Improving delivery of building services systems by implementing; Augmented and Virtual Reality technologies.

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Summary
Construction projects are generally short term engagements between multidisciplinary teams with different levels of process maturity and varying information handling capabilities. Clarity of communication is essential in order to achieve a successful project. Innovative visualisation technologies such as Virtual Reality (VR) and Augmented Reality (AR) create a new way of envisaging the end product whilst also potentially improving team collaboration. It is argued that VR and AR have the potential to increase efficiency in construction projects at every stage of the building life cycle, from design concept, through construction, maintenance to demolition.

Building Information Model (BIM) supported by innovative visualisation technologies such as VR and AR offers a holistic and system-driven approach to the whole life cycle of a project.

Keywords: Augmented Reality, Virtual Reality, Building Information Model

1.0 Introduction
The construction industry has been criticised for its poor profit margins and low efficiency levels (Wokseep, 2007) and overall, is considered to be in need of improvement in a number of areas, especially in terms of the creation, innovation, utilisation and implementation of efficient processes at strategic and operational levels (Kagioglou et al, 1999).

The introduction of ICT visualisation technologies into the construction industry significantly influenced the design process and created the opportunity for better collaboration, unfortunately, the implementation ratio of model based working methods within the construction industry is still very low, and a lack of knowledge and
understanding of the potential of ICT visualisation technologies has been blamed for this. The UK construction industry needs to follow the lead of the manufacturing sector in order to achieve significant performance improvements (Kagioglou et al., 1999). Manufacturing as a sector is very open to innovative ICT visualisation technologies; back in the 1980s, the implementation of computer aided design (CAD) software increased designers’ productivity, improved communication and the quality of a design (Narayan et al., 2008). Although the CAD platform is well-established within the construction sector, the manufacturing industry has now begun to implement a new set of innovative visualisation tools such as VR and AR because they see the potential that these tools and technologies could improve collaboration and efficiency at the design stage of the process. By contrast, VR and AR are relatively new and undiscovered within construction. However, in very near future these new technologies will be as affordable and usable as the CAD platform currently is today. There is significant potential for using VR and AR within the construction sector, not only to improve efficiency during the design and planning stages, but also to provide support throughout the building life cycle via their integration with BIM software applications.

2.0 Virtual Reality and Augmented Reality

In principle Virtual Reality systems use real-time stereoscopic computer graphics in order to make a user believe that they are part of a virtual domain, allowing a potential user to reach out and move around within a three dimensional digital environment, as well as edit and delete objects as if they really existed in physical dimension (Vince, 2004). Woksepp et al., (2005) describe VR as a communicative and spatial medium with great potential for improving the construction process. However, it has only recently started to play an important role as an enabling technology within the construction sector. On the other hand, Westerdahl et al. (2006) argue that the usefulness of VR technology at different stages of the construction process has yet to be established clearly, although he agrees that the benefits of using VR increase when it is used in conjunction with concurrent engineering. Vince (1995) stated that VR will transform the way we work, live and communicate. VR models are commonly displayed on immersive 3D stereoscopic displays such as Computer Automatic Virtual Environment (CAVE) or Active Walls.
Augmented Reality is a type of mixed reality (MR), where the degree of reality perceived by the user appears greater than in virtual reality. A good way of explaining the difference is that instead of immersing a user into a virtual world, as with VR, AR attempts to embed synthetic information into the real environment (Bimber & Raskar, 2005). AR technology has developed in line with mobile technologies and often takes the form of application software (app) that can be displayed on smart phones, tablets or even innovative augmented goggles which is what makes it affordable in comparison with VR.

2.1 Implementation of VR during design stages

Concept design requires collaborative working and understanding between all teams. In most situations, concept design involves many different types of stakeholders such as architects, engineering teams, commercial teams, planners, most importantly clients and end users. Every stakeholder has different needs and approaches to design; each understands the design process from a different point of view. VR can improve communication and collaboration amongst all stakeholders, as well as allow teams to create a different type of mock ups in a short space of time in full immersive environment, which is especially beneficial during consultations with a client. Savioja et al (2003) confirmed that VR improved communication and the decision making process in comparison with previous conservative design methods.

Prefabrication and modularisation of project components are playing an important role when it comes to project delivery and have a direct impact on the main project drivers: safety, cost and time. Adopters are using modular processes widely across a variety of buildings, from data centres and hotels to health care facilities. Prefabrication is most often used in building superstructures (27%), followed by Mechanical, Electrical and Public Health (MEP) systems (21%). The main reason for using prefabrication is to increase productivity, reduce project schedules, and cost and budget (McGraw-Hill Construction, 2011).

In order for modularisation to succeed at the installation stage, collaboration, coordination and communication is required amongst all design teams during the design development process. Kondratova et al (2009) investigated the implementation of virtual reality technologies for modular construction and come to the conclusion that “VR technologies go beyond the capabilities of 3D design to include aspects such as time and more effective communication”.

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The additional dimensions added to design visualisation by VR can assist designers in assessing these complicated modules in order to plan an efficient assembly, as well as co-ordinate transportation from manufacturer to a site. Another positive aspect of using VR is that it provides interface and additional assembly drawings in addition to traditional 3D plans.

The complex MEP modules assembly process can be visualised and planned in detail in an easy way by using VR, allowing managers, engineers and fitters to review an installation sequence, as well as review all Health and Safety (H&S) assembly issues, which would most definitely speed up the design and assembly process of MEP modules, thus speeding up the whole project delivery time (Latford, 2012).

2.2 Implementation of VR and AR during installation stage

During the project installation stage, most of the subcontractors have difficulty converting the design into workable solutions. Egan (1998) estimated that up to 30% of construction is remedial work, mostly due to misunderstandings, and inadequate design information, which causes delays and budget overruns. Currently design information is delivered to onsite teams mostly by 2D drawings and written statements. Paper based communication is insufficient and doesn't provide the necessary collaboration between design and installation teams. The paper based communication could be replaced by visualisation based communication, which is more powerful and efficient.

There is a definite need for adopting new innovative visualisation methods of communication within construction (Ganah et al, 2005).

The VR is “a connection between theory and practice on site” and it could be used as a practical tool on construction sites to: improve collaboration, co-ordinate and plan future activities and reduce lead time and speed up information flow (Woksepp & Olofsson 2008).

Kamat (2013) showed that Augmented Reality technology could also be used to improve installation stages, “construction sites can be visualised before work begins, allowing for changes to the plan and error prevention without the actual costs or safety concerns”. A computer generated model that blends with the real world environment creates the illusion that an object really exists so that, for example, before excavation works start, the site could be surveyed in order to locate any buried utilities that are not seen in the real world but are very dangerous, for example high voltage cables or gas pipelines. Smart phone / tablet application could
be used on site to preview, for example, a future pipework route or the dimensions of a particular section. Using this solution a user is able to compare the virtual building with already built parts.

2.4 Implementation of VR and AR during maintenance stage

Maintenance is a very difficult task especially because plants are complex systems. Virtual reality not only makes maintenance easier but also helps with the planning and implementation of new factory layouts. VR models also include meta data of individual components such as serial numbers, temperatures, pressures as well as training materials that enables building contractors to carry out more detailed maintenance tasks without any errors (Fraunhofer IGD, 2013).

Virtual reality provides a fully immersive interface which is an efficient tool for maintenance and repair operations (Fraunhofer-Gesellschaft, 2012). Although the big industry leaders can afford investment in VR applications, this can be a problem for smaller construction companies just why in this situation AR applications might be more accessible and affordable. The application, based on AR, makes “visible” for example already laid sockets, wires and detectors where information, about, for example, smoke detector type, installation date and testing date can be easily previewed – a really major benefit for any maintenance team. The detailed information is obtained by pointing the device (smart phone, tablet) towards the required element or service. This technology allows the maintenance process to be speeded up and cutting costs in comparison with traditional maintenance methods where specifications, design and installation drawings are required to be in place and reviewed prior to maintenance. (Fraunhofer IGD, 2013).

Presentation of a system component (e.g. a pump) and all the necessary technical information in augmented view on a smart phone or a tablet would be very beneficial for commissioning and maintenance teams. Once the BIM model reach its maturity, it is probable that all this information could be fed from it.

By pointing a tablet or smart phone at a bar code placed in a plantroom, a global positioning system (GPS) would locate the position of the user within the building and adequately bring up an augmented view of the particular model which, in this situation, would be the pump model. This technology would allow access any necessary technical information associated with that piece of equipment in BIM, such as fan duty, specific fan power, fan curves and technical data etc.

Going one step further, via an interface with BMS sensors we could actually compare
the design technical parameters against present working parameters without having to even leave the room.

2.5 Implementation of VR/AR during demolition stage
Virtual reality applications are not only used for training purposes in the demolition industry but also for the detailed planning of demolition sequences. The virtual model can potentially fully reflect the structural parameters of the real building: columns, slabs, walls, beams and joints, even structure and materials parameters weakened by corrosion can be inputted into VR model. Demolition analysis makes demolition safer by allowing failures to happen in a virtual world rather than in real life (National Demolition Association, 2012).

Deconstruction is a new field for virtual reality applications. However, current records indicate that there are significant potential and benefits for using this innovative technology for training purpose as well as planning the sequence of the demolition process itself.

2.6 VR/AR - relationship to BIM
VR and AR could play a very important role in BIM Level 2 and 3, both as a tool for improving integration and collaboration between teams, and as a way of providing simplicity during the review process, helping to troubleshoot any problems that may have occurred during the whole building life cycle. The construction industry is characterised by complex business relations and requires multidisciplinary collaboration (Ajam et al, 2010). Fast and easy access to the latest project information, very often at remote locations, creates a big challenge to ICT developers. VR and AR could successfully solve these challenges for teams involved in such projects (Jiao et al, 2012). VR displays like CAVE or Smart Wall due to their high cost and fragile nature could be integrated with BIM within office based design teams as a collaborative tool. However, the main challenge sits with AR, which could be implemented by builders on construction sites.

3. Conclusions
Virtual Reality and Augmented Reality visualisation techniques have the potential to improve collaboration and efficiency at every stage of the construction process. However, their market implementation has yet to reach maturity and are dependent on further advances in technology, adjustments to project procurement, along with
change in business culture in order to overcome certain mentality barriers, in particular, attitudes towards the adoption of novel technologies. Unfortunately, to date there has been insufficient research and investigation into the full potential of such applications. Further engagement and collaboration between research centres, ICT developers and leading construction companies is necessary in order to fully establish the full potential of VR and AR applications, along with the identification of any possible challenges.

The main obstacle to introducing such innovative visualisation technologies is currently cost. However, the initial investment in hardware and software on a project could be recovered through increased inter-disciplinary collaboration, reduced staffing costs on smaller design teams, as well as shortened construction times. On the other hand, one of the greatest benefits of using VR and AR is their ability to facilitate a greater understanding of the multidisciplinary consequences of any planning, architectural or engineering decision, which would undoubtedly influence the successful outcome of any product; in this case, a building project.

Used independently during the construction process, VR and AR will not deliver any significant advantage – in order to get the most out of them, they need to be deployed in conjunction with BIM. Both visualisation technologies could be integrated with a BIM model in order to provide a potential user with the latest available project information, be this design data, installation or maintenance information. BIM offers a holistic approach to the whole life cycle of a project. VR and AR could definitely play a significant role here by improving multidisciplinary collaboration and integration between teams, adding an element of simplicity to the process of reviewing errors, identifying and solving potential issues and delivering the latest technical information, not only to a variety of project management teams, but especially to end users such as operatives and facility management teams.

**Acknowledgments**

This working paper is based on the MSc thesis submitted for the MSc and the Diploma of Imperial College London:

STARZYK, I., 2013. *Visualisation System Technology (Virtual and Augmented Reality in Construction Industry)*. , Imperial College London, Department of Civil and Environmental Engineering.

The authors are grateful for the support from both Imperial College London and Laing O’Rourke, in particular Professor David Fisk (Imperial).
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