# A review of the ‘smart technology’ currently being explored globally and its potential impact upon the construction industry on a micro level.


## Abstract

The following paper will review literature that covers the use of ‘Smart Technology’ and ‘Big Data’ in the context of Smart Cities currently being explored globally. By investigating into the perceived benefits of implementing the digital economy in to essential infrastructure the paper will look at how the construction industry can benefit. The literature covered found that through the adoption of Smart Technology within a Smart City framework there are benefits available for all industries; such as greater efficiencies and forecasting ability, resulting in savings. However the integration of real time data on-site could possess great potential for construction managers as they look to make more informed and accurate decisions. However the extents of the benefits are unclear as many pieces of literature state that the potential use of Big Data is almost unimaginable currently. Urbanisation is forcing city authorities to adopt more strategic approaches to their decision making processes which has resulted in the emergence of ‘Smart Cities’. Case studies around the globe have shown promising and innovative potential for a range of stakeholders. These are promising signs for the industry as it still seeks considerable investment and testing before it can be scaled up. However further work should look to investigate first-hand how construction managers could benefit from open source ‘Big Data’ collected by city authorities. This would add evidence to the many theoretical benefits that are possible.


**Keywords:** Smart Cities, M2M Interactions, Urbanisation, ICT Infrastructure, Sensor and Actuator Networks (SAN)


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# 1 Introduction

In 2013 the human race reached an unprecedented level of urbanisation (50% of the world's population now live in cities) with cities containing an increasingly large share of the world's highly skilled, educated and entrepreneurial population (Dirks et al. 2010; Nokia Solutions and Networks 2010). In reaction to this economic shift, city authorities have looked towards smarter and strategic approaches in order to react to this changing demographic (Dirks et al. 2010).

Smart City technology has been tipped by many to play a large role in reducing the environmental impacts of urbanisation (Nokia Solutions and Networks 2010). Literature has shown the use of ICT and Machine to Machine (M2M) interactions can impact upon key industries such as education, healthcare, transport, real estate and utilities, by becoming more 'aware, interactive and efficient' (Hernández-Muñoz & Vercher 2011). There are reports suggesting that by 2020 ICT efficiencies will translate into a global financial savings of €600 billion (The Climate Group 2008). A 'Smart City' has been defined as when investments in human and social capital along with traditional (transport) and modern (ICT) communication infrastructure fuels sustainable economic growth and a higher quality of life (Schaffers et al. 2011). The digital economy is suggested to possess huge potential which is driven by the recent advances in Sensor and Actuator Networks (SAN) along with rising broadband penetration (Hernández-Muñoz & Vercher 2011; Schaffers et al. 2011). However it is important that city authorities implement strategic initiatives that will promote this practise whilst sustaining a viable long term business model (Schaffers et al. 2011; Dirks et al. 2010).

It is anticipated that further collaboration of 'real-world' urban data will improve the understanding and ability to forecast flows whilst pushing the intelligence of cities forward (Schaffers et al. 2011). There is currently a large amount of live research regarding the distribution of ICT and M2M infrastructure on a large city scale; this naturally carries several barriers i.e. up scaling.

The following paper will comprise of several case studies and literature to show examples of potential areas where the theory behind 'Smart Cities' can be applied on a micro/project based level. Whilst exploring the potential relationships between an open source stream of data from ICT infrastructure and a construction site. Typically a project manager or site manager will consider transport to and from the site, resource allocation and distribution, management of waste and its implications to local inhabitants, performance measuring/benchmarking, site security and hazard awareness. All of which are potentially measurable and the sharing of such information with a local authority could aid planning and efficiency along with potential time and cost savings.

# 2 Smart Cities

Recently the number of people living in urban environments has just exceeded that of rural areas for the first time – shown in figure 1(The Climate Group 2008; China Development Research Foundation 2010). Reports suggest that by 2050 70% of the world's population will inhabit urban cities (China Development Research Foundation 2010). This changing demographic has forced city authorities to become more strategic in order to compete.

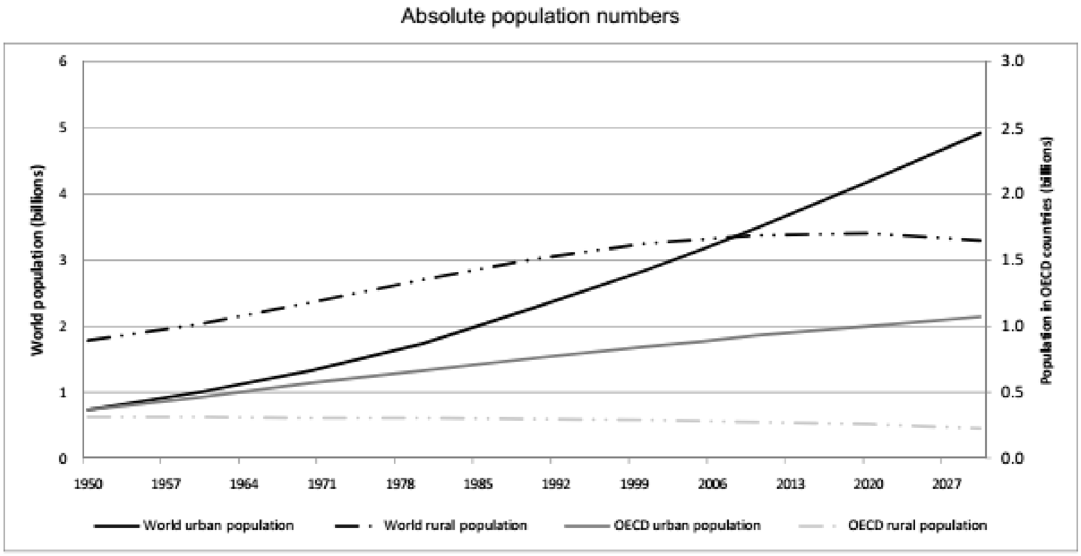


*Figure 1: Urban and rural population in the world and the OECD (1950-2030) (China Development Research Foundation 2010)*

Traditionally the focus for ICT innovation has been on the penetration and implementation of broadband infrastructure (Schaffers et al. 2011). However this is changing as attentions are pointing towards enhancing the quality of life for citizens (Schaffers et al. 2011). As mentioned in section 1, a Smart City represents a city that strategically integrates technology into sustainability, citizen well-being and economic development (Vilajosana et al. 2013; Schaffers et al. 2011; Hernández-Muñoz & Vercher 2011). The Smart City market is estimated to become worth €600 billion by 2020, a lucrative market for potential investors (Vilajosana et al. 2013; The Climate Group 2008). Through improved efficiencies, emission savings of approximately 7.8 $GtCO_2e$ can be achieved by 2020 globally (The Climate Group 2008). Attached to the aforementioned point; the production and collection of 'Big Data' is a promising field for exploitation (Vilajosana et al. 2013) a point explored later in this paper. Furthermore Smart Cities have the potential to create a new generation of services that cannot even be envisaged currently (Hernández-Muñoz & Vercher 2011) – a positive view`, however one that carries uncertainty.

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*"Investments in making a city's core systems smarter will create cost savings and increased efficiencies whilst positioning it for long-term economic growth."*

*(Dirks et al. 2010)*

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## 2.1 Barriers

The idea of a ‘Smart City’ has strong societal, industrial and political drivers; however large investments are not of abundance yet; barriers to the introduction of Smart Cities are (Vilajosana et al. 2013):

- Laborious Policy Change
- Limited Capital Availability
- ‘Piecemeal’ Funding Structures
- Future Political Uncertainty

European Union grants are funding the first run of trials which not only contain financial and political barriers but also geographical (Vilajosana et al. 2013). The dispersed nature of these small scaled projects is seen as a risk by investors, therefore a barrier to ‘up scaling’ (Vilajosana et al. 2013). Schaffers et al. (2011) devised a two stage approach required to successfully create a Smart City. Firstly a sufficient amount of broadband infrastructure along with a large amount of embedded sensors and smart devices are needed. These systems will need to be coupled with applications capable of collecting and analysing vast amounts of real time data. Finally, encouragement of large scale participation in the innovation process of applications (Schaffers et al. 2011). This will be required to explore the wide range of benefits to different sectors across the city. The range of key application areas of ‘big data’ are shown in figure 2.

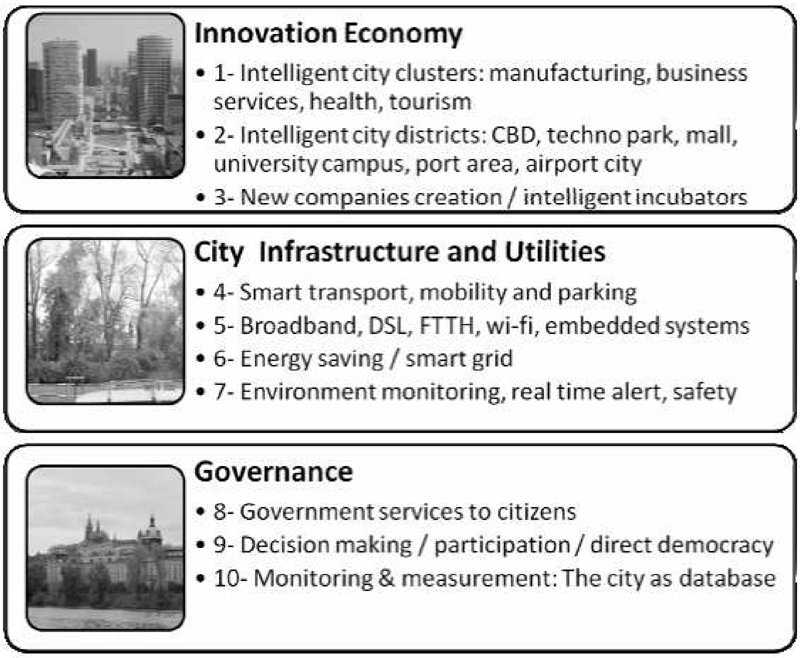


*Figure 2: Application areas for Smart Cities (Schaffers et al. 2011)*

# 3 Smart Technology

Thanks to recent advances in computing efficiencies, sensor technology and energy storage there is currently a push towards Smart Technology; a new breed of devices that are small, cheap and are so low power they can operate for long periods (Koomey et al. 2013; Hernández-Muñoz & Vercher 2011). Smart Technology has the potential to vastly improve our capability to observe and react to the environment around us (in this context cities) (Koomey et al. 2013). A key characteristic of Smart Technology is that the amount of computing carried out by a single sensor is negligible, however collectively as part of a system real value can be delivered through live data (Koomey et al. 2013). Furthermore relatively small amounts of electricity used within Smart Technology can have large effects when used within big systems (Koomey et al. 2013). A simple example could be washing machines; the tiny on-board sensors and computer technology make savings in hot water and motor use resulting in large net energy savings (Koomey et al. 2013). This example shows in theory how Smart Technology ties in with the idea of Smart Cities.

When designing M2M networks comprising of sensors; wireless interactions are cheaper to install and offer greater flexibility as opposed to more traditional wired networks (Koomey et al. 2013). By using a network of many devices the energy required to deliver signals is considerably smaller; constrained to distances of around 10m – the energy requirement increases as the square of the distance (Koomey et al. 2013). A point that supports the use of Smart Technology on a construction site.

It is important to note that the adoption of Smart Technology is not a substitution for traditional manual methods; as demonstrated by Cheng & Teizer (2013), new approaches and technologies are more support mechanisms.

This section has primarily covered M2M networks and sensor technology which will typically measure light, temperature and pollution (Kramer 2013). However there are other sources for data, such as; personal sensors like Fitbit and Up wristbands which record location, activity and physiology of a user (Kramer 2013). Open source social media such as Twitter and blogs are home to a vast array of searchable live data (Kramer 2013). Crowd-source monitoring of infrastructure status or condition is also possible through the use of ‘smart phones’ and applications (Kramer 2013). Even older technology such as RFID tags to monitor flows of citizens and vehicles could be further utilised and collaborated (Kramer 2013). The benefits of such infrastructure would be the monitoring, management and optimisation of live data for example the management of traffic flow or the notification of pot holes in roads (Kramer 2013).

This section has not delved into much technical detail; however it is clear from the literature that the advancement of sensor technology and ICT in recent decades has driven the Smart Cities agenda and opened an array of new opportunities. In summary both Koomey et al. (2013) and Hernández-Muñoz & Vercher (2011) have highlighted that applications of Smart Technology within the context of a Smart Cities cannot be completely comprehended, there is a huge amount of potential for growth.

## 3.1 Big Data & IoT

Big Data has been labelled the ‘new buzz word’ for the technology industry; there is also a range of conflicting definitions however the following one is very applicable to Smart Cities:

*“Big data is a collection of data from traditional and digital sources inside and outside your company that represents a source for ongoing discovery and analysis.”*

*(Arthur 2013)*

In the context of Smart Cities the production of Big Data is something that several pieces of literature see as a new area for exploitation that posses’ large potential (Schaffers et al. 2011; Koomey et al. 2013). The ability to collect live data and analyse it on a city scale will help improve the ability to forecast and manage urban flows, making cities more intelligent (Schaffers et al. 2011).

Additionally the term Internet of Things (IoT) is commonly used in conjunction with Smart Cities and Big Data. The IoT refers to the use of Smart Technology in a network that communicates, changing the way that decisions are made. The following definition is used by Cisco an American multinational corporation that manufactures and sells networking equipment:

*“The Internet of Things (IoT) is the network of physical objects accessed through the Internet, as defined by technology analysts and visionaries. These objects contain embedded technology to interact with internal states or the external environment. In other words, when objects can sense and communicate, it changes how and where decisions are made, and who makes them.”*

*(Cisco Systems 2013)*

Hernández-Muñoz & Vercher (2011) reported that the IoT brings not only greater efficiencies and accuracy but also through creating an ‘open innovative platform’ future applications can be conceived. Something of importance to the European Union as it seeks for a homogenous platform to encourage scalability across the continent (Hernández-Muñoz & Vercher 2011).

In summary the IoT and Big Data are key components to the ideology of Smart Cities; however Koomey et al. (2013) highlighted the importance of adapting and developing how data is perceived and analysed.

# 4 Case Studies

## 4.1 Santander, Spain

Frayer (2013) reported on the Smart City pilot project initiated in 2010 by the European Commission within the small Spanish port of Santander. An $11 million grant to implement 12,000 sensors with many underground to measure everything from pollution levels to free car parking spaces illustrated in figure 3 (Frayer 2013; Kramer 2013). The project integrated the IoT and smart sensors into many forms of infrastructure along with applications to engage the citizens of the city.

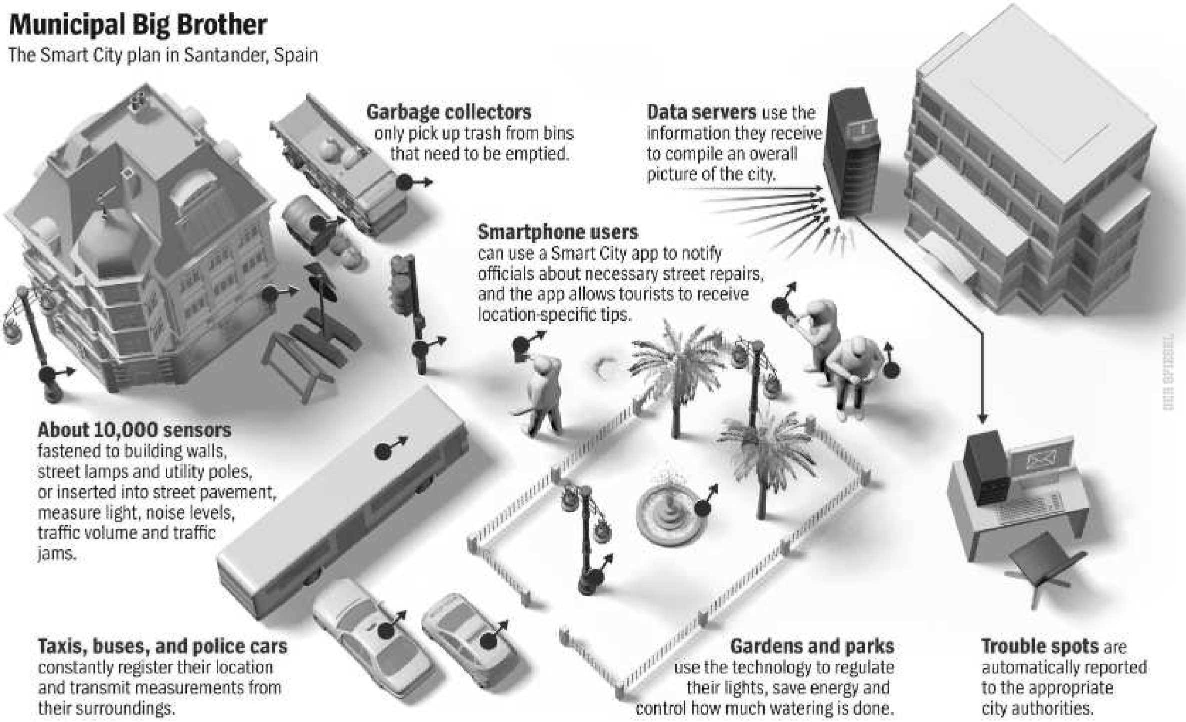


*Figure 3: Info graphic of Santander Smart City Case Study (National Geographic 2013)*

Since its introduction the project has received constant feedback via social networks such as Twitter as how to enhance the experience and lives of the citizens. As a result, the city of Santander has seen reductions of 25% on electricity bills and 20% on municipal waste – it is also important to note that utility companies foot the bill for life cycle maintenance of sensors due resultant money savings. Such an interactive IoT opens commercial revenues that may not have been possible otherwise; such as a 75 year old shoe shop ‘Benito’s Shoes’ has a ‘Smart Santander Sticker’ on its window (Frayer 2013). This interactive sticker allows shoppers to instantly access the shops website for online shopping during out of hours – something that has shown real potential and use.

## 4.2 Los Angeles, United States of America

Similar to Santander the authority of Los Angeles, United States of America have gone into partnership with Xerox Research on a pilot project to implement a range of sensor technology. Bisson (2013) explains how like many cities around the world Los Angeles is experiencing citizens moving out of the city centre to suburbs, which is having direct impacts of the types of transport being used. The authorities have ambitions to attract citizens back to the city centre for leisure however they face an issue with parking (Bisson 2013) – this is where both 'Smart Technology' and 'Smart City' thinking apply.

There were 7,000 sensors deployed which monitor car space usage; figure 4 illustrates the usage, showing the peak or hot zones (Bisson 2013). Firstly the visualisation of such data is useful for city planners; however by manipulating this Big Data further real application can be developed.

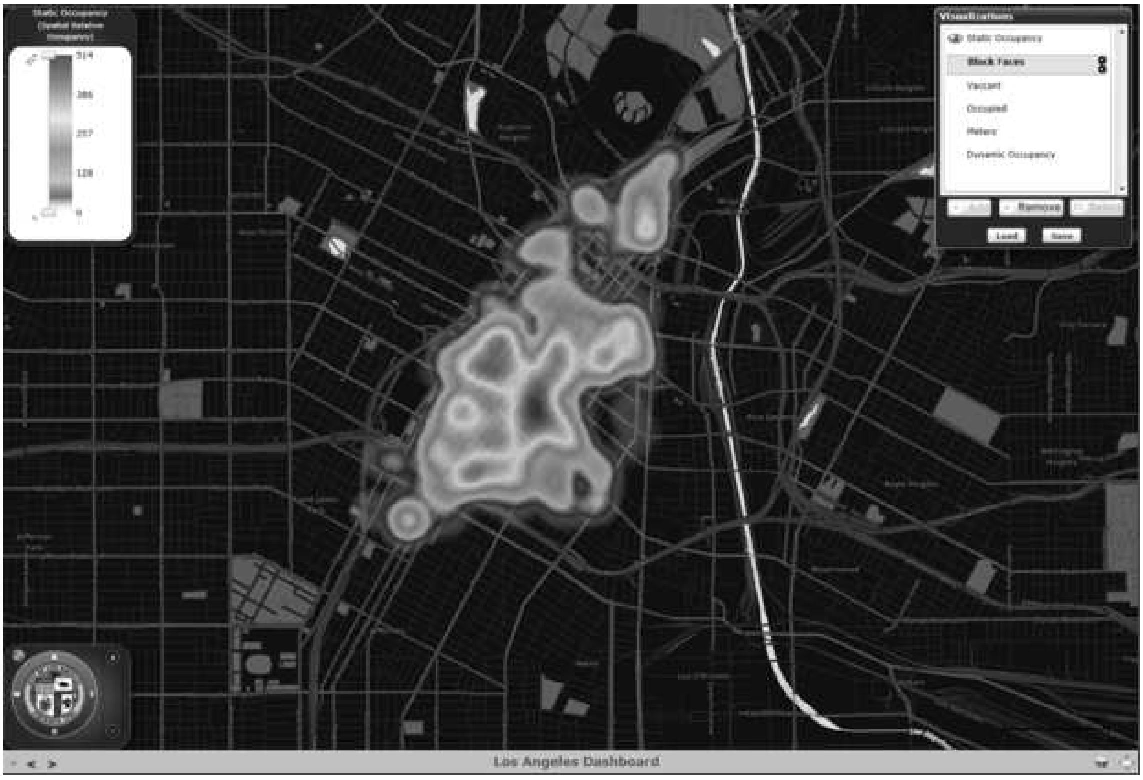


*Figure 4: Car Park Usage in Los Angeles, USA (Bisson 2013)*

This pilot project has taken this data and attached it to a dynamic pricing model, allowing for the prices of parking to be manipulated depending on availability. For example, to encourage usage into areas of low demand prices will be reduced and to discourage usage in high demand areas prices will be increased. The hope of such a project is to influence the parking behaviours of citizens and also to monitor certain areas of the city that could be further designed to improve quality of life.

The final step of this project is the availability of this information to the public through the use of ‘smart phones’ and applications; this allows for great interaction and feedback between the user and authority. This pilot project is a prime example of Smart Cities allowing both authorities and users to make better, more informed decisions which result in greater convenience and improved quality of life (Bisson 2013).

# 5 Future Trends & Relationships

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*“What is happening at an urban scale today is similar to what happened two decades ago in Formula One auto racing. Up to that point, success on the circuit was primarily credited to a car’s mechanics and the driver’s capabilities. But then telemetry technology blossomed. The car was transformed into a computer that was monitored in real time by thousands of sensors, becoming intelligent and better able to respond to the conditions of the race. In a similar way, over the past decade, digital technologies have begun to blanket our cities, forming the backbone of a large, intelligent infrastructure.”*

*(Kramer 2013)*

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The following section will address the future relationship between the construction industry (micro level) and the Big Data (macro level) use of Smart Technology and their collaboration. From the perspective of a construction site manager there is improved capability to make more effective and efficient decisions both on and off site (Cheng & Teizer 2013). Through further integrating on site operations with that of the wider environment through Big Data, site managers can enhance and improve decision making.

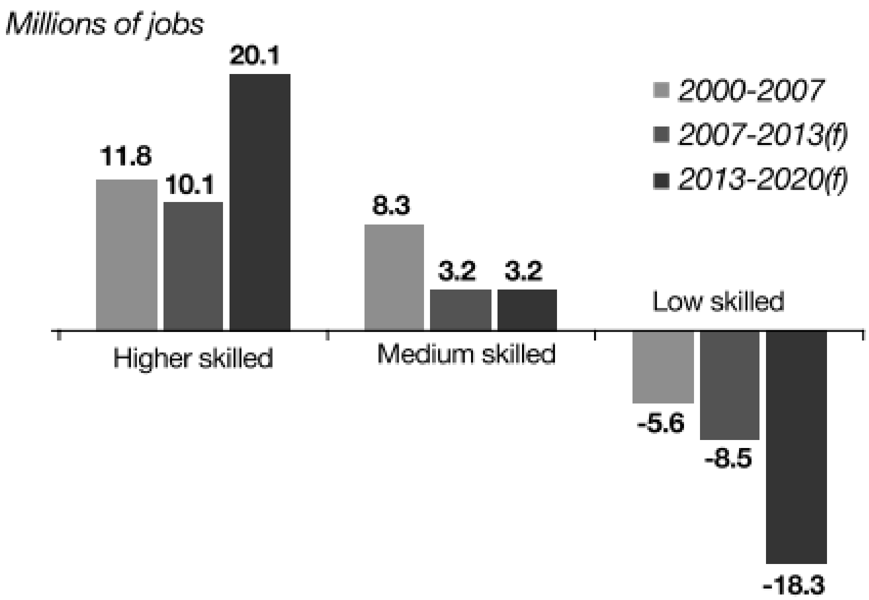


*Figure 5: Changes in demand for skills in European Union (Dirks et al. 2010)*

Virtual Reality (VR) technology has been used commonly on construction sites to aid project management and the spatial planning of resources (Cheng & Teizer 2013). However one particular relationship that` has not been explored is one between onsite VR and real time data from surrounding infrastructure, for example on site waste management and local waste services. Construction managers would potentially have the capabilities to coherently integrate known wastage from construction of their site into local collection services through collaboration and communication. Aside from the technical advances of ICT and their potential to improve efficiencies and the intelligence of cities, there are important social impacts of such change. Dirks et al. (2010) explained that a consequence of urbanisation would lead to greater competition between cities to attract skilled workers. Figure 5 illustrates how currently in Europe there is a growing demand for higher skilled workers; a driver for further competition (Dirks et al. 2010). Further to this trend it is also important to retain this desired demographic as well simply attract (Dirks et al. 2010; Schaffers et al. 2011). This is achieved through the creation of a sustainable policy structure along with a viable business model in order to attract investment both from the public and private sectors (Schaffers et al. 2011). This demographic change with have a knock on impact to the construction industry within these cities; it is of benefit to construction organisations to be based within cities that have the capability to attract and retain a skilled labour force. Dirks et al. (2010) reported that in order to successfully attract and retain a skilled labour force, city authorities must improve ICT infrastructure, analytics and take a more citizen centric approach to services. However in contrast to attracting a highly skilled labour force, Kramer (2013) highlighted the potential for citizens to feel at risk of privacy invasion; this is a barrier avoided by reassuring anonymity.

# 6 Conclusion

The above paper has highlighted the range of benefits that Smart Technology can have upon the efficiencies and management of Smart Cities. The range of applications of this emerging trend is not entirely clear yet; however it is clear that the construction industry is well placed to exploit these technologies. Construction managers will have the capabilities to adopt a more coherent and proactive approach to project management allowing for greater efficiencies and performance. It is important that both the construction industry and city authorities look to the future at emerging trends in order to benefit from changing market conditions, a point echoed by Dirks et al. (2010).

A particular challenge for Smart Technology and Smart Cities is the scaling up of projects and the platforms used to handle and analysis Big Data. Therefore it is a suggestion of this paper to further collaborate with current projects to begin planning towards adopting what may become a very diverse market of different software packages.

Under future work it is suggested that further research into current live projects would be beneficial, looking particularly at exactly how Big Data could be used to benefit a construction site manager. First hand exploration of that relationship would provide a good basis for further direction for research within this field. Reports have given theoretical examples of how the construction industry would benefit, however there is little to no actual evidence to support these claims.

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