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Technology management in construction: Lessons for the practice of architecture

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Abstract

The relevance of managing technology to architectural practices in South African construction cannot be overemphasised. As major stakeholders in the construction industry with particular significant contributions in the property sector, practising architects cannot afford not to exploit old technologies, and embrace new technologies with a view to improving their business and competitiveness.

The thrust of the issue addressed in this article is the assessment of the status accorded to issues relating to technology in the form of a technology audit and/or management in architectural practices. In furtherance of this issue, a quantitative survey was conducted among Eastern Cape-based South African Council for the Architectural Profession (SACAP) registered architects.

Selected findings include that respondents perceived that there are no barriers to communication in organisations as technology does not only form part of the organisational business strategy, but also benefits project partners during implementation. In addition, with the use of office technologies, management is able to forecast and plan future requirements for their practices, while marketing-related technologies allow the closing of identified performance gaps as well as the development of best practices by the firms. Therefore, periodical technology audits are recommended for practices intending to remain competitive in the market.

Keywords: Architectural practice, technology audit, South Africa

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Abstrak

Die relevansie van tegnologiebestuur vir argitektuurpraktyke in Suid-Afrikaanse konstruksie kan nie genoeg beklemtoon word nie. As hoofaandeelhouers in die konstruksie-industrie met spesifieke bydraes tot die eiendomsektor, kan praktiserende argitekte nie bekostig om nie ou tegnologie te benut, en nuwe tegnologie te omarm met 'n visie om hul besighede en bekwaamheid te verbeter.

Die dryfkrag van die saak wat in hierdie artikel aangespreek is, is die assessering van die status toegeken aan sake betreffende tegnologie in die vorm van 'n tegnologiese oudit en/of die bestuur in argitekspraktyke. In bevordering van die saak, is 'n kwantitatiewe opname gedoen onder argitekte van die Suid-Afrikaanse Raad vir die Argitekseprofessie (SARAP) gebaseer in die Oos Kaap.

Bevindinge sluit in dat respondente ervaar dat daar geen struikelblokke in kommunikasie in organisasies is nie, omdat tegnologie nie alleen deel vorm van die organisatoriese besigheidstrategie nie, maar dit ook projekvennote gedurende implementering bevoordeel. In aansluiting hierby, met die gebruik van kantoortegnologie, is bestuur in staat om vooruitskattings en toekomstige vereistes vir hul praktyke te beplan terwyl bemarkingsverwante tegnologie die sluiting van geïdentifiseerde prestasiegapings asook die ontwikkeling van beste praktyk by die firmas toelaat. Daarom word periodieke tegnologie oudits aanbeveel vir praktyke om mededingend in die mark te bly.

Sleutelwoorde: Argitekspraktyke, tegnologie oudit, Suid-Afrika

1. Background

Technology can be defined as knowledge, products, processes, tools, methods, and systems employed in the creation of goods and/or services. In other words, it is a way of doing things and the means whereby objectives are accomplished (Khalil, 2000: 1). By investing in technology an organisation is able to undergo organisational changes that lead to faster and economically efficient operations that are particularly required within the Architecture, Engineering, and Construction (AEC) sector (Wainwright, 2010: 210). Thus, technology has had a profound effect on human development and the advancement of civilisation. The Urenio Research Unit (2001: 1) contends that technology leads to socio-economic development, because organisations use technology to advance and/or achieve their goals.

In this context, Barrow (2004: 131) contends that failure to appropriately respond to societal and technology evolution can result in a loss of professional status. To the modern architect this is of serious concern to the profession and other construction stakeholders. In fact, Soons (2004: 10) noted that many South African architectural practices are not yet computer-equipped, or sufficiently abreast with developments in technology to produce the standard of designs or products beneficial to the industry. In

other words, it is important for architectural practices to go beyond the provision of e-mails or outdated computer-aided design (CAD) packages in their practices in order to remain competitive in the market. In particular though, CAD technology that is to a large extent driven in architectural design practice by internal rather than external influence factors may be considered one of the most important IT innovations of the past four decades. The fear of losing competitive advantage, erosion of legitimacy, and the fear of losing stakeholder support may be responsible for the dominance of imitative behaviour among design firms, which then determines the choice of CAD technology adopted for use in a firm (Kale & Arditi, 2005: 1140). Opposed to this trend, external factors such as capacity and interfiled adjustability should rather drive decisions when CAD technologies are considered. AEC firms should conduct a comprehensive analysis before adopting a technological innovation.

This is even more important as Building Information Modelling (BIM) technology that reportedly captures behaviour and relationships between parts and assemblies of a building in database form is yet to gain widespread acceptance and usage in the AEC sector despite its ability to trigger significant positive changes in the design and construction process that can translate to increased project success for stakeholders (Brewer & Gajendram, 2011: 638). In particular, Brewer & Gajendram (2011: 638) noted that BIM could provide technological solutions aimed at standardising and streamlining business processes across the design, construction, and operational phases of a building. For example, Ariyici, Coates, Koskela, Kagioglou, Usher & O'Reilly (2011: 190) observed that, because of the need to improve its capacity for greater integration and collaboration with other disciplines in the production process, and to adopt technology change in order to provide a more effective business process, a Liverpool United Kingdom (UK)-based architectural practice had to embrace BIM after using various forms of CAD software packages since 1991. The decision was taken when the firm noted that their use of 2D CAD tool caused some inefficiency such as timescales, deadline pressures, duplications, lead times, lack of continuity in the supply chain, overprocessing, rework, overproduction, conveyance, distractive parallel tasks, lack of rigorous design process, lack of effective design management, and communication (Ariyici *et al*., 2011: 190).

However, 18 months later, the firm already made significant progress in improving the skills of its employees, technology infrastructure development, and lean process improvements. Ariyici *et al*. (2011:

194) contend that the implementation of BIM in the architectural practice followed a bottom-up approach rather than a top-down approach in order to engage people in the adoption; ensure that people's skills and understanding increase, and firms build up their capacities. In other words, the implementation of technology entails a focus on the technology itself as well as a focus on people and processes at the same time (Ariyici *et al*., 2011: 194).

Consequently, the thrust of the issue addressed in this article is the assessment of the status accorded to issues relating to technology (CAD, BIM, and so on) in the form of a technology audit and/or management in architectural practices in South Africa.

2. Technology audit and management

Phaal, Farrukk & Probert (2004: 7) contend that technology management deals with effective identification, selection, acquisition, development, exploitation and protection of technology in the form of product, process, and infrastructure needed to achieve, maintain, and develop a market position and business performance in accordance with organisational objectives. This definition suggests that establishing and maintaining the linkages between technological resources and organisational objectives is of the utmost importance and represents a continuing challenge for many firms. Effective technology management requires a number of management processes such as identification, selection, acquisition, exploitation, and protection of technology, which can be deemed not to be very visible in firms as these functions are mostly found distributed within other business processes such as strategy, innovation, and operations. Therefore, technology management focuses on processes needed to maintain a stream of products and services in the market. According to Phaal *et al*. (2004: 7), technology management deals with all aspects of integrating technological issues into business decision-making, and it is directly relevant to a number of business processes, which include strategy development, innovation and new product development, and operations management, to name but a few. Consequently, it can be argued that healthy technology management requires establishing appropriate knowledge flows between commercial and technological perspectives in a firm in order to achieve a balance between market 'pull' and technology 'push' (Phaal *et al.*, 2004: 8). Hence the nature of these knowledge flows depends on both internal and external contexts such as business aims, market

dynamics, organisational culture, and technological context (Probert *et al*., 2000, cited by Phaal *et al*., 2004: 8).

In addition, the Business e-Coach (2003: 1) argues that by utilising a technology audit, a firm's need to design a technology plan can not only be highlighted, but the need to improve the management of existing technology capabilities can also be addressed. In this sense, Khalil (2000: 267) suggests that areas of concern with respect to new technology trends and management include:

- Corporate environment (management, strategy, project management, culture, and people);
- Technology categorisation (project control and collaboration, and office and marketing technologies);
- The market and competitors (market needs and competitor status);
- Innovation (idea generation, technology generators, and project progression);
- Value-added functions (research and development and project impact assessment technologies), and
- Acquisitions and exploitations of technologies (technology transfer).

According to the Construction Industry Computer Association (CICA) in the United Kingdom (UK), management often neglects the fact that to be on the cutting edge of competition all practices should have access to the same tools and that the IT skills of their employees is the important difference between firms (CICA, 2002: 1). In addition, CICA suggests that to maximise return on capital investment in information technology (IT) systems, firms cannot afford to neglect training their employees. Failure to train and educate employees may lead to erosion of existing competitive advantages a firm may possess. Therefore, it is important to have a corporate strategy in place for technology. Narayanan (2001: 250) even suggests that technology strategy is the revealed pattern in the technology choices of firms. These choices, which determine the character and extent of the firms' principal technical capabilities, involve the commitment of resources for the appropriation, maintenance, deployment and abandonment of technological capabilities. Thus, effective integration of technological considerations into corporate/ business strategy is an important aspect of business planning based on the premise that a technology strategy should not be developed independently from the business strategy, but rather that technological resources should be considered an integral part of

business planning (Phaal *et al*., 2004: 8). In this context, technological considerations may include external factors such as the nature of technological change and competitor activity and internal factors such as technological capabilities.

To be succinct, while corporate strategy is primarily concerned with sustaining competitive advantage, technology strategy is more concerned with acquiring technology that can lead to an advantage over competitors in order to ensure that a competitive edge is maintained. With respect to technology categorisation, while Khalil's (2000: 4-6) classifications include new technology, emerging technologies, high technologies, low technologies, medium technologies, appropriate technologies, codified versus tacit technologies, Lindsay (2000: 22-23) classifies technology into enabling technology, critical technology, pacing technology, and emerging technology. However, regardless of the classification used, the intent of technological advancement and its implementation is never far from performance improvement.

Improving performance entails marketing activities that are enabled by developing marketing plans to capitalise on the characteristics of technologies so that they can become accessible to clients (Khalil, 2000: 96). Further, relative to innovation, Narayanan (2001: 75) suggests that:

- Market-pull deals with technology advancement directed primarily to a specific market need and secondarily towards increased technical performance, and
- Technology-push, that is the advancement of technology, primarily deals with an increase in technical performance and secondarily with a market need.

Consequently, innovations may be stimulated when a firm strikes a balance between both technological-push and market-pull. Arguably, therefore, technology management focuses on the principles of strategy and organisational involvement in technology choices that are guided by the purpose of creating value for investors (Narayanan, 2001: 8).

Findings that arose from case study research conducted by Brewer & Gajendram (2011: 652) appropriately amplify the need to conduct technology audits in AEC firms as the research results suggest that, despite the enabling environment and technology, temporary project team members failed to embrace its widespread use. In particular, although the architectural practice involved in the project provided both the BIM and other ICT applications necessary

for the project data exchange, it conspicuously failed to champion the use of either. In general, an analysis of the interactions between the project teams revealed disparate understanding of the term BIM, with many viewing it as a vague 3D CAD model, and thus most of them were reluctant to wholeheartedly invest their time and effort in it. As a result, the use of ICT for the project implementation was clearly below par because of cultural issues rooted in attitudes and behaviours.

3. Research method

The quantitative survey was conducted among South African Council for the Architectural Profession (SACAP) registered architects based in the Eastern Cape. A total number of 15 firms were randomly chosen from 51 firms. The firms that responded to the survey were classified as small (1-2 employees); medium (2-5 employees), and large (more than 5 employees). In this context, 4 small-sized firms (26.6%), 4 medium-sized firms (26.6%), and 7 large-sized firms (46.8%) were surveyed. It is significant that a 100% response rate was recorded as all the firms surveyed responded to the survey.

In terms of demographic information, only 10% of the employees in large firms surveyed have a Masters degree qualification; 29% of employees in large-sized firms, 38% of employees in medium-sized firms, and 100% of employees in small-sized firms have a Bachelor degree qualification. Although the respondents did not distinguish in terms of M.Arch. or M.Sc. and/or B.Sc. or B.Arch. qualifications, this level of education is not surprising as SACAP requirements set a minimum qualification benchmark for each grade of registration.

4. Research findings

Given that respondents were required to respond to four-point Likert scale questions, a measure of central tendency in the form of a mean score (MS) was computed to enable a comparison between factors. Furthermore, given that the difference between the lower and upper ends of the scale is 3.00, and that there are four points thereon, the extent of the ranges is determined by dividing 3.00 by 4, which equates to 0.75. Therefore, the ranges used to present the results are:

- Agree to strongly agree/strongly agree ($> 3.25 \leq 4.00$);
- Near agree to agree/agree ($> 2.50 \leq 3.25$);
- Disagree to near agree/near agree ($> 1.75 \leq 2.50$), and
- Strongly disagree/disagree ($>1.00 \leq 1.75$).

Table 1 indicates 21 assessment areas relative to technology in a corporate environment in terms of percentage responses to a scale of 1 (strongly disagree) to 4 (strongly agree), and a mean score (MS) ranging between 1.00 and 4.00. It is notable that all the MSs are above the midpoint score of 2.50, which indicates that, in general, the respondents can be deemed to agree with the statements.

The > 3.25 ≤ 4.00 MSs suggest that the respondents perceive that there are no barriers to communication in organisations; technology forms part of business strategy; firm and clients benefit from new technology implementation; commitment to enhancing technology within the firm; investment of time and money to enhance technology implementation; culture support technology; training of employees is of utmost importance to management; willingness to organisational change that favours new technology, and change is an opportunity not a barrier to the use of new technology, fall between agree to strongly agree/strongly agree.

Table 1: Technology in a corporate environment

Statement	*Response (%*				*MS*	*Rank*
	Strongly disagree..Strongly agree					
	1	*2*	*3*	*4*		
Management:						
Commitment to enhancing technology within the firm	0.0	0.0	53.3	46.7	3.47	4
Investment of time and money to enhance technology implementation	0.0	0.0	60.0	40.0	3.40	5
Technology forms part of business strategy	0.0	6.7	26.7	66.7	3.60	2
Firm and clients benefit from new technology implementation	0.0	13.3	20.0	66.7	3.53	3
Willingness to organisational change that favours new technology	0.0	0.0	66.7	33.3	3.33	8
Strategy:						
Defined corporate strategy aimed at achieving firms' visions in place	0.0	33.3	40.0	26.7	2.93	13
Corporate strategy considers technological needs of the firm	0.0	60.0	20.0	20.0	2.60	17
Specific technology strategy currently exist in firm	0.0	60.0	26.7	13.3	2.53	18

Statement	*Response (%*				*MS*	*Rank*
	Strongly disagree..Strongly agree					
	1	*2*	*3*	*4*		
Project management:						
Exploration of new technologies with respect to specific projects	0.0	60.0	26.7	13.3	2.53	19
Assessment and implementation of technology specific to projects	6.7	33.3	40.0	20.0	2.73	15
Clients are encouraged to use new technology in construction	0.0	20.0	43.7	33.3	3.13	11
Culture:						
Culture supports technology	6.7	0.0	40.0	53.3	3.40	6
Change is an opportunity not a barrier to the use of new technology	0.0	6.7	53.3	40.0	3.33	9
No barriers to communication in organisation	0.0	0.0	40.0	60.0	3.60	1
People:						
Employees are encouraged to attend training for skills development	6.7	13.3	33.3	46.7	3.20	10
Employees are rewarded for acquiring new skills	6.7	6.7	53.3	33.3	3.13	12
Reward systems are in place for efficiency and motivational reasons	13.3	33.3	20.0	33.3	2.73	16
Appraisal system is in place for employee promotional assessment	6.7	26.7	46.7	20.0	2.80	14
IT specific employees are in place to maintain firms' IT infrastructure	26.7	33.3	13.3	26.7	2.40	20
Online access to all HR information is granted to employees	26.7	33.3	26.7	13.3	2.27	21
Training of employees is of utmost importance to management	6.7	6.7	26.7	60.0	3.40	7

In addition, > 2.50 ≤ 3.25 MSs suggest that the respondents perceive that employees are encouraged to attend training for skills development; clients are encouraged to use new technology in construction; employees are rewarded for acquiring new skills; defined corporate strategy aimed at achieving firm's visions is in place; appraisal system is in place for employee promotional assessment; assessment and implementation of technology specific

to projects are usually done; reward system is in place for efficiency and motivational reasons; corporate strategy considers technological needs of the firm; specific technology strategy exists currently in most firms, and exploration of new technologies with respect to specific projects, fall between near agree to agree/agree.

The > 1.75 ≤ 2.50 MSs indicate that the respondents perceive that IT specific employees are in place to maintain firms' IT infrastructure, and online access to all HR information is granted to employees fall between disagree to near agree/near agree. It is notable that of the 21 corporate environment statements, 9 are > 3.25 ≤ 4.00.

In brief, the relatively high MSs achieved in the management section of Table 1 suggest that, in terms of corporate environment, firms tend to ensure that management buy-in is in place in order to make sure that they embrace and enhance the overall level of technology in the firm. In the strategy section, although the MSs could be deemed average, they nevertheless suggest that there is a gap between functional strategy deployment with respect to technology and corporate strategy adopted by the respondents. For the project management section, the average to above average MSs achieved underscores the importance of project management in construction. For instance, despite the benefits that may accrue as a result of the implementation of new technology, it is common in construction to encounter risk-averse clients that will rather stick to tested construction methods as opposed to exploring new technologies in order to ensure that a project is delivered within the cost and time constraints. In the culture section, the relatively high MSs may be attributed to the nature of architecture as a profession that fosters creativity in order to inspire competitive edge in a firm. In the people section in Table 1, the generally average MSs achieved suggest that there is major scope for improving the human resources management competency with respect to the implementation of new technologies.

Table 2 indicates the assessment areas relative to categorisation of technology in a corporate environment in terms of percentage responses to a scale of 1 (strongly disagree) to 4 (strongly agree), and a MS ranging between 1.00 and 4.00. It is notable that, with the exception of one MS, all the MSs are above the midpoint score of 2.50, which indicates that, in general, the respondents may be deemed to agree with the statements.

The > 3.25 ≤ 4.00 MSs suggest that the respondents perceive that employees have e-mail and internet access; core services identified so that management can exploit them, and IT is recognised as an

important success factor for the firm, fall between agree to strongly agree/strongly agree. In addition, > 2.50 ≤ 3.25 MSs suggest that the respondents perceive that management are aware of current technological trends; ability to satisfy clients' technological needs; new CAD systems are assessed and implemented robustly; digital backup is in place to store all project data; development and implementation of new office technologies is important; automation of administrative functions is important to management; sound and aggressive market technology is used to attract clients; firm is up to date with respect to IT systems required for operations; secondary tasks such as network maintenance, are outsourced; and management is able to forecast and plan future office requirements, fall between near agree to agree/agree. However, the respondents perceive that web-based facilities are used to attract and secure new clients falls between disagree to near agree/near agree, as its MS is > 1.75 ≤ 2.50.

Table 2: Categorisation of technology in a corporate environment

Statement	*Response (%*				*MS*	*Rank*
	Strongly disagree..Strongly agree					
	1	*2*	*3*	*4*		
Project control and collaboration:						
Core services identified so that management can exploit them	0.0	13.3	40.0	46.7	3.33	2
Management awareness of current technological trends	0.0	20.0	40.0	40.0	3.20	4
Secondary tasks (e.g. network maintenance) are outsourced	6.7	20.0	53.3	20.0	2.87	12
Extranets are in place to encourage collaboration between project teams	40.0	33.3	6.7	20.0	2.07	15
IT is recognised as important success factor for the company	0.0	20.0	26.7	53.3	3.33	3
System is in place for monitoring technological trends	26.7	53.3	20.0	0.0	1.93	16
Office technologies:						
Development and implementation of new office technologies is important	0.0	20.0	53.3	26.7	3.07	8
Automation of administrative functions is important to management	6.7	20.0	40.0	33.3	3.00	9

Statement	*Response (%*				*MS*	*Rank*
	Strongly disagree..Strongly agree					
	1	*2*	*3*	*4*		
Firm is up to date with respect to IT systems required for operations	6.7	20.0	46.7	26.7	2.93	11
New CAD systems are assessed and implemented robustly	6.7	6.7	46.7	40.0	3.20	6
Employees have e-mail and internet access	0.0	13.3	33.3	53.3	3.40	1
Management is able to forecast and plan future office requirements	6.7	13.3	80.0	0.0	2.73	13
Digital backup is in place to store all project data	6.7	26.7	13.3	53.3	3.13	7
Marketing technology:						
Sound and aggressive market technology is used to attract clients	0.0	33.3	40.0	26.7	2.93	10
Ability to satisfy clients' technological needs	0.0	13.3	53.3	33.3	3.20	5
Web-based facilities are used to attract and secure new clients	13.3	46.7	33.3	6.7	2.33	14

The implications of the respondents' perceptions tabulated in Table 2 are interpreted in the light of various MSs achieved in each section. In the project control and collaboration section, the cumulative average MSs achieved suggest that there may be a general lack of adequate organisation-wide technology-driven systems deployed for forecasting future trends in project control and collaboration-related technologies. This inevitably implies that firms may be unable to harness opportunities as they become available in the national and international arena. This assumption is equally supported by the perceived low level of the use of extranets for communication purposes. In addition, the MSs relative to the office technology section suggest that the respondents are of the opinion that the use and implementation of office technologies is important to their practices. In other words, the MSs could be interpreted to mean that the majority of the respondents acknowledge the usefulness of office technologies such as CAD and other administrative software to an architectural practice. While the MSs relative to marketing technologies may be deemed to be average, they nevertheless indicate that architectural practices need to improve their abilities in this section.

Table 3 indicates the perceptions of respondents relative to the influence of technology on the market and competitors in terms of percentage responses to a scale of 1 (strongly disagree) to 4 (strongly agree), and a MS ranging between 1.00 and 4.00. It is notable that all the MSs are below the midpoint score of 2.50, which indicates that, in general, the respondents may be deemed to disagree with the statements.

The > 1.75 ≤ 2.50 MSs suggest that the respondents are of the opinion that best practice, and policies developed in order to close identified gaps; core competencies and technological status are assessed; competitors are assessed periodically for benchmarking purposes, and market assessment tool is in place for identifying new market trends, fall between disagree to near agree/near agree.

Identifying new market trends is a particularly weak area based on the perceptions of the survey respondents. This finding suggests that improvement must be embarked upon in the area of market needs as anecdotal evidence suggests that, in order to provide a sustained optimum service, firms need to undertake market assessments so that they are aligned with their clients' requirements. Furthermore, with MSs less than 2.50, assessment of competitor status through the use of technology is another area of weakness identified in the study. The findings imply that, without a competitor assessment system in place, firms may be unable to benchmark their performance against the best in the industry.

Table 3: Technological influence on market and competitors

Statement	*Response (%*				*MS*	*Rank*
	Strongly disagree..Strongly agree					
	1	*2*	*3*	*4*		
Market needs:						
Market assessment tool is in place for identifying new market trends	33.3	46.7	20.0	0.0	1.87	4
Competitor status:						
Competitors are assessed periodically for benchmarking purposes	33.3	40.0	26.7	0.0	1.93	3
Core competencies and technological status are assessed	26.7	53.3	20.0	0.0	1.93	2
Best practice, and policies are developed to close identified gaps	20.0	66.7	13.3	0.0	1.93	1

Table 4 indicates the perceptions of respondents relative to technology that drives innovation in terms of percentage responses to a scale of 1 (strongly disagree) to 4 (strongly agree), and a MS ranging between 1.00 and 4.00. It is notable that all the MSs are above the midpoint score of 2.50, which indicates that, in general, the respondents may be deemed to agree with the statements.

The > 3.25 ≤ 4.00 MSs suggest that the respondents perceive that clients are assured of product and service quality; new products and processes are suggested to clients as alternatives; and clients' briefs are available to all employees or project teams, fall between agree to strongly agree/strongly agree. However, the respondents are of the opinion that improvement of project schedule is made on each project; employees are encouraged to explore and assess new IT systems; employees are persuaded to communicate through existing channels; project cost information is available from the project team at each stage, fall between near agree to agree/ agree (> 2.50 ≤ 3.25), while reward systems are in place to motivate innovation within the firm, falls between disagree to near agree/ near agree (> 1.75 ≤ 2.50).

As the majority of MSs related to idea generation in Table 4 are close to 3.00, it can be assumed that, in general, the respondents are of the opinion that idea generation favours the exploitation of technology in architectural firms. Similarly, the MSs that are relative to technology generator in Table 4 suggest that adequacy of communication interfaces between designers and clients may also favour the generation of technology-driven initiatives. These findings are particularly important in the architectural practice context as profession is service-oriented in that it should always strive to satisfy professional norms and the client.

Table 4: Innovation driven by technology

Statement	*Response (%)*				*MS*	*Rank*
	Strongly disagree..Strongly agree					
	1	*2*	*3*	*4*		
Idea generation:						
Employees' inputs are encouraged relative to new project innovations	6.7	13.3	40.0	40.0	3.13	5
Employees are encouraged to explore and assess new IT systems	0.0	26.7	46.7	26.7	3.00	6
Employees are persuaded to communicate through existing channels	6.7	13.3	53.3	26.7	3.00	7

Statement	*Response (%)*				*MS*	*Rank*
	Strongly disagree..Strongly agree					
	1	*2*	*3*	*4*		
Reward systems are in place to motivate innovation within the firm	6.7	53.3	26.7	13.3	2.47	9
Technology generator:						
Clients' briefs are available to all employees or project teams	6.7	0.0	46.7	46.7	3.33	3
Clients are assured of product and service quality	0.0	0.0	46.7	53.3	3.53	1
New products and processes are suggested to clients as alternatives	0.0	6.7	53.3	40.0	3.33	2
Project progression:						
Project cost information is available from project team at each stage	20.0	20.0	33.3	26.7	2.67	8
Improvement of project schedule is made on each project	0.0	6.7	66.7	26.7	3.20	4

Table 5 indicates the respondents' perceptions with respect to value-added functions derived from the implementation of technology management initiatives in terms of percentage responses to a scale of 1 (strongly disagree) to 4 (strongly agree), and a MS ranging between 1.00 and 4.00. It is notable that all the MSs are above the midpoint score of 2.50, which indicates that, in general, the respondents may be deemed to agree with the statements.

Though, all the MSs are > 2.50, only one MS (3.27) is > 3.25 ≤ 4.00. This suggests that the respondents are of the opinion that concern related to the use of sustainable design and materials in construction projects fall between agree to strongly agree/strongly agree. The MSs relative to R&D further suggest that investment of resources in R&D must be improved, while the MSs relative to project assessment technologies suggest that more importance must be attached to issues relative to project assessment technologies as clients' demand for improved performance is on the upswing.

Table 5: Value-added functions related to technology management

Statement	*Response (%)*				*MS*	*Rank*
	Strongly disagree..Strongly agree					
	1	*2*	*3*	*4*		
Research and development:						
Time and money is spent on materials and techniques related R&D	13.3	46.7	13.3	26.7	2.53	5
Post-project reviews are conducted for future reference	0.0	33.3	60.0	6.7	2.73	4
Project assessment technologies:						
Concern for the environment is prioritised in development projects	13.3	13.3	40.0	33.3	2.93	3
Concern related to the use of sustainable design and materials in projects	0.0	13.3	46.7	40.0	3.27	1
Life cycle implications of designs and materials are assessed	0.0	20.0	40.0	40.0	3.20	2

Meanwhile, the other MSs > 2.50 ≤ 3.25, which suggest that the respondents perceive that life cycle implications of designs and materials are assessed; concern for the environment is prioritised in development projects; post-project reviews are conducted for future reference, and time and money is spent on materials and techniques related R&D, fall between near agree to agree/agree.

Table 6 indicates the perceptions of respondents with respect to the acquisition and exploitation of technology in terms of percentage responses to a scale of 1 (strongly disagree) to 4 (strongly agree), and a MS ranging between 1.00 and 4.00. Though, the MS is > 2.50, it nevertheless suggests that the respondents perceive that the ability to transfer technology from other industries to construction falls between near agree to agree/agree.

Table 6: Acquisition and exploitation of technology

Statement	*Response (%)*				*MS*
	Strongly disagree..Strongly agree				
	1	*2*	*3*	*4*	
Ability to transfer technology from other industries to construction	0.0	33.3	40.0	26.7	2.93

5. Conclusions and recommendations

The empirical study justified the perception that there is significant scope for the development of technology management principles and/or capabilities within architectural firms in order to enhance

their competitiveness. The findings also suggest that there may not be an existing mechanism that allows management to adequately assess and analyse the use and requirements for technology within their firms. Based on the findings, it can be argued that the respondents are not taking adequate advantage of technology in order to improve and sustain their competitive advantage in the industry. In other words, within a firm technology-related strategies will require objectivity and complete focus in order to assist the firm in positioning itself appropriately in the marketplace. Conducting a technology audit provides a platform for evolving appropriate technology strategy for a firm, as valuable resources related to information will be brought to light in the auditing process.

Consequently, architectural practices should endeavour to embrace the use of technology for building and sustaining competitive advantages in the market as mere internet access or e-mail usage in a firm is not adequate use of information technology. In this sense, systems/strategy for monitoring technological trends should be put in place in the workplace in order to improve, *inter-alia*, firms' project-related efficiency and client satisfaction. Therefore, periodic technology audits are recommended for architectural practices intending to remain abreast of trends and developments in the industry. This is particularly relevant to firms undergoing major organisational changes in the form of mergers or acquisitions. In this context, technology audit is expected to effect complete understanding of the 'existing' capabilities of a firm, and lead to the development of 'future' technology-based capabilities of the firm.

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