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Research article

The use of smart technologies in enabling construction components reuse: A viable method or a problem creating solution?

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ABSTRACT

The exploitation of Radio Frequency Identification (RFID) for tracking and archiving the properties of structural construction components could be a potentially innovative disruption for the construction sector. This is because RFID can stimulate the reuse of construction components and reduce their wastage, hence addressing sustainability issues in the construction sector. To test the plausibility of that idea, this study explores the potential pre-conditions for RFID to facilitate construction components reuse, and develops a guidance for promoting their redistribution back to the supply chain. It also looks at how integrating RFID with Building Information Modelling (BIM) can possibly be a valuable extension of its capabilities, providing the opportunity for tracked components to be incorporated into new structures in an informed, sound way. A preliminary assessment of the strengths, weaknesses, opportunities and threats of the RFID technology is presented in order to depict its current and future potential in promoting construction components' sustainable lifecycle management, while emphasis has been laid on capturing their technical, environmental, economic and social value. Findings suggest that the collection of the right amount of information at the design-construction-deconstruction-reuse-disposal stage is crucial for RFID to become a successful innovation in the construction sector. Although a number of limitations related to the technical operability and recycling of RFID tags seem to currently hinder its uptake for structural components' lifecycle management, future technological innovations could provide solutions that would enable it to become a mainstream practice. Taken together these proposals advocate that the use of RFID and its integration with BIM can create the right environment for the development of new business models focused on sustainable resource management. These models may then unlock multiple values that are otherwise dissipated in the system. If the rapid technological development of RFID capability can be allied to policy interventions that control and manage its uptake along the supply chain, the sustainable lifecycle management of construction components could be radically enhanced.

1. Introduction

Construction and demolition waste (CDW) constitutes one third of the total solid waste generated in Europe, accounting for over 800m tonnes of waste generated per year (European Commission, 2016b). The high potential for reusing and recycling the multiple components/materials of which CDW is comprised, coupled with the need to close the material loops and move towards a circular economy, has led to categorisation of CDW by the European Commission as a priority waste stream (BIO Intelligence Service, 2011; European Commission, 2016a). This has urged the construction sector to introduce sustainable practices that seek to support and promote efficiency associated with the production of various construction components (e.g. fabricated pipes, structural steel members, precast concrete blocks, etc.), their use, end-of-use (EoU) and end-of-life (EoL) management (Iacovidou and Purnell, 2016). Although recycling of CDW is considered to be an established process for the CDW management (mainly driven by the requirement to divert it from landfill and only minimally by the recovery of technically or economically valuable material), the recovery of the structural or functional value of construction components via reuse has been largely overlooked.

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Reuse is recognised by the European Commission as a better practice in the construction sector as it promotes higher recovery of value as opposed to recycling (European Commission, 2016a). A number of design interventions that can stimulate the reuse of construction components have thus been widely documented in the global literature and recently reviewed (Iacovidou and Purnell, 2016). These interventions - adaptive reuse, deconstruction, design for deconstruction (DfD), design for reuse (DfR) and design for manufacture and assembly (DfMA) - have many benefits to offer. Short-term economic and organisational factors, as well as technical constraints associated with the identification, recovery and handling of construction components currently impede the realisation of these benefits (Iacovidou and Purnell, 2016). This is largely attributed to the lack of information regarding the lifespan of construction components; transformation of their physical and technical characteristics over their service life; and the options available for optimising the recovery of their value at their EoL stage, all of which make the implementation of such interventions and/or the recovery of construction components from CDW a real challenge.

Present design practices focus on initially documenting a relatively small subset of nominal 'upstream' technical properties for a given construction component, e.g. strength, stiffness, generic durability class and financial cost. Between this subset of properties and the additional 'downstream' properties required to promote reuse of components, e.g. the exposure and loading history of the component, its connection details, and the likely lifespan of the component (Iacovidou and Purnell, 2016), there is a knowledge gap that needs to be filled. Issues regarding the documentation, archiving and updating of 'upstream' and 'downstream' data, which may only exist in initial inventories and CAD drawings, and whose transfer to subsequent owners and operators of structures may not be reliable in practice, would also need to be addressed. As such, adding greater consistency and automation to the task of identifying, characterising and tracking construction components could aid their documentation and recovery during downstream activities, enabling their redistribution back into the supply chain.

During the last decades, a number of advanced "smart" technologies have emerged including radio frequency identification (RFID) tags, optical character recognition, 3D scanning laser, building information modelling (BIM), 3D computer-aided design (CAD), etc., becoming important tools in the construction sector (Ergen et al., 2007a; Majrouhi Sardroud, 2012). Among these technologies RFID - a wireless sensor technology operating based on the transmission of data via radio frequency (RF) signals to and/or from physical 'tags' attached to products and components (Dobkin, 2008; Domdouzis et al., 2007; Jaselskis and El-Misalami, 2003; Landt, 2005; Majrouhi Sardroud, 2012; Mennecke and Townsend, 2005; Sun et al., 2013; Valero et al., 2015; Yan, 2015) — stands out as one of the greatest contributing technologies of the 21st century. This is ascribed to its automatic data collection, information storage capability, ease of handling, durability and affordability (Hunt et al., 2007; Lim, 2012; Majrouhi Sardroud, 2012; Motamedi and Hammad, 2009).

There are currently three types of RFID tags available: passive; semi-passive; and active RFID tags (Cisco, 2014; Impinj, 2016; Sun et al., 2013; Valero et al., 2015). Active tags, due to owning their power source, have a greater read-write range (5–30m) than passive tags (read-write range of less than 2m long), but are more expensive than passive tags due to higher material and manufacturing costs (Kaur et al., 2011; Schindler et al., 2012). As such, active tags are usually applied in specialist areas where the higher costs and higher detail level of information stored are justified (e.g. in locating large assets). Passive tags due to their simplicity, adaptability and resistance to harsh environments have a vast number of generic applications in a variety of industries and sectors (Jaselskis and El-Misalami, 2003; Kaur et al., 2011; Schindler et al., 2012).

An additional advantage that has made RFID attractive is its ability to be integrated with a range of other technologies, maximising as such its potential to capture, transmit and collect data, providing business benefits and return on investments (CoreRFID, 2008; Valero et al., 2015). Depending on the task at hand, RFID can be integrated with geographic information system (GIS) and global positioning system (GPS) or ultrasound technologies (e.g. for locating materials and estimating their position in the construction site); personal digital assistant (PDA) technologies (e.g. for monitoring information such as material/component inventories and building drawings and other documentation and safety management); and BIM technologies (e.g. for storing and retrieving component lifecycle data and integrating those into new designs). BIM is a technology used to 'build' a structure in a digital environment, using virtual components, the characteristics and properties of which are analogous to the physical components available in the market which represent the physical and functional characteristics of a structure (Akbarnezhad et al., 2014; Bryde et al., 2013; Crotty, 2013; Sacks et al., 2010; Volk et al., 2014). The quantities and properties of the building components and materials used, as well as the building and component/product geometry, spatial relationships, geographic information, functionality etc., are typically embedded in BIM by the designers, owners and contractors, forming a useful database that is continuously updated (Akbarnezhad et al., 2014; Bryde et al., 2013). A unique RFID tag assigned to a construction component can be linked to a BIM database, enabling the recovery and organisation of its pertinent information during all building project phases. This can then be incorporated into a 3D information model. In that way reclaimed construction components can find their way in being reused into new structures in a much easier, cost-efficient and accurate way (Cheng and Chang, 2011; Motamedi and Hammad, 2009).

BIM's ability to digitally represent the physical and functional characteristics of a structure, and to retrieve data from a database, offers an effective way of modelling and managing this information in order to view, analyse and test the behaviour of a structure, while also permitting design changes to be made in a quick, effortless and reliable manner; forming a reliable basis for decision-making (Akbarnezhad et al., 2014; Cheng and Ma, 2011; Cheng and Chang, 2011; Crotty, 2013; Čuš-Babič et al., 2014; Ness et al., 2015; Sacks et al., 2010). There is now a suite of studies that demonstrate the feasibility of using BIM for streamlining whole-life performance of structures, from construction to EoL management (Akbarnezhad et al., 2014; Azhar et al., 2011; Volk et al., 2014); DfD interventions (Akinade et al., 2015, 2017); green building certification (Wong and Zhou, 2015); waste minimisation at the design and construction stage of a building (Akinade et al., 2015; Liu et al., 2015); all with the overarching aim of enabling an enhanced communication between the various stakeholders involved in modern construction projects in order to improve the environmental, economic and social performance of the construction industry (Arayici et al., 2011; Bryde et al., 2013; Costin et al., 2015; Sacks et al., 2009, 2010). However, the use of BIM to enable the reuse of construction components remains a niche.

Given the early-stage of RFID-BIM integration, this study is set on describing the role of RFID in storing, managing and supporting information flow through the construction components lifecycle, promoting their redistribution back to the supply chain. The prospect of integrating RFID with BIM for facilitating construction components reuse is explored as a means to enabling the construction sector to make the shift from a massive waste generator to a resource recovery implementer, streamlining the delivery of

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