15.026	59.392
4	.862	7.841	67.232						
5	.699	6.351	73.583						
6	.643	5.844	79.427						
7	.578	5.258	84.685						
8	.524	4.766	89.451						
9	.416	3.779	93.229						
10	.394	3.581	96.810						
11	.351	3.190	100.000						

Extraction Method: Principal Component Analysis.

	Component		
	1	2	3
Usage of robots is incompatible with current construction practices		.772	
Usage of robots will be difficult due to low technology literacy		.797	
Usage of robots will be difficult due to no local commercial availability	.508		
Robots will not be accepted by the Construction industry	.723		
Usage of robots is not practical due to high cost	.641		
Robots will be difficult to work side by side the labour	.717		
Robots is not feasible in small construction works	.686		
Robots is practically not possible	.735		
Automation is extensive for building and facility management			.703
Automation is not suitable for construction projects			.856
Automation reduces the direct employment opportunities			.566

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 7 iterations.

Based on the factor loadings, three factors were extracted as per the Rotated Component matrix in Table No.8. These extracted factors being the resistance to adaptation of robotics and automation in Indian construction were given factor labels as: User rejection, Low user awareness and Suitability (to construction projects) as given in Table No. 9.

Table No. 9: Factor Labels for 3 Resistance Factors Extracted

Factors Extracted	Resistance Factor Labels	Comprising of Variables
Factor 1	User Rejection	No local commercial availability, not acceptable, high cost, cannot work side by side labour, not feasible for small projects, not practical
Factor 2	Low User Awareness	Incompatible with current practices, low technology literacy,
Factor 3	Suitability (to construction projects)	Extensive requirement, not suitable, impacts employment

With the emergence of a "Low User Awareness" we wanted to test the awareness of the respondents regarding the difference between the two terms Robotics and Automation for which from a question in the survey instrument we formulated our hypothesis and conducted one sample KS test using NPAR tests.

Null Hypothesis H_0 = Robotics and Automation (R&A) do not mean the same thing.
Alternative Hypothesis $H_{a\,=}$ Robotics and Automation (R&A) mean the same thing.

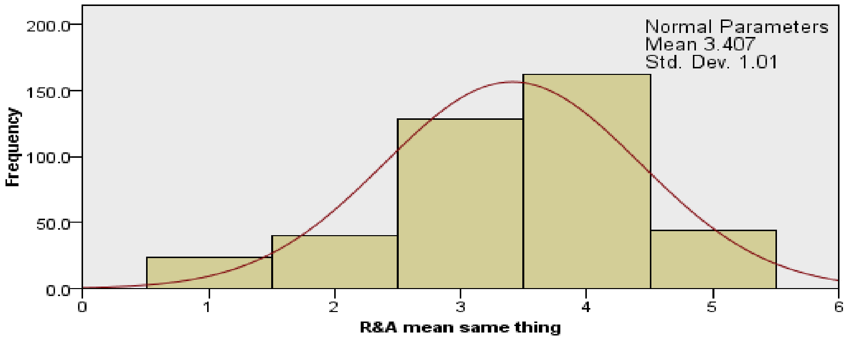
Table No. 10: Hypothesis that Robotics and Automation Are Same

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of "Robotics & Automation are not same" is normal with mean 3.407 and standard deviation 1.01.	One-Sample Kolmogorov-Smirnov Test	.000[1]	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

One-Sample Kolmogorov-Smirnov Test



Total N		398
Most Extreme Differences	**Absolute**	.238
	Positive	.169
	Negative	-.238
Test Statistic		0.238[1]
Asymptotic Sig. (2-sided test)		.000

[1] Lilliefors Corrected

Since the result (as per Table No. 10) was significant we reject the null hypothesis and accept the alternate hypothesis that Robotics and Automation (R&A) mean the same thing. Implying that the respondents do not distinguish between robotics and automation and treat them as one.

Objective 4 - To determine the views of Indian Construction industry professionals about suitability of robotics and automation.

To test our hypothesis about the suitability of robots to other than developed countries we formulate the hypothesis:

H_o = Robots are not suited for developing countries
H_a = Robots are suited for developing countries

This was tested through one way ANOVA using the 4 favourable composite factors and 3 resistance composite factors as independent variables and the "suiting developing countries" as a dependent variable and the results are given in Table No. 11:

Table No. 11 ANOVA[a]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	55.737	7	7.962	11.674	.000[b]
Residual	266.001	390	.682		
Total	321.739	397			

a. Dependent Variable: Robots are suited for developing countries
b. Predictors: (Constant), User Value-add and Satisfaction, Financially and Commercially viable, Suitability (to Construction Projects), Savings and Efficiency Booster, User Rejection, User incompatibility, Low User Awareness

Since the significance of p<.05 [F (7,390) = 11.674, p = .000] we reject the null hypothesis and accept the alternate hypothesis that Robots are suited for developing countries.

Table No. 12: Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	3.925	.041		94.805	.000
User Incompatibility	.073	.053	.081	1.385	.167
User Rejection	.114	.045	.127	2.542	.011
Low User Awareness	.184	.054	.205	3.424	.001
Savings and Efficiency Booster	.021	.048	.024	.445	.657
Suitability (to Construction Projects)	.193	.044	.214	4.420	.000
Financially and Commercially viable	-.027	.042	-.030	-.635	.526
User Value-add and Satisfaction	.086	.059	.096	1.474	.141

a. Dependent Variable: Robots are suited for developing countries

As per Table No.12, since the predictor p values which are significant are for User Rejection p = .011, Low User Awareness p = .001, Suitability (to construction projects) p = .000 we state that these factors are the most important to the Indian construction industry professionals.

VIII. Conclusions

This research study revealed several perceptions of the Indian construction industry professionals regarding robots, robotics and automation in construction. The main findings can be summarised as:

1. Direct source of awareness of RAC from workplace is low perhaps because robots and automation usage in India is minimal. Knowledge and information about RAC is mainly from on-line sources like You Tube, Face Book etc.
2. Regarding applications of RAC to construction activities there is a general perception that although RAC is suited for all types of construction activities mainly it can be used for Earth work, Concreting and Finishing Works.
3. That four factors are favourable for RAC Savings and Efficiency Boosters, Suitability (to construction projects), Viability (financial and commercial), User satisfaction and value-add
4. That three factors are creating resistance in the minds of the construction industry professionals viz. User Rejection, User incompatibility, Low User Awareness.
5. There is a perception that robots and automation mean one and the same thing. From the test of our hypotheses we can conclude that it is a common perception of Indian construction managers that both Robotics and Automation are the same and interrelated.
6. There is a perception that RAC is suited for developing countries.
7. That a predictor factor "Low user awareness" is significant along with two other factors "User rejection' and "Suitability (to construction projects)". This reveals the current perception of Indian construction industry that there are doubts about the compatibility of robots to various construction applications, users could also reject the use of robots and automation due to the complexity involved and lack of awareness about their suitability amongst users. This awareness needs to be increased considerably. These factors are important for the robotics and automation industry to overcome resistance from the construction industry managers so that implementation and integration of robotics and automation in the Indian construction industry can be taken up on a vast scale.

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