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DIFFUSION OF INNOVATIONS: AN ASSESSMENT OF BUILDING INFORMATION MODELLING UPTAKE TRENDS IN SOUTH AFRICA

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ABSTRACT

Building information modelling (BIM) is currently being adopted by the South African industry, although current uptake is lagging behind other countries. The construction industry internationally is realising the benefits of using a single source of construction information, and the increasing functionality of the hardware, software and connectivity is providing an environment for the different organisations involved with a construction project to collaborate. The study evaluates adoption in South Africa and other countries using the line of enquiry known as the 'diffusion of innovations' to determine a trend in South Africa and to predict rates of adoption based on those of other countries. Factors that inhibit take-up in South Africa are examined and recommendations are made based on the findings of the research.

Key words: Adoption, BIM, collaboration, diffusion of innovations, single information source

1. INTRODUCTION

The construction industry literature increasingly refers to collaboration between the parties involved with a construction project. Building information modelling (BIM) is seen by many commentators as the system that allows for a more collaborative working environment. While the BIM phenomenon has been around for over two decades it is only recently being adopted on an industry wide scale and commentators have noted how the construction industry is slow to adopt change. Suermann (2009) suggests that the construction industry is not optimising the pace of implementation of the technology. Typically, architects that have adopted BIM solutions use it for developing visualisations, drawings and schedules, while it is not generally used as a cross-disciplinary information sharing data-base.

The use of BIM is increasing in South Africa. However, it is being used in an isolated environment and is not being used as a collaborative tool.

Other countries are increasingly using BIM for innovative approaches to construction relationships, which is likely to give them a competitive advantage in an increasingly globalised economy.

The approach to the research was quantitative in nature and the data were extracted from the results of two surveys, conducted electronically and aimed at South African contractors and architects. The results were analysed and compared with independently conducted surveys in other countries that examined BIM adoption rates. The adoption rates were viewed in terms of the line of enquiry known as the 'diffusion of innovations' to predict trends in South Africa.

2. LITERATURE REVIEW

2.1 Building Information Modelling

A building information model (BIM) is a computer simulation of a building. Hardin (2009) gives the following definition:

"BIM is a digital representation of the building process to facilitate exchange and interoperability of information in digital format."

Lee, Wu, and Aouad (2007) use the term nD to suggest the multi-dimensional aspect of BIM, as it can be used for design, analysis, construction, management, maintenance and operations. Krygiel (in Hardin, 2009) observes that workflows aligned to better visualisation, better building metrics and improved analysis are changing the way the industry communicates and designs buildings. Previously, information was exchanged using two dimensional ideas on paper. BIM produces three dimensional virtualised buildings that contain vast amounts of information. This allows for an unprecedented amount of knowledge and control over the building before work starts on site. Lee, Wu, and Aouad (2007) state that the success of construction undertakings depends on the ability of the stakeholders to consider and communicate multi-disciplinary concerns, constraints, goals and perspectives. They remark that this needs to occur in a 'timely, economical, accurate, effective and transparent way'. They suggest that multi-dimensional modelling (BIM) is possibly the most promising tool and method available to address this challenge. The BIM database and collaboration software allow for a single point where construction project organisations (CPOs) input and extract information. This allows for a simpler knowledge management mechanism and facilitates CPO collaboration.

An exploratory study conducted in South Africa (Smallwood, Emuze, & Allen, 2012) found that there is limited use of BIM in South Africa. The study also suggested that architects view BIM as having its main potential during the design stage. This suggests that architects use BIM in an isolated environment, as the full functionality of BIM can only be exploited if it is used throughout the project in a collaborative environment. The accelerating advance of both hardware and software is changing the way the industry works, allowing for a collaborative approach more so than was previously possible.

However, adoption rates in South Africa lag behind other countries that are implementing BIM. Industry stakeholders need to be aware of these trends in order to remain competitive in a changing environment.

2.2 BIM adoption in other countries

While commentators have noted the use of BIM to replicate traditional processes, Race (2012) discusses the drive in other countries to adopt BIM in conjunction with collaboration, and how it is actively being encouraged by major clients and government bodies. He refers to the National 3D 4D BIM program additional BIM Guide Series, issued by the Office of the Chief Architect in the USA. Race (2012) recalls that in 2010 the UK's chief advisor on construction indicated that BIM would play a key part in the government's procurement strategy. He suggests that the government's lead in incorporating BIM could have a significant shift in the way that the UK construction industry operates. Gibbs, Emmitt, Ruikar and Lord (2012) also comment on how BIM has gained more interest due to the UK government's drive to use it on all public sector projects by 2016.

It has been noted that the UK construction industry is becoming a leader in the implementation of BIM (Race, 2007). The government's current chief construction advisor in the UK, Peter Hansford (BIM Task Group, 2013), predicts that beyond 2016 no government intervention will be required for government funded projects to use BIM. The current drive will provide a kick start. The Chair of the BIS (Business Innovation and Skills), Dr Barry Blackwell (BIM Task Group 2013) notes that their programmes are being commented on around the world and that the approach is improving the image of the construction industry, both nationally and internationally. He says that the 'genie is out the bottle' and that innovation will be relatively swift with the new technology. Standing still in the new environment will mean going backwards, as other countries will 'leap-frog' the implementation of BIM in an increasingly global environment. Countries will not remain globally competitive without embracing the new technology and that these opportunities will erode the domestic insulation from global companies. He believes that the UK government's current drive will give them a competitive advantage.

The UK government's BIM strategy paper (HM_Government, 2012) also comments on the rapid uptake of BIM in other countries and that developing markets may be able to 'leap frog' using innovative technologies and methods of working. They note that in China the government is fully supportive of using BIM and that BIM will be the future information technology solution in China. Wang (2012) notes that in 2012 the Chinese government's Ministry of Housing and Rural Urban Development released several BIM related national standards programmes. In Australia, the Built Environment Industry Innovation Council identified two key recommendations on BIM. The first is to encourage industry wide adoption and support and the second is to consider BIM as a key part of the government's procurement process.

Takim, Harris and Nawawi (2013) note that BIM is being adopted at the national level in many countries around the world, including Hong Kong, Singapore and South Korea. They state that Finland is the world leader with regard to BIM implementation.

Norway has also created a national standard for using BIM (Statsbygg, 2011). These findings contrast with South Africa, where there is no national or industry led drive to adopt BIM.

2.3 The diffusion of innovations

Rogers (1983) discusses what he has called the 'diffusion of innovations' and shows how an innovation takes some time to spread, even if it is objectively better. He refers to the 'diffusion effect' where the rate of adoption of an innovation creates self-generated pressure towards adoption. As there is more take-up of an innovation, more awareness is generated through peer networks, which increases the rate of take-up. Once adoption of the innovation has reached 50% the rate of adoption starts to slow, as the awareness levels with regard to the innovation become widespread throughout the adopting group.

Adoption levels are related to the amount of information that an individual has with respect to the innovation. Where there is not much knowledge about the innovation, any single individual is unlikely to become an adopter. However, as the knowledge of the innovation increases, it passes a threshold level where adoption starts to take place. There is a relationship between the amount of knowledge and the adoption rate of an innovation, but it is not direct or linear. When the awareness rate advances to between twenty and thirty percent, adoption rates are low. Once the threshold has been passed, there is increasing adoption, where every percentage point of increase in awareness relates to an increase in adoption of several percentage points (Rogers, 1983). Rogers notes that the threshold is different for every innovation, but appears to happen when opinion leaders start to favour the innovation.

Rogers discusses categories of adopters and how they are distributed. Adoption of an innovation is based on a normal (bell) curve and one method of dividing adopters into categories is by using the mean of the sample and the standard deviation. Using this method, categories of adopters are derived and shown in Figure 1. Innovators then fall into the first category, which is two standard deviations below the mean. Early adopters fall into the second category, which is between one and two standard deviations below the mean. The early majority fall between the mean and one standard deviation below the mean, while the late majority fall between the mean and two standard deviations. Rogers (1983) suggests that there is no point in categorising the laggards as there is no clear distinction between what may be classified as early and late laggards. Rogers (1983) states that adoption rates of between 10% and 20-25% represent the heart of the adoption process. After this point it becomes difficult or impossible to stop the further diffusion of the idea.

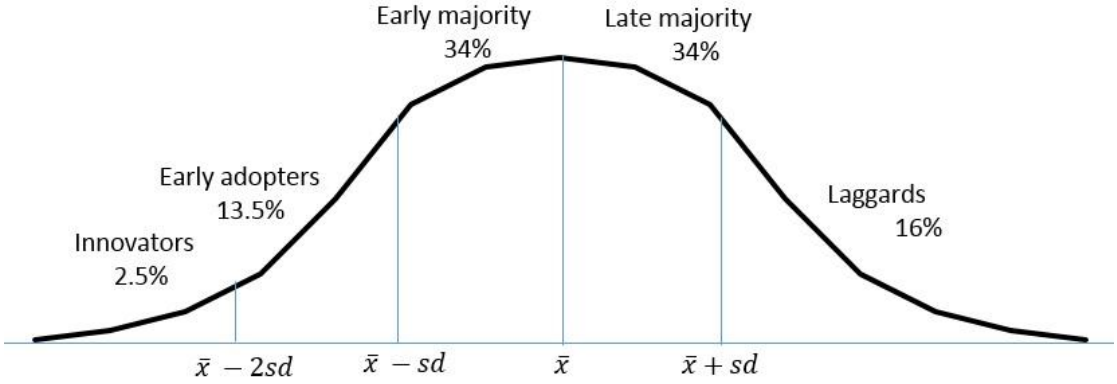

Figure 1: Innovation diffusion categories (Rogers, 1983)

Wejnert (2002) shows that there are a number of factors that influence the adoption of an innovation. She discusses two consequences of innovation adoption, being public consequences (such as the national adoption of a new education model) and private consequences (where the adoption only directly influences the individual). It can be seen that the adoption of BIM has both public and private consequences, as the technology can increase productivity for the individual organisation, and also play a positive role for the industry and country, due to increased productivity and efficiency for private and public projects.

Wejnert (2002) discusses the environmental factors that affect adoption. These include geographic setting, societal culture, political conditions and globalisation and uniformity. It is observed that in other countries there is a national and industry level drive to implement BIM, whereas in South Africa, political conditions are inhibiting the adoption of BIM, due to the requirement for a single stage tendering arrangement, with separate bids from different organisations that are involved in the project. While other countries are implementing regulations to ensure the use of BIM and implementing programmes to increase awareness, there is no such effort in South Africa. This could affect the rate of BIM adoption in South Africa.

Although the BIM concept has been around for over twenty years (Merschbrok & Munkvold, 2012), its ability to be used as a collaborative tool is a recent phenomenon, due to increased software, hardware and connectivity advances. Recently, cloud based BIM environments (Autodesk, 2013) can substantially improve the platform for collaboration, as the model can be accessed from any location. It can be seen that the technological platform for efficient IPD is a recent phenomenon. Schumpeter (1962) introduced the economic theory of creative destruction, which shows how new technologies tend to replace old technologies. He suggests that the capitalistic or free market environment is constantly evolving and destroying the systems or structures that are being replaced.

Cox and Alm (2008) discuss the concept of creative destruction and observe that the survival of producers depends on their ability to streamline production by introducing newer and better tools that increase productivity. Companies that do not deliver consumer requirements at competitive prices will lose customers and die.

3. RESEARCH METHODOLOGY

The purpose of the surveys was to determine the extent to which IPD technologies are currently being used by the construction industry in South Africa. These results were then compared to the uptake of these technologies in other countries that were examined in the literature review.

3.1 Precedents

In order to gather comparable results, the questions were aimed at gathering similar information to that available from other countries. The McGraw-Hill survey has done extended research on BIM use in Europe and the USA.

Three recent precedent studies are relevant to this research in order to compare the South African environment with those of other countries. The first is a survey conducted by the NBS in the UK in 2011 which analysed current BIM use and perceptions of architects. The second is a McGraw-Hill survey that compares the UK and USA markets and looks at BIM use and perceptions, expertise levels and take-up among architects, engineers and contractors, conducted in 2010. A subsequent survey by McGraw-Hill was conducted in the USA in 2012.

3.2 Survey questionnaire

The question types that were used in the surveys were generally closed-ended multiple choice questions, although there was also an opportunity for respondents to answer an open-ended question should they have had further information to add.

The following section shows the results of two surveys that examined different aspects of the use of BIM in South Africa. The survey were sent to all contractors in the top three grades in the general building category in South Africa and architects, predominantly from the Eastern and Western Cape, due the difficulty in gaining contact information for the other regions. The following section looks at relevant parts of the results from the two surveys.

The surveys were set up in an electronic format that could be accessed over the internet. Separate covering emails were sent to contractors and architects, with links to industry-specific surveys. A total of 612 links were sent, after removing the invalid email addresses. A total of 118 responses were received, representing a response rate of 19.3%. Contractors responses amounted to 52 (15.5%) and architects returned 66 (24.2%) responses. Due to the difficulty in obtaining architects contact details for some regions, and the lack of assistance from the regional institutes, the survey targeted architects from the Eastern and Western Cape, where contact details were readily available. This represents a weakness in the study, although a similar survey in the USA did not show much regional variation (McGraw-Hill, 2012: 9).

3.3 Survey findings

The survey results were analysed and the findings are presented below. The survey for architects was different to the contractor's survey, but where relevant, the same questions were asked in both surveys. An initial observation was the substantial difference in the response rates for the surveys, where a similar method of notification and delivery was used. The difference is potentially attributed to the awareness levels of the two different groups, where architects were substantially more aware than contractors of the BIM concept. This may have encouraged more architects to respond to the survey.

3.4 Awareness of BIM

It was seen that there is a substantial contrast between architects and contractors when it comes to BIM awareness, with less than a quarter of architects (21%) not being aware, against nearly three quarters (73%) of contractors not being aware of BIM. 58% of architects considered that they were familiar with, or had a fair understanding of the BIM concept, compared to only 10% of contractors that were familiar with, or had a fair understanding of BIM.

The use of BIM by South African architects can be compared to the findings of a survey conducted in the UK in 2011, where 58% of architects were aware of BIM (NBS, 2011). Architects may be more familiar with BIM as they are more likely to use it due to the time savings that BIM offers during the design stage. Trends for contractor BIM awareness can be compared with a study conducted in the USA, which showed that contractors are becoming increasingly aware of BIM, with a higher adoption level than architects or engineers (McGraw-Hill, 2012). A study conducted in Europe in 2010 (McGraw-Hill, 2010) reported that 24% of contractors had adopted BIM in Europe (UK, Germany and France). The survey does not report on awareness of BIM, but it is likely that the figure for awareness of BIM is higher than the adoption rate. The researchers predicted that contractor adoption rates would rise substantially in the following two years, based on the findings of the surveys conducted in the USA.

3.5 Use of BIM

Most architects (54%) use some form of BIM, and 15% of architects work exclusively in a BIM environment. As with awareness, contractors' use of BIM is limited in South Africa, with only 12% having used some form of BIM and none that use BIM for all projects.

The results were compared with surveys conducted in other countries. The first is the McGraw-Hill survey, conducted in 2010 (McGraw-Hill, 2010) which compared findings in Europe (France, Germany and UK) with findings from the USA. 36% of the Western European countries' construction industries had adopted BIM (2010), compared to 49% in the USA (2009). This was compared to a prior study in the USA (2007) where there had been a 28% up-take. A further survey by McGraw-Hill (McGraw-Hill, 2012) found that this had increased to 71% in 2012 in the USA, which illustrates how fast BIM is being adopted.

The second survey was conducted by the NBS group for the Royal Institute of British Architects (RIBA) in 2011 and surveyed construction industry professionals on BIM (NBS, 2011). The professionals that were surveyed included architects, engineers, quantity surveyors and building surveyors, with the majority of respondents involved in architectural practices. Contractors were not included in the survey. The survey did not differentiate between the different professions of the participants and found that 13% of participants had adopted BIM. This contrasts with the findings of the McGraw-Hill survey (McGraw-Hill, 2010) where 36% of the industry had adopted BIM. The reason for this discrepancy is not known, but might be attributed to the fact that contractors were not included in the survey and that the McGraw-Hill surveys did not survey other industry professionals, such as quantity surveyors.

3.6 How long have users been using BIM?

The question was raised to determine how long current users had been using BIM. The results could then be compared to other countries and were also used to determine a trend line of BIM take-up in South Africa.

The results showed that a number of architectural practices had used BIM for more than five years and that there had been an increase in adoption recently. The trend line generated from the data (Figure 2) shows how the use of BIM has increased substantially in recent years and compares favourably with other countries, which are superimposed on the graph.

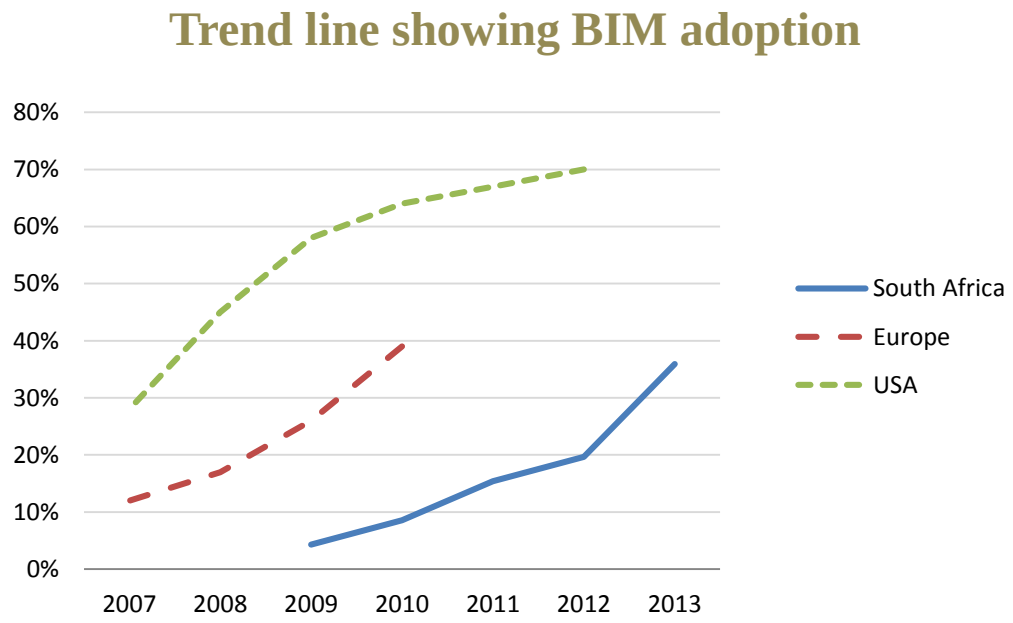

Figure 2: BIM adoption

Rogers (1983) refers to the 'diffusion effect' where the rate of adoption of an innovation creates self-generated pressure towards adoption. Once adoption of the innovation has reached 50% the rate of adoption starts to slow, as the awareness levels with regard to the innovation become widespread through the adopting group.

It is seen that the adoption curve for the USA is now starting to flatten, which indicates that adoption has reached the late majority stage on the curve shown by Rogers (1983). Western Europe was in the early majority stage in 2010, while South Africa has now entered the early majority stage. This is illustrated in Figure 3.

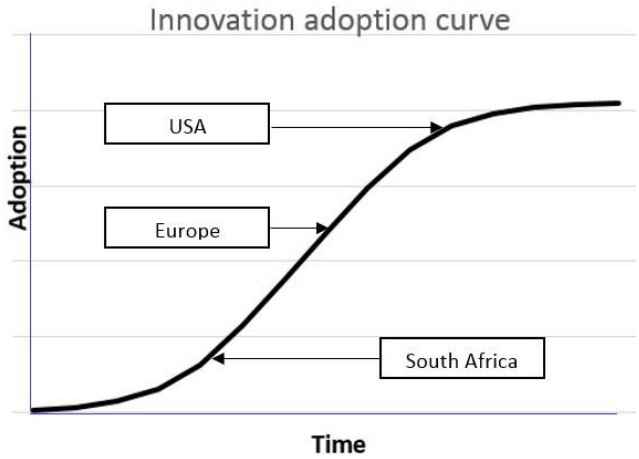

Figure 3: Adoption of BIM

South African BIM awareness and adoption can be compared with the adoption categories. The innovation adoption distribution is shown again in Figure 4 with BIM awareness and adoption rates plotted on the graph. It can be seen that South African architects fall into the early majority with reference to BIM adoption (53%) and the late majority for BIM awareness (79%). Contractors fall into the early majority with respect to awareness (27%) and the early adoption category for adoption (12%). Rogers (1983) notes that once awareness levels reach about 30%, adoption of the innovation starts to occur significantly faster, and once adoption rates reach 20-25%, the diffusion of the innovation becomes difficult to stop (Rogers, 1983). This suggests that BIM adoption within architectural organisations is well underway and the trend is likely to gain momentum. The awareness rate for contractors suggests that the adoption rates of contractors are likely to start gaining momentum.

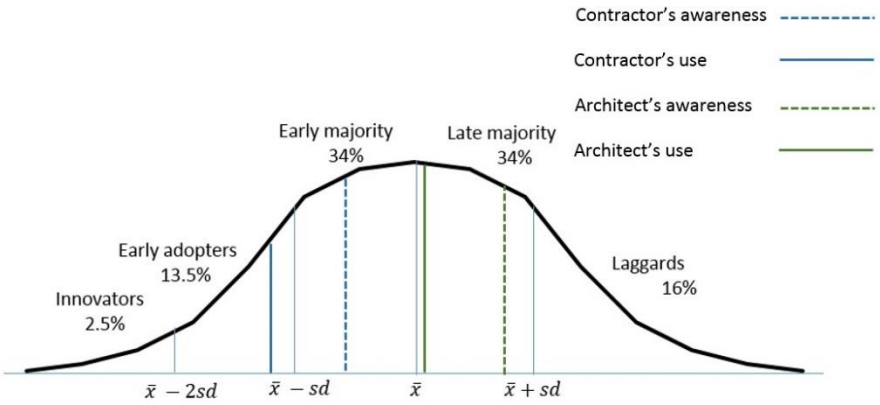

Figure 4 Innovation adoption curve (Rogers, 1983)

When the results of the survey are compared with the adoption rate of innovations discussed by Rogers (1983), it can be seen that while the USA is in the late majority stage of adoption, South Africa is in the early majority stage of adoption for architects, while contractors are in the early innovators stage of the adoption curve. The trend seen in the USA suggests that BIM take-up in South Africa is likely to increase and will soon be in the late majority stage for architects and the early majority stage for contractors.

Combined BIM use between architects and contractors in South Africa is 35%, suggesting that South Africa is about five years behind the USA and about three years behind Western Europe with respect to BIM adoption.

3.7 What do users use BIM for?

Architects that used BIM were asked about the functions that they used and what functions would be improved by using BIM. It was observed that architects use BIM predominantly for its drawing, visualisation and conceptual design functions. A third of respondents indicated that BIM is being used to collaborate with other consultants. Nearly a third (30%) of architects use BIM for scheduling while a minority are using it for more advanced features such as analysis, programming, costing and collaborating with the contractor. The results are shown in Figure 5.

3.8 Processes that are perceived to be improved by BIM

Architects were asked which processes were perceived to be improved by using BIM. The results confirm that BIM is primarily seen to improve early conceptual design, visualisation and drawing production. However, a substantial percentage believes that BIM will improve collaboration with other consultants (37%). Some architects indicate that collaboration with the contractor is improved by using BIM, while a minority believe the more advanced features, such as analysis (24%), extracting quantities (16%) and project programming (10%) are improved by using BIM.

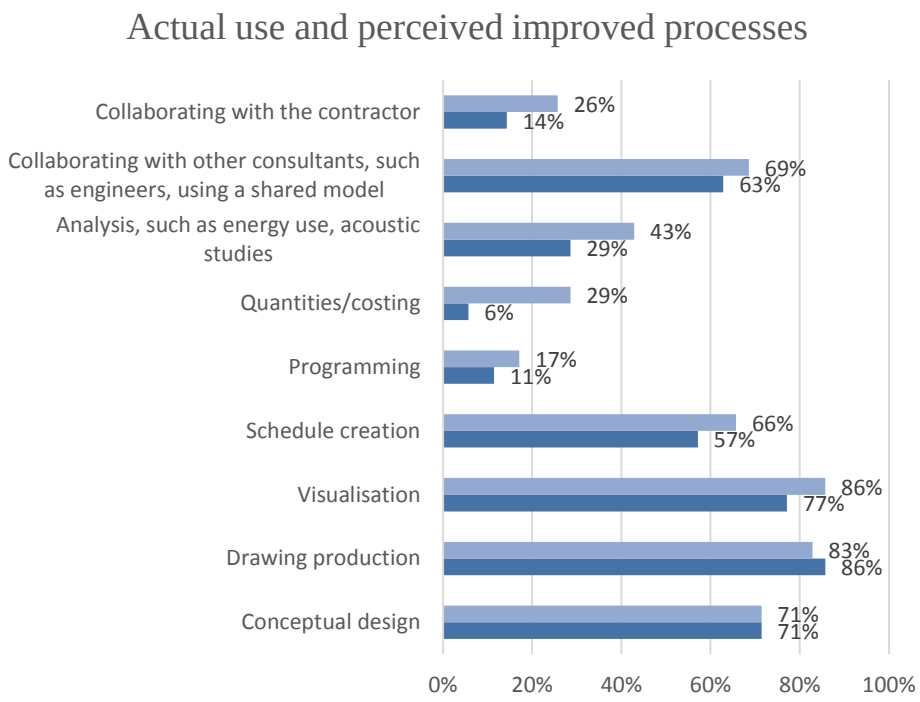

Figure 5: Comparison of actual use and perceived improved processes

Figure 5 compares architects' actual use (light blue) with their perceptions of processes that are improved using BIM (dark blue). The largest discrepancy observed is with regard to BIM's ability to use the inherent quantities for costing, where 29% of architects believe that BIM can improve the process, while only 6% use this function. However, architects perceive that most of the functions highlighted are improved by using BIM, besides drawing production, where their use of the function exceeds the perception that the process is improved. This may be explained by the fact that most architects that use BIM already use it for drawing production.

Contractors were asked a similar question. Only 21% of contractor respondents that answered this question had an opinion, so it is difficult to give any validity to the results. Of those that answered, most saw BIM as a tool for information production (10%) and visualisation (13%). Only 10% perceived that it could improve or streamline the costing process, while 8% believed that it can improve programming. The results show that contractors are largely unaware of the advantages that BIM can offer. The lowest score was for collaborating with consultants (2%), which substantially contrasts with the architects' score (26%). The research indicates that a single data source is one of the most important reasons to use BIM. It can be seen that the South African industry is largely unaware of the functionality of BIM and the concept of using BIM as a tool for collaboration.

3.9 Perceptions on shared information and collaboration

Both architects and contractors were asked if they believed there was value in sharing information from a central source.

More architects saw value in a central source of information that was accessible to project participants, where only 8% perceived that there was no value. This contrasts with the contractors' perceptions, where 24% believed that there was no value. It can be seen that 62% of architects believed that there is substantial value in sharing the model, while only 36% of contractors perceived this.

Although a small minority of the architects surveyed use a shared building model, a substantial majority see the advantage of doing so. The survey question did not differentiate between users and non-users. The number that answered 'no value' is similar to those that 'do not intend to use BIM in the near future', although no correlation between the two could be drawn.

It can be seen that most architects and contractors believe that collaboration has advantages although architects perceive this more so than contractors. More architects (63%) perceive that there is a substantial advantage when compared to contractors (33%), although most respondents from both groups believe that there are at least some advantages. Most architects see the advantage of collaboration more so than sharing information with the contractor. However, contractors that were surveyed perceived more value in collaborating than sharing information. This shows that many architects and contractors do not see a relationship between collaborating and sharing information.

3.10 Factors that limit collaboration

The survey sought to reveal the perceptions of both contractors and architects on the limiting factors of collaboration. Architects perceived contractual boundaries as the main limiting factor, with 40% listing this. Only 20% of contractors saw this as a limiting factor. Contractors (39%) listed confidentiality of information as the main limiting factor, and many architects (35%) also perceived this. The perception that a lack of trust or communication limits collaboration was the second most important factor that limited collaboration for contractors and third most important for architects. Nearly a quarter of architects (23%) and 16% of contractors perceived that the South African environment was a factor that limited collaboration.

4. DISCUSSION

The survey results show that there is increasing awareness of BIM in South Africa among architects, with trends and usage patterns reflecting the findings of other countries. However, South African contractors are largely unaware of the concept with only 4% of contractors saying that they were familiar with the concept. This varies substantially with observations from other countries, such as the USA where the majority of contractors had already adopted BIM.

The early majority in the architectural category are generally operating in a BIM-only environment, while none of the contractors surveyed said that they used only BIM. When these trends are compared to adoption rates in other countries and the diffusion of innovation theory developed by Rogers (1983), it may be anticipated that architectural adoption will start moving into the late majority phase, while contractors are entering the stage of awareness of the innovation that suggests that adoption rates should start to increase.

It can be seen that there are two characteristics of BIM adoption in South Africa, which are interacting independently. The first is the adoption of BIM technology by organisations, which is a feature of individual consequence. This offers many advantages for the production of information. The second characteristic is the adoption of the new working methods associated with BIM. Adoption in other countries is occurring on an industry wide and national level, which is a feature of public consequence. While adoption of BIM on an organisational level is following international trends, this is not observed at a national or industrial level. The current adversarial environment cannot be addressed using BIM in isolation. Takim, Harris and Nawawi (2013) also discuss how the adoption of BIM happens at two levels. In order for a technology to be adopted at the national level, the government has to mandate or regulate it. This results in policies for national standards and enforcement acts, such as making it mandatory for BIM use on public works projects if it can be shown that there are benefits.

5. CONCLUSION

The research shows that there are numerous advantages for organisations that use BIM, even in an isolated environment. BIM adoption is following international trends at an organisational level, but at a national level, the collaborative advantages of BIM have not been recognised or addressed. This poses a threat to the South African industry, where increasingly productive international markets in a progressively globalised economy may result in the inability of the South African industry to compete.

The inherent inefficiencies and non-value adding tasks that have traditionally been part of the construction industry are borne by the client, adding substantially to the cost of the built environment. Larger clients and government bodies in other countries are beginning to stipulate that BIM is used on their projects as the advantages and cost savings become apparent. The research suggests that using BIM results in better buildings, as the rich data can be used for analysis before construction begins. The functioning of the building can be determined beforehand, and the streamlined design and construction process can reduce the costs of buildings. Major clients in the UK are increasingly insisting on a BIM platform for their new facilities, and the UK government is driving the process by funding research and requiring that new public buildings are produced in a collaborative environment using BIM.

Consultants benefit from using BIM. Research in the USA (McGraw-Hill, 2012) showed a strong correlation between user competency and return on investment (ROI).

This suggests that higher competencies among BIM users in architectural practices will improve the workflow during the project.

A higher degree of modelling will allow analysis of the building that is not currently being done. Better buildings can be produced. The increased use of BIM will also allow for real collaboration among consultants during the design stage, and facilitate earlier contractor involvement and full partnering relationships. Smith and Tardif (2009) suggest that leaders of design firms often have grossly inaccurate perceptions of the impact that BIM has had on their firms. They state that this makes it impossible for leaders to make strategic decisions with regard to their BIM use. The full benefits of BIM and the inherent data and information can only be utilised once there is more collaboration during the project. This may become increasingly obvious as both hardware and software capabilities advance and global connectivity increases.

Hardin (2009) observes how contractors that work with design teams that still use CAD often choose to create their own separate model based on the 2D drawings. This allows them to increase their efficiencies and have a better understanding of the design intent and how it is to be constructed. However, significant resources are required to accurately model the building and this is possibly beyond the capability of many contractors. Contractors need to address this. The research indicates that only a small minority of South African contractors create their own models, or have them created by a third party. The lack of awareness and use of BIM by South African contractors contrasts with adoption rates elsewhere, where in the USA there was a 74% adoption rate (McGraw-Hill, 2012) among contractors. The advantages of using BIM have been demonstrated by the research and it can be seen that there are tangible benefits to contractors that use BIM. Clash detection software along with 4D (costing) and 5D (scheduling and programming) processes could significantly streamline the construction phase. Contractors need to become more aware of the technology that has now reached maturity and is likely to offer increasing benefits as hardware and software processes improve.

Suppliers have an opportunity to introduce unique selling points to their products by providing accurate, information-rich components for a BIM environment. There is currently an opportunity for suppliers to gain an early competitive advantage due to the relative immaturity of the market in South Africa. This will require new competencies in order to both compile the data and model the components. Training that addresses BIM modelling competencies can provide new employment opportunities for component modellers.

The literature review confirmed that BIM is increasingly being used internationally and that programmes are being actively developed by industry bodies and governments in many countries, such as the USA, UK, Australia Finland, Norway and China. The Chair of the body that is driving BIM awareness in the UK, Dr Barry Blackwell (BIM Task Group, 2013) believes that the BIM 'genie is out the bottle' and that innovation will be relatively swift with the new technology. He suggests that countries will not remain globally competitive without embracing the new technology. Countries that do not remain competitive will struggle as global markets increasingly compete for local work using streamlined processes.

Industry bodies, such as those that represent architects, contractors, construction managers, engineers and quantity surveyors, need to become more aware of international trends.

A review of these bodies' websites did not reveal any information on using BIM or on collaborative methods of working. The extremely fast pace of change that is being witnessed globally needs to be recognised and embraced in South Africa. The South African construction industry may become increasingly non-competitive and marginalised if the new methods of working are not acknowledged.

In order to harness the benefits of BIM and partnering, legislators need to create an environment that is more conducive to new ways of working. The current procurement processes emphasise black empowerment issues and are not currently aligned to partnership agreements. This discourages collaborative arrangements. Legislation needs to allow for combined teams (partnerships) to tender for work as a unit. It was seen that in the UK the government has largely driven the process to increase BIM use and encourage collaborative arrangements.

The research has demonstrated that there is less use both of BIM and partnering in South Africa, when compared to Western Europe and the USA. The use of BIM by architects in South Africa slightly lags that of other countries, and a trend is identified which suggests that architectural take-up is likely to continue. However, contractor awareness and take-up is substantially behind these countries. This represents a challenge for the industry, as the lack of take-up by contractors is inhibiting the collaborative use of BIM in South Africa. The research reveals a potential threat to the South African construction industry in that global companies may become more competitive than local companies. This could negatively affect the local construction industry.

Factors that inhibit partnering and restrict BIM use in South Africa were identified. These include:

- Lack of awareness by large clients;
- Lack of awareness by the government;
- Lack of awareness by industry bodies; and
- A procurement process that discourages collaborative processes.

The research has provided new primary data and quantifies the degree of BIM use and the rate of take-up in South Africa among architects and contractors. Perceptions on BIM and collaborative arrangements were documented.

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