Unmanned Aerial Vehicle (UAV) Technology Based Safety Monitoring for Expressway Construction Projects

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Abstract: The distinctive nature of construction industry causes for numerous accidents and injuries. Safety monitoring in expressway construction projects is complex because of the extensive use of plants, equipment and workforce. Accidents and injuries can be prevented by proper safety monitoring techniques. On the other hand, the use of UAVs become common in progress monitoring in construction industry. Thus, the study aims to develop a framework assessing UAV technology-based safety monitoring in expressway construction projects in Sri Lanka. Initially a literature review was carried to identify the use of UAVs in construction industry. Review revealed that monitoring unsafe behaviour of workers, integration of site information with storage facilities, autonomous site inspection with GPS technology and identifying safety hazards are the usages of UVAs. Case study strategy is employed with three expressway projects. Experienced safety professionals were interviewed and content analysis was adopted to analyse the data. The findings revealed that UAV technology can be applied for the prospect of using efficient and accurate safety monitoring technique for identifying the presence of unauthorized people and vehicles, faulty works and non-use of safety measures. Research recommends to use UAV technology for safety monitoring in expressway projects in Sri Lanka.

Keywords: Safety monitoring; Unmanned Aerial Vehicle (UAV); expressways

1. Introduction

During construction, accidents can be avoided by proper monitoring the workers and the environment of the project (Mohamed et al., 2020). Techniques for monitoring safety on construction projects are mainly manual and are decided on subjective opinion basis (Outay, Mengash & Adnan, 2020). Among safety monitoring activities, inspections and job safety observations are more complex in construction as those are more labour intensive and time-consuming. Recently, Virtual Reality (VR) technology, CCTV technology, Wearables technology and UAV (Unmanned Aerial Vehicle) technology are been used to monitor safety on construction projects while avoiding traditional shortcomings faced by safety supervisors (Tatum & Liu, 2017)

UAV is easily identified as drone, quadcopter, octocopter, helicopter, or fixed wing vehicle (Opincar, 2016). UAVs have been used to acceleration of project progress reports, construction project safety enhancement, quality control, project management and scheduling (Howard & Murashov, 2018). It helps to improve real time monitoring in projects (Tatum & Liu, 2017). Safety supervisor can obtain

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faster and more accurate information on work progress, working environment or identifying illegal activities inside construction project through UAV technology (Howard & Murashov, 2018). The UAVs are also capable of conducting automatic programmed security sweeps periodically to monitor safety in projects (Alizadehsalehi et al., 2018).

Expressway construction projects safety monitoring is complex because of the extensive use of plants, equipment, labourers, multidisciplinary and multitasked aspects of its project workforce. To avoid construction accidents and injuries, suitable safety management approaches are fruitful. Hence, a modern information technology-based method is required rather than traditional approaches for safety monitoring. As, it is difficult to monitor safety in expressway construction projects by traditional approaches, UAV based safety monitoring method will fruitfully enhance the safety monitoring in expressway projects. Although, most of researches have concentrated on enhancing the safety managing, only few have addressed on safety monitoring. Further, no evidences of previous studies were found on the application of UAV technology for safety monitoring in Sri Lankan expressway construction projects. Therefore, the study aimed to explore the applicability of UAV technology for safety monitoring in expressway construction projects in Sri Lanka to develop a framework.

2. Literature review

2.1. Usage of UAV technology in construction industry

Taking above definitions into consideration, Unmanned Aerial Vehicle (UAV) could be introduced as any motorized aerial vehicle that is not transporting a pilot, lifted using forces of aerodynamics, can fly on its own(self-processed) or be controlled by an operator on the ground, can be expendable and can carry a lethal (explosive war heads) or non-lethal (passengers or cargo) payload. Every type of UAV has components like frame, propellers, flight controller, motors, electronic speed controller (ESC) and battery (Tatum & Liu, 2017).

Due to versatile properties of UAVs, they could be widely used in the construction projects (Skorupka et al., 2017). UAVs are being applied in construction projects for various purposes. These technologies include project management, quality controlling, safety, time management, surveillance and uncooperating 3D photos through to a 4D BIM (Opincar, 2016). These technologies can be frequently used to inspect construction projects, monitor work progress, implement safety regulations and observe existing structures which are out of human reach (Outay et al., 2020).

Inspecting infrastructures such as road and rail network, liquid (water and oil) pipelines, aqueducts, tunnels and channels are essential to certify the reliability, strength and durability of these erections due to their massive land coverage areas (Hubbard, et al., 2015). Above authors have stated that UAVs can provide real-time visual details for inspection of the construction project area in bird's eye view. A UAV can remain or fly over on an infrastructure and produce high quality images and video streams for surveillance and observation purposes (Irizarry & Johnson, 2014). Hence, Liu, et al. (2014) stated that UAVs facilitate a helpful perspective to catch up evidence from an extra point of view and potentially result remarkable advantages to construction industry.

Moreover, UAV technology can be combined with other modern technology to reduce the uncertainty of construction industry (Howard & Murashov, 2018). Most UAVs are programmed to travel along an earlier defined route by a GPS point arrangement known as waypoints that can be used to monitor or inspect infrastructure autonomously (Congress & Puppala, 2019). The UAV utilized with suitable detectors accomplishes taking measurements in different places. The temperature at the site,

gas or electricity leaking and abnormally high temperature can be detected using a thermal imaging camera (Liu, et al., 2014). Perfect accuracy, efficiency and measurements speed are advantages of using above technologies. So that application of UAV technology ensures addressing drawbacks from traditional methods (Skorupka et al., 2017). Further, UAVs can be used to Safety Monitoring in construction projects.

2.2. Usage of UAV technology in Construction Industry for Safety Monitoring

Vigorous and automatic ways of field surveillance techniques connected with UAV have been useful for safety monitoring by obtaining details from photos and videos at the site as useful solutions due to current time-consuming and irresponsible visual observational methods (Jawade & Butale, 2020; Alizadehsalehi, Yitmen, Celik & Arditi, 2018). Moreover, using UAV technology for safety monitoring is the best alternatives among computer vision techniques (Howard & Murashov, 2018). Visualization technology with combined site details and storing media, can increase efficacy and usefulness of safety management by assisting Inspection Officers (Safety Officers) in monitoring the insecure activities of employees and construction equipment and tools in real time (Guo, Liu, & Zhang, 2014). Further, the authors stated that UAVs could be served as their eyes in the sky instead of safety managers physically going to each area to identify potential hazards. The Safety Inspection Officer's responsibility of directly observing the site and interacting with employees constantly in real time are aided with exceptional application of UAVs (Outay et al., 2020). It would facilitate to catch up places with poor human access in the site and assist safety officers with live streaming videos (Gheisari et al., 2014). Therefore, safety officers can interact with workers easily (Siebert & Teizer, 2014). Moreover, the authors have stated that UAVs make it possible for safety inspection officers to communicate with workers if hazardous situations arise (Hubbard, et al., 2015). UAVs can also be useful in applications where accessibility is difficult (Skorupka et al., 2017).

Interference of UAV with AR can be recognized as a model of an effectively operating safety observation (Irizarry & Johnson, 2014). Moreover, the authors mentioned that UAVs with AR with real subjects can be used while performing a safety manager associated job under various conditions such as counting the number of safety helmets. Safety inspection officers should be able to control the UAV visually as well as autonomously (Alizadehsalehi, Yitmen, Celik, & Arditi, 2018). Having predefined paths or waypoints that obtained from GPS technology, UAV can automatically use with minimum user interference (Jawade & Butale, 2020; Opincar, 2016). Modern UAV technologies are being developed which associate X-ray technology and are capable of designing high resolution 3D maps of objects (Mohamed et al., 2020; Irizarry & Johnson, 2014). Above authors also have stated that this technology can be used to establish precise models of unidentified areas such areas behind walls for monitoring the structure of dangerous buildings, bridges or other complexes. In addition, multicomputers have unique advantages compared to other UAV types due to its low purchasing cost, low operational cost and maintenance costs. Its operating flexibility, the ease to steer it accurately in self-processing and pilot modes and good stability are known to be some unique advantages (Siebert & Teizer, 2014). These types of UAVs are capable of staying in sky while flying to monitor something even during rough weather condition (Skorupka et al., 2017).

The usage of UAVs in Sri Lanka has grown exponentially at present (Rifan & Adikariwattage, 2018). Low technological usage level in Sri Lankan construction industry has resulted the lack of using UAV at construction projects (Priyadarshani et al., 2013). However, according to Rifan & Adikariwattage (2018),

UAV technology is mostly used in cinematography field in Sri Lanka rather than in construction field, which only shows 5% total usage of the UAV technology.

3. Research methodology

Due to the less popularity of the UAV concept in the construction industry of Sri Lanka, limited number of experts are available who have adequate knowledge and experience on the related area. Nevertheless, the study was carried out based on the opinions of the limited number of experts available in Sri Lankan Construction industry who have a sound knowledge on the subject area. Moreover, Saunders, Lewis & Thornhill (2009) expressed that qualitative approach is the best method when researcher's objective is to collect the participant's opinion on their knowledge and experience. Hence, as the most suited method, a qualitative research approach was selected to carry out this research.

Creswell (2014) has stated that research strategy relies upon the research approach, data to be collected and expected outcomes of the research. Furthermore, Saunders et al. (2009) stated that the case study strategy is used in particular interest where the researcher wishes to gain a depth understanding of the context of the study and the processes. Thus, case study strategy is most suited for this study as it requires an in-depth analysis of the applicability of UAV technology for safety monitoring in expressway construction projects in the given context. However, unit of analysis for the case study is considered as 'expressway construction project in Sri Lanka'. In the process of selection of cases, the study has selected multiple cases against a single case, as multiple cases provide multiple sources of evidence and replication of findings. Therefore, with the intention of increasing the reliability of the overall research, this study selected three expressway construction projects in Sri Lanka which involve sound applications on safety monitoring at different locations such as Colombo, Kandy and Matara. A brief description of the background of three selected cases is given in Table 1.

Table 1: Profile of cases

	Case A	Case B	Case C
Project cost	Rs.252 Bn	Rs.306 Bn	Rs.67 Bn
Scope	Construction of 96km long four lane expressway and construction of 06 nr of interchanges	Construction of 76.8 km long four lane expressway and construction of 07 nr of interchanges	Construction of 9.6km long four lane expressway and construction of 02 nr of interchanges
Project Duration	3.5 years	2.5 years	3.5 years
Project Status	On going	On going	On going

All three projects are still ongoing and are broken down into sections due to complexity of expressway construction projects. However, as depicted in the table 01, all three projects were estimated more than Rs. 50 Bn and Road Development Authority (RDA) is acting as the client on behalf of the government. In terms of project duration, all three projects have exceeded two and half years of project duration and in terms of scope, all three projects are entailed with four lanes and two of them

have exceeded 75 km. However, all three projects have applied modern technologies during safety monitoring.

In addition, interviews have been chosen as data the collection technique of cases due to requirement of depth analysis. Thus, semi structured interviews were carried out with the participation of nine experts on the research area to extract relevant information from the interviewees to gather accurate and in-depth data. Under each case, three interviewees were selected representing both contractor and consultant parties and thus altogether nine interviews were conducted. The following Table 2 described the profile of interviewees.

Table 2: Profile of Interviewees

Case	Interviewees code	Position	Qualifications	Scope of work	Years of experiences
Case A	A1	Health, Safety, Environment and Public Liaison Manager	B.Sc. and M. Sc.in Civil and Environmental Engineering	Maintaining safety and health at the project and public liaison	11 Years
	A2	Site Engineer	National Diploma in Technology in Civil Engineering	Constructing road and Building works	8 Years
	A3	Consultant Site Engineer	B.Sc. (Hons) in Civil Engineering	Monitoring the construction works	10 Years
Case B	B1	Health Safety and Environment Manager	B. Sc. (Hons) in Physical Science and post graduate diploma in Environmental Management	Maintaining safety and health at the project	20 Years
	B2	Health and Safety Manager	B.Sc. (Hons) in Facility Management	Maintaining safety and health at the project	13 Years
	B3	Road Safety Engineer	B.Sc. (Hons) in Civil Engineering and following M.Sc. in Occupational Safety and Health Management	Monitoring the safety plan	12 Years
Case C	C1	Maintenance Road Safety Engineer	B.Sc. (Hons) in Civil Engineering	Monitoring maintenance work and safety plan	25 Years
	C2	Site Engineer	B.Sc. (Hons) in Civil Engineering	Monitoring construction works	11 Years
	C3	Assistant Safety manager	B.Sc. (Hons) in Civil Engineering	Handling the safety at the site	19 Years

As shown in the above table, majority of interviewees were chosen from contractor party due to their better experience with safety management procedures within the construction site itself. Accordingly, two interviewees from contractor party and one interviewee from consultant side were selected. In terms of experience all interviewees had more than 8 years of experience in the construction industry with two having 5-10 years of experiences in the field of safety management, four having 10-15years of experiences in same field and rest with more than 15 years of experiences in field of safety management. Hence based on their experience and educational qualification levels, it is clear that all interviewees have extensive knowledge on the related area. Moreover, nine Interviews were conducted as face to face interviews and each interview was conducted around 45 minutes. This revealed that the research employed in-depth data collected from experienced professionals and confirms its reliability. According to Hardly & Bryman (2009) content analysis is essentially used to organize qualitative information to determine the sequence of information while collecting data, maintaining patterns in the presenting and reporting of information. Therefore, content analysis was selected as the data analysis method for the study.

4. Data analysis

All interviews were conducted based on the interview guideline prepared and interviewees were questioned on safety monitoring in expressway projects and current application of UAV technology for expressway projects in Sri Lanka. Thus, the data analysis was done based on nine interviews carried out considering three selected cases.

4.1. Safety monitoring in expressway construction projects

Through literature synthesis, visual inspection, manual checklists, CCTV technology, VR technology and wearables technology were identified as commonly used safety monitoring techniques in construction projects. However, in all three cases, visual inspection has been used for safety monitoring. Checklists have also been optimized in all three cases for decreasing complexity of the visual inspection. Under visual inspection, daily, weekly, monthly, random and on time safety monitoring techniques were generally used in all three cases. In case B, based on meeting minutes or investigation reports, safety monitoring has been done without site inspections. Besides for Case C time safety monitoring was not required. Thus, logical thinking capacity of humans to make correct decisions has been highlighted in Case C rather than any technologies. Beside visual inspections, CCTV technology and dash camera of projects' vehicles were used in case A for safety monitoring. However, all interviewees mentioned the importance of having better safety monitoring techniques for expressway construction projects in Sri Lanka.

4.2. Current application of UAV technology in Sri Lankan expressway construction projects

As all interviewees were knowledgeable about the applicability UAV technology in the expressway projects, they were asked about applicability of UAV technology in Sri Lankan expressways construction projects as per the interview guideline. According to the literature findings, this technology could be

frequently used to inspect construction projects, monitor work progress, implement safety regulations and observe existing structures which are out of human reach.

According to the interviewees, Multicomputer with a camera has been used in all three cases for the application of each purposes. In terms of frequency of usage, the UAV technology in the projects, it was limited to once per month due to unfamiliarity with UAV technology in the Sri Lankan context. Although literature identified multiple purposes of application of UAV technology in expressway construction projects, it seems very less in real time. In case A, UAV technology mainly used for progress reporting. In addition to that, the pre-condition survey of the site had been done by using UAV with camera. The video captured from UAV for progress reporting has been used for safety monitoring purposes. In both case B and C, UAV technology was only used for progress reporting purposes.

4.3. Applicability of UAV technology-based safety monitoring in Sri Lankan expressway construction projects

All interviewees were asked about applicability of the UAV technology for safety monitoring in expressway construction project. Monitoring unsafe behaviour of workers easily, integration of site information with storage facilities, autonomous site inspection with GPS technology, creating accurate models of unknown areas by 3D maps, minimizing the invalid safety monitoring and easily identifying safety hazards were identified as outcomes of using UAV technology for safety monitoring in construction projects. Initially, the applicability of UAV technology for safety monitoring in Sri Lankan selected projects was discussed with all interviewees.

Thus, A01 stated that “Progress of safety monitoring works can be evaluated by using the UAV technology. Therefore, safety officers and traffic controllers who are doing their duty can be detected through it”. A01 further stated that the traffic controllers who are on duty near schools might be always on their duty location. If the person is not in his duty location at the time the students leave school, safety manager would easily detect and immediately take action’. Further, the video captured for progress reporting was used for identifying safety hazards under safety monitoring. In addition to that, interviewees of case A described that clear view of the activities was captured easily for better monitoring purposes. Interviewee from C01 explained about invalid safety monitoring activity such as launching beam to the bridge/viaduct. C01 further stated that “It is necessary to check whether the beam is safely launched to the beam before removing cranes. But anyone cannot inspect it without reaching the beam. Reaching the beam while launching is an impossible task for a human”. C01 expressed that this risky safety monitoring activity would be minimized by sending the UAV with a camera near the beam in order to inspect it. Hence, as a mechanism to detect faulty works and to explore safety compliance by workers, UAV can be implemented as per interviewees from Case 01.

Interviewee B02 mentioned that “The UAV can be flown in a limited area. (like 2/3 km). Therefore, it cannot be implemented for daily inspection instead of safety officers. It can be used in confined areas for safety monitoring like batching plants”. In case B, all interviewees stated that capturing aerial view by UAV would be caused to easily identify safety hazards at the whole site. Interviewee B01 mentioned that “UAV can be implemented in confined areas for safety monitoring. A lot of people and machineries are present when working in a confined area like asphalt paving activity. Safety officer cannot inspect it correctly because of lots of people in small range.”. further the interviewee stated that UAV with a camera can be implemented instead of a safety officer for safety monitoring in the project. Thus, UAV

according to interviewees in Case 2, UAV could especially be used to identify the unauthorized people and vehicles and to further detect faulty works.

C02 stated that “UAV technology with camera can be used as real time safety monitoring technique in Sri Lankan expressway sites”. The interviewee further mentioned that the video that captured from the UAV could be live streamed to the site office for the safety manager’s inspection. While agreeing with above mentioned live streaming process, C02 added that “Special places, like batching plants can be monitored with UAV technology as real time safety monitoring is essential due to its chemical usage. And further, safety manager can inspect that flagmen, safety officers are doing their duty in proper manner”. Hence Case 03 interviewees highlighted the minimising invalid safety supervision and improving real time monitoring through application of UAV technology in expressway construction projects in Sri Lanka. However contrary to above findings, C03 stated “If UAV technology is used to find workers who do not wear PPEs, it is unable to find one worker who is not wearing PPEs among 5 or 6 workers gang when all other workers are wearing PPEs because the. UAV fly normally at height about 10 m above the ground level”. According to C02’s opinion, the visual observation that captured from UAV would not be clear enough to identify the safety hazards at the relevant moment which could be identified as a drawback to implement UAV technology in the given context. Thus, the applicability of UAV technology-based safety monitoring in Sri Lankan expressway construction projects was discussed.

5. Conclusions and recommendations

The empirical study focused on applicability of UAV technology for safety monitoring in expressway construction projects in Sri Lanka. Initially a comprehensive literature review was done to identify the usage of UAV technology in construction industry for safety monitoring. Then a case study analysis was done based on three selected expressway projects in Sri Lanka to explore the current application of UAV technology for Sri Lankan expressway construction projects and to find the applicability of UAV technology-based safety monitoring in Sri Lankan expressway construction projects.

According to the literature findings UAV technology helps in easily conducting project management, quality controlling, safety, time management, inspection, uncooperating 3D images into a 4D BIM, monitoring work progress, providing real-time visual information and taking the measurement in different places. But considering its usage in site monitoring identified key rewards through literature are monitoring unsafe behavior of workers easily, integration of site information with storage facilities, autonomous site inspection with GPS technology, creating accurate models of unknown areas by 3D maps, minimizing the invalid safety monitoring and easily identifying safety hazards.

However, minimizing invalid safety monitoring, identifying unauthorized people and vehicles, identifying faulty works and non-use of safety measures, improving real time monitoring, easily identifying safety hazards at whole site (unsafe behavior of workers, unsafe conditions of site), identifying disruptive works by third parties(thieves), identifying defaults on duties by safety officers are considered as some of key applications of UAV technology in safety monitoring mechanism of expressway construction projects in Sri Lanka. Thus, based on the study findings a framework was developed as indicated in figure 1 to achieve the ultimate research aim.

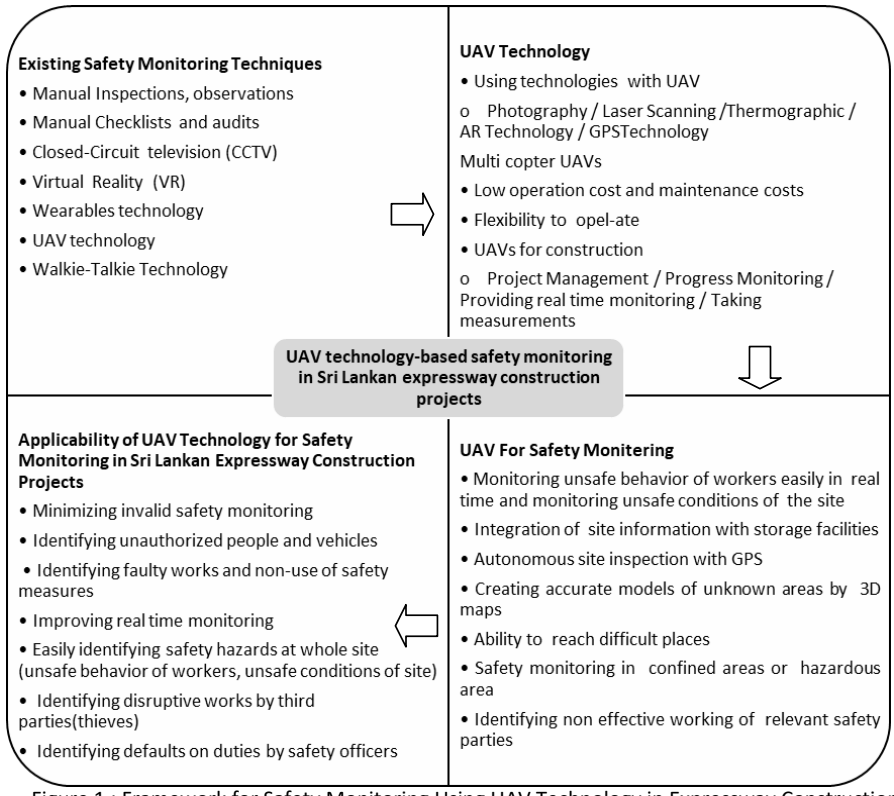

Figure 1 : Framework for Safety Monitoring Using UAV Technology in Expressway Construction Projects in Sri Lanka

Accordingly, the study critically analyzed the applicability of UAV technology in safety monitoring of expressway construction projects in Sri Lanka. Although, the adaptation of the innovative technologies in Sri Lankan construction industry is still at a lower level, the implementation of UAV technology-based safety monitoring mechanism in Sri Lankan expressway construction projects would facilitate numerous benefits as identified by interviewees and it would ultimately overcome the drawbacks of existing safety monitoring techniques.

6. Limitations

This research was carried out amongst a few limitations. The main limitation is restricting the study only to expressway construction projects as building projects ware not considered because it requires a clear air running route that visible to the operator. Other one is that, although UAV technology could be implemented for safety management process the study was restricted to only for the safety monitoring process in safety management due to the limitation of the time to execute the research.

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