B

Remotely piloted aircrafts (RPA) are unmanned aerial vehicles (UAVs) that are used for commercial purposes (CASA, 2016). UAVs, popularly known as drones, can be simply defined as: “any aerial vehicle that does not rely on an on-board human operator for flight, either autonomously or remotely operated” (Rao et al., 2016, p. 84). Given the technological advancements on miniaturization of components; the availability of smaller, lighter and cheaper aircrafts; and increased capabilities, RPAs will secure a significant share in various

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Nearly one-and-a-half centuries after Montgolfier brothers designed the first widely known manned flight (a hot air balloon), the Hewitt–Sperry Automatic Airplane in 1916 was demonstrated as the first modern UAV (Zaloga, 2011). UAVs were initially developed for carrying weapons and explosives as early as 1915 in the USA and as targets around 1930 in the UK (Clarke, 2014b). However, these decommissioned military devices have found alternative uses and applications within civilian society. According to the Civil Aviation Safety Authority of Australia (CASA, 2016), UAVs can be categorized into two types:

(1) RPAs which are used for government, commercial or research purposes; and
(2) model aircrafts used only for entertainment, in sport and recreation activities.

The distinction between the two is that, for a model aircraft, no fee is paid for the service (Clarke, 2014b). Consequently, RPAs represents terminology applicable to the commercial purposes on construction sites and is used within this study. For a further and more exhaustive treatment of terminologies and the various methods of UAVs classification, interested readers should consult with Clarke (2014b).

The fastest commercial growth opportuni

approach is essential when exploring the barriers to adoption of technological innovations (Antioco and Kleijnen, 2010).

The technology acceptance model (TAM) and the task–technology fit model (TTF) represent two significant models for explaining user acceptability of technological innovations (Dishaw and Strong, 1999; Imoudu Enegbuma et al., 2014). TAM has been criticized for weakness in terms of its lack of task focus – that is, robustly evaluating the technological innovation acceptance, use and performance, as argued by Dishaw and Strong (1999). Conversely, TTF developed by Goodhue (1995) has been widely used to successfully explain the factors that affect the adoption of technological innovations (Junglas et al., 2008):

- investigate software maintenance systems (Dishaw and Strong, 1998);
- investigate group support systems (Zigurs and Buckland, 1998; Dishaw and Strong, 1999); and
- evaluate performance factors of an integrated information center on end-users (Goodhue, 1997; Goodhue et al., 1997).

Specifically, TTF is not reliant upon historical information on the use of the technological innovations (Schlauderer et al., 2016) and is therefore, more suitable for RPAs that do not have a long history of use.

TTF can be assessed as a trichotomous variable, namely: "ideal-fit", "under-fit" and "over-fit" (Junglas et al., 2008). Ideal-fit indicates an exact match between task requirements and the functionality of a technological innovation. Over-fit occurs when more functionality is provided than is required, and under-fit reflects situations in which technological innovation is not capable of: "facilitating solving the problem at hand in an ideal manner" (Junglas et al., 2008, p. 1050).

Data for systematic reviews are available from databases such as the Web of Science (WoS), PubMed, Google Scholar and Scopus. Of these, Scopus was selected because it has a wider range of coverage, faster indexing process and lists more recent publications (Hosseini et al., 2018). To identify pertinent keywords, it should be acknowledged that various terms are commonly used in referring to RPAs across the construction industry. For example, the Federal Aviation Administration of the USA uses remotely piloted vehicles (RPVs) and RPA. In the UK, the term remotely piloted air system (RPAS), UAV and drone are preferred (Fishpool, 2010; Herlik, 2010; Marchant et al., 2015). The Civil Aviation Safety Authority in Australia shifted from using the terms UAV and drone to RPAs, and unmanned aircraft systems (UASs) (

“construction”

Barriers to adoption

operations should have an emergency fail-safe plan. The GPS-based flight positioning system of the RPAs can also engender flight inaccuracy when operating within confined and/or indoor areas (Siebert and Teizer, 2014; Reagan et al., 2016). Similarly, height and speed variations of the flights can also cause inaccuracy within the RPAs positioning system (Li et al., 2016).

dangerous batteries, and their incorrect use can lead to fire or even explosion (Droneblog Editor, 2016).

From an operator's perspective, the ease of RPA use is an imperative factor. Kim et al. (2016)

Kim et al., 2016)

Organizational barriers

Acquisition, setup, operating and maintenance costs of RPAs at the current state are relatively high (Opfer and Shields, 2014; Kim et al., 2016; Kumar et al., 2016). There are also major risks in using RPAs such as a loss of asset in case of breakdown or crash of aircraft (Kaćunić et al., 2016). A study by Siebert and Teizer (2014) shows that the running costs of flying systems (such as airships, fixed-winged aircrafts and helicopters) for surveying tasks in earthwork projects are relatively higher than RPAs. RPAs at their current state are still evolving beyond their military origin to become powerful business tools (Goldman Sachs, 2016) and require further customizations for civil engineering tasks – where the costs of customizations can be high (Liu et al. (2014). Considering the growing number of RPAs throughout the industry, there is an opportunity in the future for the mass production of specific/bespoke RPAs for construction usage that would reduce their costs. Kim et al. (2016) argue that lack of support from owners and project managers is a major barrier for using RPAs in the construction sites, one explanation being the fear of additional liabilities incurred. This barrier would require a comprehensive understanding of the benefits and risks that RPAs bring to site operations.

[illegible]

Research and industry reports have acknowledged the existence of barriers that hamper the wider adoption of RPAs in the construction context (Dupont et al., 2017; McCabe et al., 2017; McMinn, 2017; Zhou and Gheisari, 2018). With this in mind, this study provides original insight by taking the argument about the barriers to the next level. Raising awareness of the nature of these barriers, exploring and providing a typology of them are among the major contributions of this study. Moreover, addressing the identifi

(John et al., 2018). The primary challenge, therefore, is to improve the collision avoidance technology in RPAs. Given the limitations of payloads, an effective collision avoidance technology is still missing. That is, under current circumstances, viable

workers can be using proximity sensors and Internet of Things (IoT) for autonomous navigation of RPAs around construction sites (Palossi et al., 2018). As practiced by Teizer and Cheng (2015), real-time location tracking systems (RTLS) can spot the location of workers, off-highway plant and equipment and produce warnings in unsafe proximity cases.

Construction-related operations require an understanding of the nature of construction activities, and hence, particular training courses can enhance the effectiveness and safety of flights (McMinn, 2017; Ayemba, 2018). Further, proximity detecting sensors can be helpful in this regard, as they can prevent unpleasant clashes between RPAs and human or site objects (Teizer and Cheng, 2015; Corrigan, 2018b).

[illegible]

RPAs represent an emerging technological innovation that will revolutionize the construction industry, given its potential in improving productivity, enhancing site logistics, accelerating project progress and increasing site safety. Construction companies, however, face a wide range of barriers to adopt RPAs on site. This research represents the first move toward a widely accepted framework to overcome the barriers, to make the RPA market sustainable. These limitations, hence, provide fertile grounds for future research and much-needed wider academic debate. Future studies can also delve into the nature of each identified barrier and attempt to provide remedial solutions for each item. The findings of the study also warrant further research into improving the collision avoidance technology used in RPAs, given the conditions of their application on construction sites. In addition, given the large market size for RPAs in the construction industry, research into the design of customized RPAs for construction purposes might be another area of investigation offered through the findings presented here.

Alsafouri, S. and Ayer, S.K. (2018), "Review of ICT implementations for facilitating information flow between virtual models and construction project sites", Automation in Construction, Vol. 86, pp. 176-189.

Anastasios, P., Nektarios, K. and Mikela, C.M. (2018), "Hazard analysis and safety requirements for small drone operations: to what extent do popular drones embed safety?", Risk Analysis, Vol. 38 No. 3, pp. 562-584, doi: 10.1111/risa.12867.

Antioco, M. and Kleijnen, M. (2010), "Consumer adoption of technological innovations: effects of psychological and functional barriers in a lack of content versus a presence of content situation". European Journal of Marketing, Vol. 44 Nos 11/12, pp. 1700-1724, doi: 10.1108/03090561011079846.

ATSB (2017), "A safety analysis of remotely piloted aircraft systems 2012 to 2016: a rapid growth and safety implications for traditional aviation", Australian Transport Safety Bureau, available at:

Clarke, R. (2014a), "The regulation of civilian drones' impacts on behavioural privacy", Computer Law and Security Review, Vol. 30 No. 3, pp. 286-305.

Clarke, R. (2014b), "Understanding the drone epidemic", Computer Law and Security Review, Vol. 30 No. 3, pp. 230-246.

Clothier, R.A., Greer, D.A., Greer, D.G. and Mehta, A.M. (2015), "Risk perception and the public acceptance of drones", Risk Analysis, Vol. 35 No. 6, pp. 1167-1183.

Cole, H. Creech, J. (2016), "

Goldman Sachs (2016), “Drones reporting for work”, The Goldman Sachs Group, available at: www.goldmansachs.com/our-thinking/technology-driving-innovation/drones/ (accessed 19 September 2017).

Golizadeh, H., Hon, C.K.H., Drogemuller, R. and Reza Hosseini, M. (2018), “Digital engineering potential in addressing causes of construction accidents”, Automation in Construction, Vol. 95, pp. 284-295.

Goodhue, D. (1997), “The model underlying the measurement of the impacts of the IIC on the end-users”, Journal of the American Society for Information Science, Vol. 48 No. 5, pp. 449-453.

Goodhue, D.L. (1995), “Understanding user evaluations of information systems”, Management Science, Vol. 41 No. 12, pp. 1827-1844.

Goodhue, D.L. and Thompson, R.L. (1995), “Task-technology fit and individual performance”, MIS Quarterly, Vol. 19 No. 2, pp. 213-236.

Goodhue, D., Littlefield, R. and Straub, D.W. (1997), “The measurement of the impacts of the IIC on the end-users: the survey”, Journal of the American Society for Information Science, Vol. 48 No. 5, pp. 454-465.

Omar, T. and Nehdi, M.L. (2017), “Remote sensing of concrete bridge decks using unmanned aerial vehicle infrared thermography”, Automation in Construction, Vol. 83, pp. 360-371.

Opfer, N.D. and Shields, D.R. (2014), “Unmanned aerial vehicle applications and issues for construction”, in 121st ASEE Annual Conference and Exposition.

Pádua, L., Vanko, J., Hruš