Stakeholder Perspectives on the Adoption of Drones in Construction Projects

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Abstract –

Drones or Unmanned Aerial Vehicle (UAV) and services based on them have been used globally in various sectors including but not limited to construction, real estate, e-commerce, agriculture, utilities & energy, financial services, and media & entertainment. Use of such robots have a potential to reduce the cost & time and increase safety & productivity among other benefits. The use of drones is increasing in India and the UAV market is expected to grow at a CAGR of 18% during 2017-2023 in terms of revenue. While the use of drones is primarily in defence sector compared to commercial use, it has been reported that drone-based solutions are being explored in agriculture, energy & utilities, insurance, infrastructure, media & entertainment and mining in India. Hence, there exists a need to investigate the level of awareness, application, benefits and barriers of using drones in Indian construction.

The primary objective of this study is to investigate the level of awareness and the application of drones among the key stakeholders in Indian construction through questionnaire survey-based quantitative research among key stakeholders. The study revealed there is high level of awareness of drones and low level of usage in Indian construction. The overall pattern in the data revealed that the respondents have rated most of the indicators highly important. Following are the top-rated attributes: Drones must be experimented before using it in the construction projects (relevance); Surveying (application); Drones provide real time updates from the site (benefit); Weather related issues (barrier) and Health and Safety (KPI). It has been observed that there is statistically significant difference in perception among contractors, consultants and clients with respect to relevance & application of drones and not so for benefits, barriers & impact on KPI.

Keywords –

Awareness; Drones; Indian construction; Unmanned Aerial Vehicle (UAV)

1 Introduction

The construction industry globally is worth 10 Trillion Dollars per annum. The countries around the world spend around 9-15% of the Gross Domestic Product on the construction sector. But the construction industry is very fragmented and unorganized. The construction industry is facing huge challenges compared to other sectors. There is a serious performance outfall observed over the decades in the construction industry [1].

The challenges such as lack of performance, low productivity of labours, lack of data collection and documentation, cost over runs of the project, lack of adoption of technology, delays in project completion, safety issues on site, lack of quality, lack of innovation, high expenses and management issues are observed in the construction industry [2]. The industry suffers with severe shortage of labours, lack of adoption of new technology, lack of performance due to decreased productivity [3]. Disasters such as one created by COVID-19 pandemic demand change in working conditions in addition to unavailability of resources.

One of the ways to overcome these challenges in construction operations is to implement automation and robotics to improve the performance [4]. Construction industry is labour dependent and robotics & automation has shown potential improvement in the productivity and quality of the construction projects [5]. The emerging technologies such as Building Information Modelling (BIM), Internet of Things (IOT), Light Detection and Ranging (LIDAR) and robots like bricklaying machine, glazing machine, Unmanned Aerial Vehicle or drones, autonomous ground vehicles, robotic 3d printing can be used to increase the productivity, reduce the cost over-runs and delays in the project. So there is need for adopting the innovative technologies for the development of the construction industry [4,6].

Drones or Unmanned Aerial Vehicles (UAV) can be adopted as potential solution to the challenges faced by the construction industry. While the use of drones in India is primarily in defence sector compared to commercial use, it has been reported that drone-based solutions are being explored in agriculture, energy &

utilities, insurance, infrastructure, media & entertainment and mining in India. The regulation on the use of drones in India has been released very recently. Adoption of drone technology is in its formative stage in Indian construction. Hence there is a need to investigate the adoption of drones in Indian construction. It has been attempted to study the level of awareness & adoption of drones in Indian construction and assess the perspectives of various key stakeholders.

2 Literature Review

2.1 Drones

Drones or UAVs also known as Remotely Piloted Aircraft (RPA) are the aircrafts which operates without the requirement of onboard human pilot and are controlled by remotes [7]. Drones vary in the sizes and can be equipped with various accessories. The various parts of drones include frame for supporting the components of drone, propeller and engine which constitutes propulsion system for lift off, battery which acts as power source, electronic and communication system which is used to control drone [8] . The drones are attached with sensors which are used for the alignment and positioning. Manual interference of the pilot is not required due to these sensors[9].

2.2 Types of Drones

Based on the vehicle mass principle the drones can be classified as "heavier than air" drones in which the drone uses aerodynamics and propulsive thrust, "Lighter than air" drones in which the drones which uses the principle of buoyancy. Wing type and rotor type come under the "Heavier than Air" drones. Wing and rotor are further divided as wing type multirotor, fixed-wing, flapping wing, single-rotor and fixed wing hybrid[10]. Based on take-off and landing it is further divided into two types as horizontal take-off and landing(HTOL) and vertical take-off and landing(VTOL)[11].

The classification of drones based on total weight including payload in India is shown in Table 1 [12]:

Table 1. Types of Drones

Sl. No	Type	Payload
1	Nano	≤250 Grams
2	Micro	>250 Grams and ≤ 2Kg
3	Small	>2 kg and ≤ 25 Kg
4	Medium	>25 Kg and ≤ 150 Kg
5	Large	> 150 Kg

2.3 Regulations on Drones in India

The Director General of Civil Aviation (DGCA) has released a policy on regulation of drones on 27th August and came into effect on 1st December 2018 in India [12]. The policy briefs about the classification and restriction on drones. The operators must obtain license Unique Identification number and Unmanned Aircraft Operation permit.

Any drones imported to India have to obtain Equipment Type Approval (ETA) from Department of Telecommunication. Except Nano drone all the other drone categories should apply for DGCA clearance

Unique Identification Number (UIN)

All the drones except Nano Drones must obtain the Unique Identification Number (UIN) from the DGCA.

Unmanned Aircraft Operator Permit (UAOP)

The civil drone operators must obtain the permit from the DGCA. The DGCA should provide the permit within seven days of the application submitted date. The validity of the permit is for five years from the date of issue and should not be transferred.

Drones owned by government institutions are not required to get a permit. Nano drones operating below 50 ft and micro drones operating below 200 feet are exempted from taking permit and Micro drones. All the drones must be within the Visual Line of Sight of the Operator. The maximum height allowed for the drones for various categories is as follows: Nano drone-50 ft, Micro drone-200 ft, Small, Medium, Large drones-400 ft above ground level.

2.4 Application of Drones in Construction

It has been reported that drones have been used in various activities such as damage assessment and building maintenance [13], land surveying [9,14], Safety inspection [15-17], 3-D modelling [18-20], building inspection [21], drone assembly [22,23], monitoring of progress [24], site inspection and management [25], facility management [26,27], and 3-D printing [28].

2.5 Benefits and Barriers

A study of benefits of using drones in construction sites reported that *safety inspection* and *accessibility to inaccessible location* are the top benefits [29]. Some of the critical barriers to the use of drones are *limited battery life* and *weather-related issues* [30].

2.6 Summary

The "Global Construction 2030" states that the construction industry will grow by 85% by 2030. Construction industry is purely dependent on labour,

work and materials involved in construction change. Use of robots in construction can have advantages such as higher safety by deploying machines for dangerous jobs, high quality, increased productivity, and reduction in costs [31].

The technology adoption rate in the construction industry is lagging compared to other industries and usage of these technologies is proving challenging for the management [15,17]. The traditional techniques are replaced by drones and they provide enhanced performance and early accomplishment of tasks [32]. The drones are needed in various aspects for the development of the industry [6]. With limited literature on drones in Indian construction and the potential application is humongous, there is a need to investigate the adoption of drones in Indian construction. Hence, this study is aimed at assessing the awareness of the drone technology in and analyse the perceptions of key stakeholders on the relevance, application, benefits, barriers of using drones in construction and the impact of the same on the Key Performance Indicators (KPI) of projects. The scope of this study is limited to Indian construction and the stakeholders involved are Clients, Contractors and Consultants.

3 Research Methodology

The primary research methods used to achieve the intended objectives are literature review and questionnaire survey-based quantitative study. An in-depth literature review in the field of drones in construction has been attempted to identify the variables of study (relevance, application, benefits, barriers and KPI) and the indicators as presented in Figure 1.

3.1 Experimental Design

A questionnaire instrument has been designed for the quantitative study and deployed online. The questionnaire contained seven sections with questions related to the respondent's profile, awareness, relevance, application, benefits, barriers and KPI. Five-point Likert scales (of agreement and value) are used to measure the indicators of the variables identified. The questionnaire also had a cover note and two informative short videos for clarity and benefit of the respondents.

Target population for this study are clients, contractors and consultants in Indian construction industry. Stratified sampling is used.

Descriptive statistics is used for data analysis. *Relative Importance Index (RII)* is used to rank the indicators to understand the relative importance as perceived by the stakeholders. *ANOVA analysis* is used to check the statistical significance of the perceived differences between clients, contractors and consultants. Cronbach Alpha is used for internal consistency and data reliability for analysis.

3.2 Data Collection

The questionnaire instrument is deployed on Google Forms and the enquiries are sent to over 100 prospective Indian respondents (clients, contractors & consultants) through Email, LinkedIn, and over phone. There are 75 valid responses received, which includes coincidentally 25 each from the three stakeholder groups after continuous follow-up in a span of 4 weeks.

4 Data Analysis, Results and Discussion

The data collected is screened and codified for further analysis.

4.1 Data Analysis

Cronbach Alpha is used to evaluate the internal consistency of the instrument and reliability of the data collected for further analysis. The calculated Cronbach Alpha values are presented in Table 2. It is observed that all the values are greater than 0.8 (except for KPI), which is very good, and the data collected is reliable for further analysis.

Descriptive data analysis is conducted to understand the profile of the respondents and awareness levels. *Relative Import Index (RII)* is computed for all the indicators and ranked overall and within stakeholder groups for observation. *ANOVA* test have been conducted to check for statistical significance in difference in opinion of respondent groups.

4.2 Results

Among the 75 respondents 88% belonged to private sector and rest to public sector. Majority of the respondents (~70%) are from large organisations base on turnover (>INR2500M) and number of employees (>250). It has been observed that 12, 32 & 56% of respondents represent top, middle & operations management in their respective organisation. It is also interesting to note that most of the respondents (76%) less than 5 years of experience and 15 & 8% of respondents having an experience of 5-10 & 10-20 years respectively (Figure 2). A little fraction of them have more than 20 years of experience.

4.2.1 Awareness and Use of Drones

The results of the analysis on the awareness and use of drones are shown in Figure 3 and 4. The results show that 83% of the respondents were aware of drone and 17 % of them were unaware. Among the respondents who are aware of drones, 85% of them have not used drones and 15% of them have used drones in various operations.

Code	Relevance of drones [R]
R1	Drone is an emerging robot in the field of construction
R2	Automation and robotics have an impact on construction industry
R3	Drones have potential uses in the construction industry
R4	It is simple for me to use the existing drone technology
R5	Drone are compatible to the construction industry
R6	Drones are still in inception stage in implementing when it comes to construction
R7	Drones must be experimented before using it in the construction projects
R8	Drones are difficult to handle and require a skilled personnel to handle it

Codes	Benefits of drones [B]
B1	Drones provide real time updates from the site
B2	Drones can fly to inaccessible areas and hazardous areas
B3	Drones decrease the cost of projects
B4	Drones can carry out the work faster
B5	Drones provide easier access to data to professionals of different department
B6	Drones create new job opportunities and add value to construction
B7	Drones help in accurate and enhanced data collection
B8	Drones help in effective communication
B9	Drones reduce the safety risks
B10	Drones improve the productivity
B11	User friendliness and Eco

Codes	Barriers of drones [BA]
BA1	Loss of Data and Signal
BA2	Limited Payload and Battery life
BA3	Weather related issues
BA4	Acquisition and maintenance cost
BA5	Owner and Management support
BA6	Accidents and interference in sites
BA7	Air traffic restriction and regulation
BA8	Requirement of skilled professional
BA9	Privacy Issues

Code	Application [A]
A1	Surveying
A2	Inspection
A3	3-D Modelling
A4	3-D Printing
A5	Drone Construction
A6	Progress Reporting
A7	Safety Monitoring
A8	Facility Management
A9	Logistic and Tracking
A10	Emergency Response and Accessibility
A11	Advertising and Marketing

Codes	Key Performance Indicators [K]
K1	Cost
K2	Time
K3	Quality
K4	Health and Safety
K5	Stakeholder Satisfaction

Figure 1. Indicators of Relevance, Application, Benefits, Barriers and KPI

Table 2. Cronbach Alpha

Variable	Questions	Cronbach Alpha
Relevance	Q1-Q8	0.87
Application	Q9-Q19	0.90
Benefits	Q20-Q30	0.88
Barriers	Q31-Q39	0.79
KPI	Q40-Q44	0.57
Overall	Q1-Q44	0.94

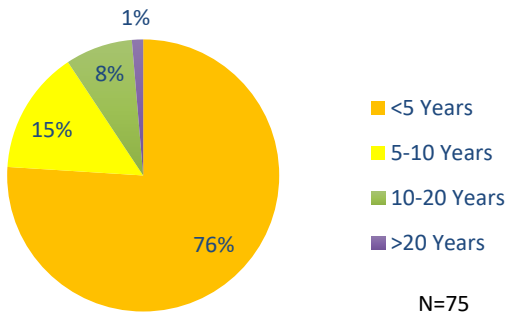

Figure 2. Experience of Respondents

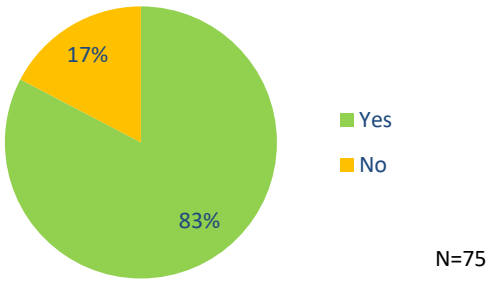

Figure 3. Awareness on Drones

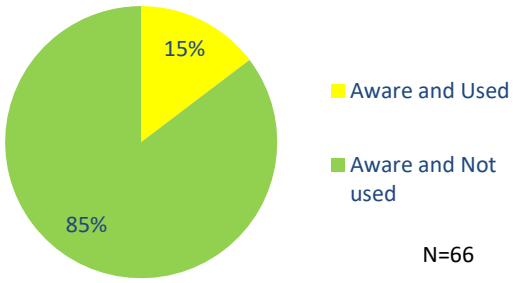

Figure 4. Awareness and Usage Chart

4.2.2 Relative Importance of Indicators (Overall)

RII has been calculated for all the indicators of chosen variables (Figure 1) using the data from all the respondents. RII along with the frequency distribution of individual ratings of indicators is presented variable-wise in Figure 5. The overall pattern in the data and RII revealed that the respondents have rated most of the indicators highly important. The top-rated indicators within the chosen variables are presented in Figure 6.

4.2.3 Relative Importance of Indicators (within stakeholder groups)

Indicators of the chosen variables are ranked using RII that is calculated based on the responses from three difference stakeholder groups (C1-Contractors, C2-Consultants and C3-Clients) in order to compare the perspectives of these groups on the relative importance. The results are presented in Table 3(a-e). The pattern in the results indicate there are differences in the relative importance of the indicators.

Table 3. Relative importance of indicators (within stakeholder groups)

a) Relevance

	C1	Rank	C2	Rank	C3	Rank
R1	**0.73**	**2**	**0.77**	**2**	**0.70**	**2**
R2	0.70	4	**0.74**	**3**	0.63	5
R3	**0.72**	**3**	0.67	7	0.66	4
R4	0.70	4	0.63	8	0.62	6
R5	0.70	4	0.71	5	**0.70**	**1**
R6	**0.74**	**1**	0.70	6	0.66	4
R7	**0.73**	**2**	**0.78**	**1**	**0.69**	**3**
R8	**0.74**	**1**	0.73	4	0.66	4

b) Application

	C1	Rank	C2	Rank	C3	Rank
A1	**0.77**	**2**	**0.79**	**1**	**0.77**	**1**
A2	0.70	5	**0.74**	**3**	0.66	7
A3	0.67	6	0.73	5	0.69	5
A4	0.64	7	0.68	7	0.70	4
A5	0.62	8	0.71	6	0.62	8
A6	**0.77**	**2**	0.74	4	**0.72**	**3**
A7	**0.75**	**3**	**0.79**	**1**	**0.74**	**2**
A8	0.67	6	0.73	5	0.67	6
A9	0.70	5	0.71	6	0.66	7
A10	**0.78**	**1**	**0.78**	**2**	**0.74**	**2**
A11	0.72	4	0.66	8	0.66	7

c) Benefits

	C1	Rank	C2	Rank	C3	Rank
B1	**0.78**	**2**	**0.79**	**1**	**0.79**	**1**
B2	**0.79**	**1**	0.74	4	**0.73**	**2**
B3	0.62	10	0.69	7	0.66	6
B4	0.62	10	0.69	7	0.66	6
B5	0.70	8	0.74	4	0.70	4
B6	0.67	9	0.74	4	**0.71**	**3**
B7	**0.77**	**3**	**0.76**	**2**	**0.73**	**2**
B8	0.73	5	0.73	5	0.70	4
B9	0.74	4	**0.75**	**3**	0.70	4
B10	0.72	6	0.73	5	0.68	5
B11	0.71	7	0.72	6	0.70	4

d) Barriers

	C1	Rank	C2	Rank	C3	Rank
BA1	0.72	8	0.70	5	**0.72**	**3**
BA2	0.76	4	**0.73**	**3**	0.65	7
BA3	**0.81**	**1**	**0.77**	**1**	0.71	4
BA4	0.75	5	**0.74**	**2**	0.68	6
BA5	0.74	6	**0.77**	**1**	**0.78**	**1**
BA6	0.73	7	0.71	4	**0.76**	**2**
BA7	**0.77**	**3**	0.70	5	0.70	5
BA8	**0.78**	**2**	**0.74**	**2**	**0.72**	**3**
BA9	0.71	9	0.70	5	**0.72**	**3**

e) Impact on KPI

	C1	Rank	C2	Rank	C3	Rank
K1	0.70	4	0.72	3	**0.72**	**3**
K2	0.67	5	0.68	5	0.64	5
K3	**0.72**	**3**	**0.74**	**2**	**0.75**	**1**
K4	**0.76**	**2**	**0.75**	**1**	**0.74**	**2**
K5	**0.82**	**1**	**0.72**	**3**	0.66	4

C1-Contractors C2- Consultants C3-Clients

4.2.4 ANOVA Analysis

It has been attempted to test this difference in perceived relative importance among Contractors, Consultants and Clients is by chance or statistically significant using ANOVA analysis at 5% significance level. The test results are shown in Table 4.

Table 4. ANOVA Analysis

Variables	F	p-value	F-crit
Relevance (R)	4.553	**0.011**	3.011
Application (A)	3.134	**0.044**	3.007
Benefits (B)	2.075	0.126	3.007
Barriers (BA)	2.948	0.053	3.009
KPI (K)	1.379	0.253	3.020

It can be noted that p-value is less than 0.05 for variables Relevance (R) and Application (A) that implies that there is statistically significant difference in perception among C1, C2 & C3. There is no significant difference with respect to other three variables.

4.3 Discussion

While high level of awareness is a welcome sign, low levels of actual usage must be looked in to by promoting the benefits/drivers and addressing the barriers. It is also supported in the higher ratings for relative importance for various indicators. Top rated relevance *Drones must be experimented before using it in the construction projects* (R7) implies that there is a need to demonstrate the use/benefits of drone through use cases. The most relevant applications for drones are *Surveying* (A1), *Emergency Response and Accessibility* (A10) and *Safety Monitoring* (A7). Necessary action plans may be drawn

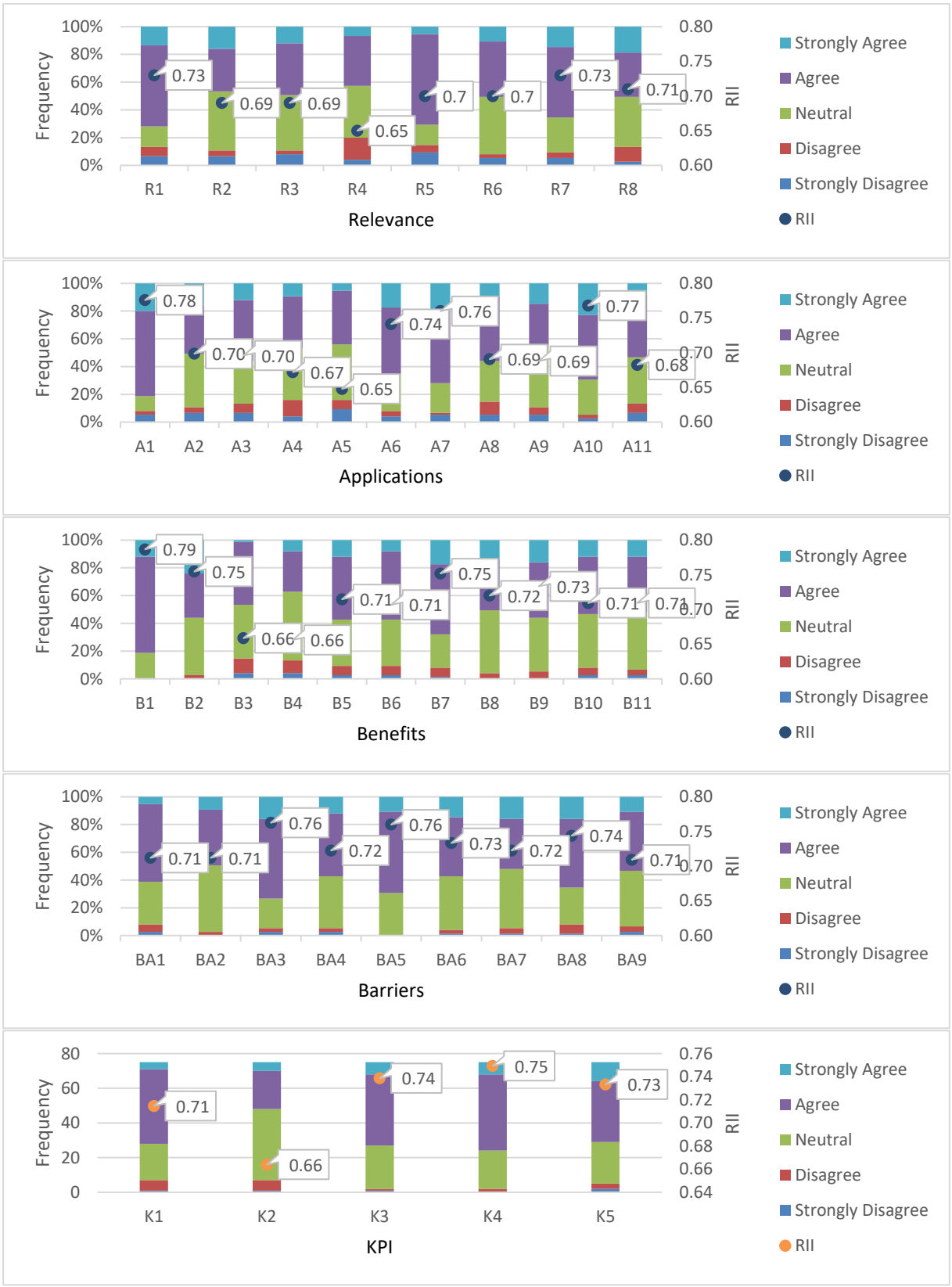

Figure 5. Frequency distribution & RII of indicators (overall)

Code	Variables/Indicators	RII	Rank
	Relevance		
R7	Drones must be experimented before using it in the construction projects	0.73	1
R1	Drone is an emerging robot in the field of construction	0.73	1
R8	Drones are difficult to handle and require a skilled personnel to handle it	0.71	2
	Application		
A1	Surveying	0.78	1
A10	Emergency Response and Accessibility	0.77	2
A7	Safety Monitoring	0.76	3
	Benefits		
B1	Drones provide real time updates from the site (through video)	0.79	1
B2	Drones can fly to inaccessible areas and hazardous areas	0.75	2
B7	Drones help in accurate and enhanced data collection	0.75	2
	Barriers		
BA3	Weather related issues	0.76	1
BA5	Owner and Management support	0.76	1
BA8	Requirement of skilled professional	0.74	2
	Key Performance Indicators		
K4	Health and Safety	0.75	1
K3	Quality	0.74	2
K5	Stakeholder Satisfaction	0.73	3

Figure 6. Top rated indicators based on RII (overall)

by the professional organisations & educational institutions to instil the skills required. The highly rated benefits are *Drones provide real time updates from the site* (B1), *Drones can fly to inaccessible areas and hazardous areas* (B2) and *Drones help in accurate and enhanced data collection* (B7). This information may be of great value for the construction contractors and drone operators. The key barriers for the adoption of drones in Indian construction are: *Weather related issues* (BA3), *Owner and Management support* (BA5) and *Requirement of skilled professional* (BA8). The project managers and drone manufacturers/operators may find this information useful to plan their business/project objectives. *Health and Safety* (K4), *Quality* (K3) and *Stakeholder Satisfaction* (K5) are the most important KPIs impacted by the use of drones. These are in line with the demands of changing business environment.

5 Summary and Conclusions

Efficient project delivery is a continuous challenge in construction. With growing complexity and uncertainty in project environments, it more prudent to promote innovate solutions to overcome the challenges and create value for the stakeholders involved. Automation and robotics have been promising in efficient and safer construction projects. However, the uptake of robot technology such as drones/UAV is slow in Indian construction. It has been attempted to study the level of awareness & use of drones as well as benefits, barriers & impact on the KPIs.

It has been observed that there is high level of awareness of drones and low level of usage in Indian construction. The overall pattern in the data revealed that the respondents have rated most of the indicators highly important. Following are the top-rated attributes: *Drones must be experimented before using it in the construction projects* (relevance); *Surveying* (application); *Drones provide real time updates from the site* (benefit); *Weather related issues* (barrier) and *Health and Safety* (KPI). ANOVA analysis revealed that there is statistically significant difference in perception among contractors, consultants and clients with respect to relevance & application of drones and not so for benefits, barriers & impact on KPI.

The sample size of the groups is limited in this study and a larger sample size may unfold results that can be generalised with much more confidence. It is worth investigating the relationship between the application, benefits, barriers an KPIs for more insight. Also, a detailed study among public & private clients shall be useful in formulating strategies for greater adoption of drones.

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