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Investigating Factors that Influence the Rate of Adoption of Innovative Construction Technologies in Kenya

Nickson Amuhaya Sagini [1], Dr. Stephen O. Dianga [2] , Dr. Titus Kivaa Mbiti [3]
Department of Construction Management,
School of Architecture and Building Science,
Jomo Kenyatta University of Agriculture and Technology,
Nairobi, Kenya.

Abstract: **The construction industry is widely perceived to lag behind manufacturing and other sectors in innovation and its adoption. Several aspects of industry structure, the innovations and institutional policies are cited as being responsible. The aim of this study was to investigate the underlying factors that significantly influence the rate of adoption of innovative construction technologies.The enquiry mode was quantitative involving a structured questionnaire survey that collected quantitative data from consultants and Contractors and developers in Kenya within the Nairobi County. The results indicated that attributes of innovation, procuremet systems, regulations and developer and Architect influence were major determinant factors in the adoption process.**

Key words: Innovation, Construction, Technologies, Rate of Adoption

I. INTRODUCTION

The Construction industry is widely perceived to lag behind manufacturing and other sectors in innovation and its adoption. This has been attributed to several aspects of industry structure such as its fragmented and cyclical nature ([1]; [2]; [3] ; [4]; [5]); procurement systems and client relationships ([6] ; [7]); and the low level of Research and Development undertaken [8]. Studies have also shown that Public policies ([9] , [10], [2]); and the nature and characteristics of construction innovations [11]; have a major effect on innovation and its adoption in the industry. However due to the increased demand from end users for greater efficiency, high quality, fewer defects, increased competition and greater speed of construction [12] , the industry has made great strides in innovation and its adoption. Areas that have seen significant innovation in include sustainable construction practices, eco innovation, use of lightweight materials of high strength and stiffness, increased reuse and recycling of construction waste, industrialized building systems and modularization ([13], [14]).

The Global innovation index report of 2015 shows Switzerland (68%), the United Kingdom (UK) (62%), Sweden (62%), the Netherlands (61%) and the United States of America (USA) 61% as the most-innovative nations [15]. Statistics on innovation diffusion within the EU indicate that as high as 39% of EU innovative firms adopt innovations with the rest generating internal innovation [16]. By 2001, penetration rate of innovative construction technologies in the USA market had reached a high of 59% [17]. The situation in developing countries is however different. Through the analysis of key indicators of technology generation such as patents, Research and Development expenditures, studies show that innovative performance of developing economies is low [18]. Majority of the countries are seldom involved in local technology generating efforts but instead thrive on assembly and adaption of foreign innovative technologies [18]. For example in 2015 the innovation index for India (31%), Jordan (33%), Kenya (30%) and Uganda (27%) were rated as having outpaced their pears yet below average [15].

The Kenyan Government has had several initiatives aimed at identifying potential sources of innovative construction technologies in order to lower the pressure on conventional construction technologies [19]. Some of the technologies derived from these efforts are Stabilized Soil Blocks and Micro-Concrete Roofing tiles. Further efforts in the private sector through collaboration with foreign markets has led to the introduction of adapted innovative technologies which include stone coated roofing tiles, lightweight steel frame construction, expanded polystyrene (EPS) panels, use of fibre mesh in concrete slabs, precast waffle slab, plastics products, recycled timber, recycled grey water, and solar water heating and lighting [20].

However, while the activity in the Kenyan Construction sector has reached record high over the last decade, the Kenyan Construction industry has been unable effectively adopt and utilize available innovative construction technologies and is still highly dependent on conventional technologies. The main aim of this study was to investigate the factors that influence the rate of adoption of innovative construction technologies in Kenya and was guided by the following specific objectives:

1. Explore the innovation and adoption trends in the Kenyan construction industry
2. Describe the level of adoption of selected cases of innovative construction technologies in Kenya.
3. Describe factors that influencing the rate of adoption of innovative construction technologies in Kenya.

II. THE TECHNOLOGICAL INNOVATION CONCEPT

In an attempted to account for the project based nature of the construction industry, [22] defines innovation as the improvement of a building component, or technology used to construct buildings with respect to its characteristics or intended uses. In this respect technology is viewed as a combination of knowledge and skills embodied in products and processes. Reference [22] classifies innovation in two dimensions as either *Product* (making beneficial changes to physical products); or *Process* (introduction of a new or significantly improved production method or delivery of output that adds value to the organization). Reference [23] further presents a typology of innovations in construction as *incremental* (small change with limited impacts on surrounding elements); *modular* (significant change in the basic concept, but also with limited impact on its surroundings); *architectural* (a small change in the respective component, but with many and strong links to other surrounding components); *system* (multiple, linked innovations); and *radical* (breakthrough in science or technology). Studies have shown that *incremental* and *modular* innovations are the most prevalent in the construction industry [23] . This is attributed to the fact that often, conventional technologies are used alongside newly developed technologies.

The early theory of technological innovation assumed a linear model of innovation suggesting that technological innovation would start with *discovery* (emergence of a concept or results that establish the innovation; D*evelopment* (discovery moves from research to the field, is scaled up, commercialized, and integrated with other elements of the production process); and *marketing* (education and demonstration that is followed by sales and eventual adoption) [24], [25]. However, when scholars started to analyses in retrospect how successful innovations came into practice, they soon discovered all sorts of deviations from the linear model. This model has been replaced by more interactive models of *technology push (*starts at the production end of the supply chain where the product is introduced to the market); *market pull (*technology diffusion is guided by the demand from the potential users); and *Complex product Systems (*develops with the interaction between suppliers and end users) [26]; [27] . Perhaps the most significant model for innovation-development process that relates to adoption was proposed by [11] . In this model innovation entails six developmental phases starting with the *emergence of need, research, development, commercialization, adoption and diffusion* and lastly consequence of *acceptance or rejection.* The principal focus of this study was the adoption and diffusion phase. It is a crucial phase to any organization in the innovation process, because the socio-economic benefits of an innovation can only be realized after it is adopted by potential end users.

III. THE ADOPTION AND DIFFUSION OF INNOVATION CONCEPT

Diffusion research originated from a French sociologist Gabriel Tarde in 1903 [11] and later 1940's, by Bryce Ryan and Neal Gross who renewed interest in the diffusion process [28]. Diffusion can be interpreted as aggregate adoption [29]. Most Popular models of diffusion were developed by Everest Rogers in 1962, Frank Bass in 1969 and Lawrence Brown in 1981. The Bass model is a useful tool for forecasting the adoption a new innovation for which no closely competing alternatives exists in the marketplace [30]. Brown's model of diffusion is intended for diffusion of technological innovation among firms and focuses on communication and information flow process where the diffusion of technological innovation is viewed from the perspective of the adoption behavior of the firms using the innovation [31]. Brown thus examines the actual usage of innovation in contrast with Rogers's framework in which the perceived innovation attributes are emphasized. According to [1], the adoption decision is influenced by four main factors: characteristics of the innovation, industry characteristics, institutional effects, and firm characteristics.

The most popular adoption model is described by Rogers Everett .In reference [32] , adoption is viewed as a decision of full use of an innovation as the best course of action available. In this perspective, the Measure of adoption may indicate both the timing and extent of new technology utilization by individuals [29]. For example, one measure of the adoption of a technology is a discrete variable denoting if this technology is being used at a certain time. Another measure could be what percentage a specific projects are using this technology.

The adoption rate theory seeks to explain how the use of new innovative technologies spreads through a social system, and why they are adopted over old methods. Reference [11], defines rate of adoption as the relative speed with which an innovation is adopted by members of a social system measured as the number of individuals who adopt a new idea in a specified period. The application of Rate of Adoption theory to innovation in this study is useful for examining how innovators can apply it to increase the adoption of innovations. In this theory, there are several variables that determine the rate of adoption of an innovation.

IV. FACTORS THAT INFLUENCE THE RATE OF ADOPTION OF INNOVATIVE CONSTRUCTION TECHNOLOGIES

Rate of adoption is a variable of great interest to innovators, since it is a reflection of the extent to which an innovation diffuses in asocial system. Five variables depicted in Rogers's theory that impact directly on the rate of adoption are: the perceived attributes of an innovation; type of innovation-decision; communication channels; nature of the social system; and extent of change agents' promotion efforts [11]. Reference [1]further illustrates the adoption decision as being influenced by four main factors: characteristics of the innovation, industry characteristics, institutional effects, and firm characteristics. Reference [1] and [11] approaches agree to the fact that characteristics of an innovation is a significant factor. Other studies have also depicted Perceived attributes of the innovation as the most prevalent factor (E.g. [32], [33], [34]). According to [11] 49% to 87% percent of the variation in the rate of adoption is explained by the perceived attributes of the innovation. However, whereas under this variable,

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[11]further provides five analytic concepts of an innovative technology as its relative advantage, compatibility, complexity, trial ability and observability; [1] depicts main characteristics as profitability or cost savings and the required investment. The attributes of an innovation are characteristics inherent to the innovation (e.g. Relative advantage) or the usage of the innovation (e.g. Complexity). Relative advantage refers to the perceived value of an innovation relative to the previous idea used to perform the same tasks. Complexity is the degree to which an innovation is perceived as difficult to use and understand [32]. This can be translated as the "ease of use", which is measured by source of frustration, degree of mental effort required, degree of learning required and ability to control outcome [34]. Complexity is negatively related to the rate of adoption of an innovation and acts as a barrier to the interaction with the innovation [32]. Trialability is the degree to which the potential adopter has an opportunity to try out and experiment with the innovation before the adoption decision. According to [32], an innovation that is accessible to the potential adopters for experiments are more rapidly adopted. Trialability is positively related to the rate of adoption of an innovation and is measured by the ease with which an innovation is available for trial before the adoption decision and the time span of the trial period [34]. In summary, [32]argues that innovations offering more relative advantage, compatibility, simplicity, trialability, and observability will be adopted faster than other innovations. One likely problem with measuring the five attributes of innovations is that they may not in all cases be the most important perceived characteristics for a particular set of respondents. The solution is to elicit the main attributes of innovations from the respondents as a prior step to measuring these attributes as predictors of the rate of adoption.

Reference [1] and [11] concur on the view that adoption of an innovation and its diffusion is accomplished through human interactions and communication between members of a social system of practice. Reference [26] presents a multifaceted approach towards innovation and its adoption that suite the construction industry modeled under Market pull, Technology push and Complex Product Systems concepts. Through these concepts, [1] discerns that [11] is biased towards the adopters of innovation, or the demand side of innovation in effect ignoring influence of factors from the innovation developers and promoters, which constitute the supply side of innovation. In this perspective, [11] theory appear to be relevant only to Market pull (client driven) innovations which may be least applicable to technological innovations as these types of innovation are subjected to more consideration and influenced by external factors. Diffusion is accomplished through human interactions and communication between members of a community of practice [11]; concept similar to the actor network in an innovation system, which is a network of interrelated individuals, organizations and enterprises who share a common field of knowledge and interest regarding innovation in a certain domain [36]. If the construction industry is viewed as asocial network or system, interactions within and without brings to the fore other contextual factors that affect the rate of adoption and diffusion of innovation. For example, [37] points out the fragmented and one-off nature of construction projects, clients and manufacturers, the structure of production, relationships between individuals and firms within the industry, relations between the industry and external parties, procurement systems, regulations or standards, and the nature and quality of organizational resources as major determinants to innovation and its adoption in the construction industry. The characteristics of the construction industry and the unique features of construction products have prompted other researchers to identify new variables that influence the diffusion process. The findings include the following factors : Industry characteristics (cyclical market; industry fragmentation), building codes; regulation and firm size, [2]; cyclical market [3];Public policy (rules and regulation) and relative advantages of innovation [10]; Traditional procurement practice, [6]; building code [17]. Reference [8] at the local setting further relates other deficiencies that impact on innovation and its adoption as absence of technical and economic feasibility studies on innovations, lack of market analysis to assess the product or process potential, unwillingness of the users of technologies to take risks on unproven technology, lack of adequate financing mechanisms, and lack of capabilities by research institutes to transfer complete research results as a package acceptable to the users.

V. CONCEPTUAL FRAMEWORK

This study focused on the technology supply side of innovation. The study was modeled on variables derived from [1] and [11] perspectives with rate of adoption of innovative construction technologies as the dependent variable. This dependent variable was depicted through the exploration of set of cases of innovative construction technologies in the Kenyan construction industry; derived from case selection for elements in a typical building ranging from the substructure, superstructure, roof and services which comprise Fibre mesh, EPS panels, stone coated roofing tiles, solar water heating, solar lighting, gypsum products, plastic products and MDF products. The independent variables were deduced from the literature review modeled under Rogers and Browns frameworks and grouped under *innovation attributes* (Relative advantage, compatibility, complexity, triability); *industry characteristics* (the structure of production, relationships, Procurement systems, Cyclic market ,technologies risks, Communication channels, Uncertainty, Innovation decision) ; and *institutional characteristics* (Regulations and laws ,Standards, Financing mechanisms, and Building codes).

VI. METHODOLOGY

This paper presents a results of a study conducted in the month of October 2015 in Kenya within Nairobi City County targeting major actors in the construction industry. The enquiry mode was quantitative. A structured questionnaire was administered to consultant's firms (Architects, Quantity Surveyors, and Structural and Services Engineers); and Construction firms (Building, Mechanical and Electrical). The sampling frame was based a list obtained from registration and accreditation institutions for the respective firms. The obtained data was coded and analyzed using SPSS program.

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VII. RESULTS AND DISCUSSION

A. Respondents profile

Table 1 below provides a summary of respondent's profile .Majority of the respondents (26%) were architects followed by Quantity Surveyors. From table 2 Majority of the respondents had working experience of between 5 and 20 years (81%) an indication that that the participants had adequate exposure within the industry.

Table 1: Type of Firm

Type of firm	Percentage
Architect	26%
Quantity Surveyor	15%
Structural Engineer	11%
Electrical Engineer	9%
Mechanical Engineer	9%
Building Contractor	11%
Electrical Sub contractor	8%
Mechanical Sub Contractor	6%
Developer	4%
Total	100%

Table 2: Years of working Experience

Range	Frequency	Percentage
0-5 Years	9	17%
5-10 Years	21	40%
10-15 Years	15	28%
15-20 Years	7	13%
Over 20 ears	1	2%
Total	53	100%

B. Respondents trends in innovation

Respondents were asked to indicate the amount of time their firms spend on tracking changes and innovative trends in the marketplace. 15% indicated they spent lengthy time, Majority indicated minimal time (45%) where as 40% spent average time. When asked about their approach towards innovation, 38% of the respondents conformed to specifying technologies that meet minimum standards whereas 25 % encouraged their clients to keep tried products.

Table 3 : Innovative Trends

Time spent on innovative trends	Percent
Lengthy	15
Minimal	45
Average	40
Total	100.0

Table 4: Firms approach towards Innovation

Approach to innovativeness	Percent
We wait for others to use/specify innovative technology	19%
We are the first to use/specify innovative technology	13%
We encourage clients to keep to tried products	25%
We specify tech. that , meet min standards	38%
we specify /use tech that exceeds min. standards	2%
Others	4%

C. Respondents level of adoption of innovative technologies

A list of 20 innovative construction technologies was presented to the respondents. The respondents were asked to indicate the number of projects in which they had incorporated each of the innovations. Table 5 below provides a summary of response. The table shows the highest level of incorporation for most innovations was in the range of 1-10 projects. The least incorporated were concrete waffles, EPS panels and interlocking stabilized soils blocks at 81%, 77% and 83 % respectively.

Table 5: Incorporation of innovative construction technologies in projects

	Nil	1-10 Projects	10 -20 Projects	20-30 projects	over 30 projects	Total
Fibre mesh	47%	43%	10%	0%	0%	100%
Interlocking stabilized soil blocks	83%	17%	0%	0%	0%	100%
Expanded polystyrene panels (EPS)	77%	23%	0%	0%	0%	100%
Light steel frame for roof	30%	55%	13%	2%	0%	100%
Sand coated roofing sheets " decra"	34%	28%	30%	4%	4%	100%
Plastics products (e.g. ceiling, skirting, cornice)	17%	43%	36%	2%	2%	100%
Laminate flooring boards	32%	38%	25%	2%	4%	100%
Medium density fiberboard (MDF)	17%	36%	40%	2%	6%	100%
Gypsum board	23%	40%	25%	8%	6%	100%
Precast Concrete Panels	55%	30%	9%	4%	2%	100%
Monolithic Concrete construction	68%	23%	10%	0%	0%	100%
Recycled Corec fencing posts	74%	21%	4%	2%	0%	100%
PPR plumbing pipes	4%	40%	46%	7%	4%	100%
Bio-digester On site Sewer System	11%	57%	30%	2%	0%	100%
Newbuild Construction Technology	68%	15%	13%	2%	2%	100%
Premix concrete	34%	55%	11%	0%	0%	100%
Concrete pumping	28%	60%	11%	0%	0%	100%
Solar water heating	4%	45%	43%	4%	4%	100%

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Solar lighting	4%	42%	51%	2%	2%	100%
Concrete Waffles	81%	17%	2%	0%	0%	100%

D. Respondents rating of attributes that influence the rate of adoption of Innovative construction technologies.

A list of 20 innovative construction technologies was presented to respondents against attributes that influence their adoption over to traditional technologies. Respondents were asked rate the attribute that were most significant for each of the innovative construction technologies. Table 6 below presents a summary of the results. MDF, Light steel frame for roof, Gypsum board Bio-digester solar water heating and lighting were noted to have the highest rating of relative advantage over traditional technologies.

Table 6 : Attributes of Innovation applicable to case innovative technologies

Innovative Technology	Relative advantage over traditional technology	Compatible with traditional technology	Complex compared to traditional technology	Easy to try compared to traditional technology
1.Fibre mesh for concrete	60%	8%	11%	19%
2.Stabilized soil blocks	53%	15%	25%	8%
3.Expanded polystyrene panels (EPS)	49%	6%	32%	11%
4.Light steel frame for roof	70%	8%	8%	15%
5.Sand coated roofing " decra"	64%	11%	9%	15%
6.Plastics products (e.g. ceiling, skirting, cornice)	62%	13%	2%	21%
7.Laminate flooring boards	59%	17%	8%	15%
8.Medium density fibre-board (MDF)	74%	8%	4%	15%
9.Gypsum board	70%	11%	9%	9%
10..Precast Concrete Panels	51%	9%	26%	9%
11..Monolithic Concrete	38%	13%	42%	6%
12.Recycled Plastic e.g. corec fencing posts	59%	25%	15%	2%
13.PPR pipes	66%	23%	4%	6%
Bio-digester	74%	2%	9%	8%
Newbuild Technology	26%	9%	57%	6%
Premix concrete	66%	9%	9%	13%
Concrete pumping	72%	8%	8%	13%
Solar water heating	77%	4%	2%	4%
Solar lighting	81%	2%	4%	13%
Concrete Waffles	42%	4%	47%	6%

E. Respondents rating factors that influence the incorporation of innovative construction technologies in construction projects.

A set statements concerning of factors that influence the adoption of innovative construction technologies were presented to the respondents. Respondents were asked to rate on a five likert scale whether they strongly agreed or disagreed with the statements. Table 7 below presents a summary of the results.

Table 7: Factors that influence the adoption of innovative construction technologies

	Strongly agree	Agree	Neutral	Dis-agree	Strongly disagree
Building Codes impede adoption of innovative Construction technology.	45%	38%	8%	4%	6%
Innovative construction technology generally cost more than the ones we currently use.	36%	36%	15%	13%	0%
Our customers prefer the “tried and true” type of technologies	34%	45%	6%	11%	4%
It is risky to be among the first firms who try new products in our market.	38%	43%	8%	8%	3%
Lack of adequate financing mechanisms impede adoption.	19%	36%	45%	15%	19%
Lack of integration in the construction industry impede	25%	66%	4%	6%	0%

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adoption of innovation					
The prevalence of traditional procurement systems impede adoption of innovations	25%	59%	4%	9%	4%
There is generally lack of product approval system	11%	62%	19%	8%	0%
There is lack of adequate information about new products	13%	59%	15%	11%	2%

F. Respondents rating of significant source of information on innovative construction technologies

The results in table 8 below showed that architects and developers were the most influential sources of information on innovation. Learning institutions and Government were the least influential

Table 8: Source of information on innovative construction technologies

	Least Influential	**Not influential**	**Neutral**	**Influential**	**Most influential**
Developer	8%	4%	19%	21%	49%
Project manager	4%	8%	6%	57%	26%
Architect	2%	0%	0%	45%	53%
Quantity Surveyor	0%	2%	4%	58%	36%
Engineers	0%	2%	4%	68%	26%
Contractor	2%	13%	13%	57%	15%
Suppliers/ Manufacturer	2%	2%	9%	42%	45%
Government regulatory bodies	6%	34%	8%	40%	13%
Institutions of higher learning	4%	43%	11%	28%	13%

G. Respondents rating of actors with significant influence on decision to incorporated innovative construction technologies in projects

The results in table 9 below showed that developers and architects were the most influential sources of information on innovation. Learning institutions and Government were the least influential

Table 9: Actors with significant influence on decision to incorporated innovative construction technologies in projects

	Least Influential	Not influential	Neutral	Influential	Most influential
Developer	2%	4%	8%	19%	68%
Project or construction manager	2%	nil	11%	32%	25%
Architect	2%	0%	0%	32%	66%
Quantity Surveyor	0%	2%	11%	41%	45%
Engineers	0%	6%	nil	64%	30%
Contractor	6%	11%	23%	49%	11%
Suppliers/ Manufacturer	4%	11%	11%	55%	19%
Government regulatory bodies	6%	40%	8%	38%	9%
Institutions of higher learning	9%	61%	13%	9%	8%

VIII. CONCLUSION AND RECOMMENDATION

There is evidence of innovation and adoption of innovative construction technologies in the Kenyan Context. However, notwithstanding such developments, barriers to innovation and its adoption have been identified. The regulatory environment and governmental institutions have a powerful effect on adoption of innovative construction technologies. Procurement systems equally deter the adoption process. Attribute of an innovation that significantly affect the rate of adoption include the advantage created by adopting the innovation and the ease at which the innovation can be adopted.

In view of this there is need for changes in Government policies in relation to building codes and approval mechanism for new technologies. There is need to disseminate policy-relevant information on how to align learning and research with the construction industry in order to reduce the

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knowledge gap. It is important at the very outset of the project to carefully consider all factors when selecting the most appropriate procurement approach for a construction project.

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