

## **A Model for Measuring the Impact of Broadband Internet on Innovations at Institutions of Higher Learning in Kenya**

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### **Abstract**

*Objective: The aim of this study is to develop a model for measuring the impact of broadband on innovations at the institutions of higher learning in Kenya.*

*Background: Universities in Kenya are investing huge amounts of money on the provision of Broadband internet. However, the extent to which broadband is being utilised in these institutions to spur innovation is not certain. There is need therefore to measure the extend at which broadband internet influences innovations in these institutions in order to assess value for broadband investment.*

*Methods: The study adopts Porter's Diamond Model to develop the model. The model has four analytical dimensions that form the basis of designing the instruments of data collection. A descriptive study is adopted for the research. Data was collected from existing records, literature review and through interviews. A five-point Likert scale was designed and employed to assess the characteristics and behaviour of broadband consumer responses. Statistical methods were used to test the internal consistency reliability and construct validity of the study variables.*

*Results: The reliability and validity of the measures and measurement instruments were above the recommended level of 0.70 as an indicator of internal consistency.*

*Conclusion: Analysis of the structural model showed that the model performed well and was adequate for the study. Since this was a pilot study and the amount of data used was small, a more comprehensive study that incorporates all the 67 universities in Kenya is recommended.*

**Keywords:** *Broadband, Innovations, Internet, Education, metrics, model*

### **Introduction**

Current development of broadband Internet (BI) access market varies across different sectors and industry in a country. Broadband Internet penetration rates, usability levels and share of different broadband access technologies also vary. Broadband Internet continues to influence every aspect of life including education. Institutions of higher learning are increasingly becoming dependent on broadband Internet for their efficient and effective operation. The rapid deployment of broadband infrastructure is also changing the nature and variety of services and content delivery methods [2]. Broadband Internet access enable e-learning, research, marketing and collaboration. Due to its ability of global reach, the internet is providing people the opportunity to connect to other people with geographical limitations [3]. In essence, BI development affects technological innovation (TI) and competitiveness.

The capacity in which universities utilize BI for innovation is critical for national development and competitiveness. Comparative advanced deployment of broadband Internet in universities in Kenya make universities an important case study for assessing the possible environmental factors that have contributed to Kenya's broadband achievement.

This study assesses the role played by institutions of higher learning in innovation, discusses the factors that influence the development of internet in Kenya and then applies a modified Porter's diamond model [4] to provide a comparison of broadband-related environmental determinants before finally developing a broadband-based innovation measurability model.

## **Problem statement**

Broadband is an important ICT infrastructure that influences innovation and competitiveness, however, the measurability of these influence is less clear [1]. Although Kenya continues to invest in Broadband Internet (BI), the extent to which broadband is being utilised in institutions of higher learning in Kenya to spur development is not certain. It is therefore necessary to examine and ascertain the level of influence BI has on technological innovations by developing a broadband innovation model. In order to develop the model, it is important to identify the uses of BI for innovation and the extent at which it is used and thereafter determine the factors that influences its use for innovation in institutions of higher learning in Kenya.

## **Objectives of the research**

This research adopts Porter's Diamond Model to asses innovation in higher education sector by analysing five environmental factors related to BI development.

1. To identify the uses of BI for innovation in universities
2. To determine the impact of competition conditions on the use of BI for innovation in universities
3. To determine the impact of advanced factor conditions on the use of BI for innovation in universities
4. To determine the impact of university policy on the use of BI for innovation in universities
5. To determine the impact of collaboration conditions on the use of BI for innovation in universities

## **Literature review**

Assessment of the relationship between BI and Technological Innovation (TI) in institutions of higher learning in Kenya requires a review of several factors. Institutions of higher learning play an important role in TI and competitiveness of the country contributing to economic development. BI provides an important environment for innovation. An understanding of BI development in Kenya and the factors that influence its development is important. Analysis of the measurement model used to assess the relationship between BI and TI is critical.

## **The role of institutions of higher learning in innovation**

Universities are the highest educational institutions that fulfil their mission of research and education to motivate the process of innovation. They are the sources of educated and skilled personnel and new ideas. Through teaching, they disseminate knowledge and improve the stock of human capital [5]. Through research, they extend knowledge and transfer it to the rest of society [6]. They also work with industry to bring about development [7]. Apart from their role in education and science and technology development, universities are expected to turn those scientific developments into useful innovations. There are numerous ways in which universities can be innovative through the use of BI. BI can be utilized in conducting research, education administration, planning and administrative tasks and online learning [8].

The rising interest in the university's role in innovation is attributed to high profile examples of successful regional economies in which the university has made contribution. The Silicon Valley, the region around Cambridge in the UK and the Boston area are but just a few. The success of companies like Cisco, Google, and Yahoo (grew out of Stanford University research) is attributed to university research.

In the last few years Kenya has invested heavily in broadband internet and emerged as an ICT hub in innovative technologies particularly in the mobile sector. The implementation of mobile money transfer services put Kenya on the world map in technological innovations. The local ICT development groups such as ilab, iHub, nailab, University of nairobi's C4Dlab and infoDev's mlabs set the stage for innovation of applications and information services

such as Drumnet, mfarm, Ushahidi, etc in many sectors of the economy. over the years, Kenya has been home to multiple African Regional hubs including, IBM's first African Research lab, Nokia's Africa Headquarters and Google's first Sub-Saharan Africa office (outside of South Africa). The Internet has also proven a dynamic tool for stimulating economic growth in developing countries, with the World Bank reporting that a 10% increase in broadband correlates to a 1.38% increase in GDP growth [9].

### **Factors influencing the development of the internet in kenya**

Before mid 2009, Kenya like the rest of the East African countries relied solely on satellite for internet connectivity and international communication. Through policy and government initiatives, subsequently, the country is connected to the international broadband highway through the SEACOM, TEAMS, EASSY and ILON undersea fibre cables.

Apart from the Government ICT infrastructure, operators in the private sector have been busy developing their own national ICT infrastructure. Particularly, the mobile and data sub-sector has resulted in extensive and aggressive deployment of infrastructure in most parts of the country by the giant telecommunications service providers (orange Telkom, safaricom, airtel and essar). Large data infrastructure operators, including Jamii Telecom, liquid Telcom, access Kenya Group, Wananchi Group, Kenya education network (KeneT), MTn, Internet solutions, amongst others are also busy developing infrastructure. This Infrastructure deployment by many operators has resulted to competition leading to a relative reduction of tariffs and increased usage of mobile phones and internet access. By September 2013, there were 31.3 million mobile subscribers and mobile penetration of 76.9 per cent and at the same time, there were 25.1 million mobile money subscribers. The estimated internet users were 19.1 million with 47.1 per 100 inhabitants having access to internet services. International internet bandwidth available was 60,900Mbps of which 41.8 per cent was being utilised [10].

### **Technological innovation model**

Porter's diamond model is an analytical framework that has been used to study the innovative nature of an industry and its competitiveness while taking into consideration the influencing factors at the national-level [11]. This model has four analytic dimensions that have been applied in analyzing an industry, a cluster/sector, or a nation as a whole. The four dimensions are; advanced factor conditions, context for firm strategy and rivalry, related and supporting industries, and demand conditions. These dimensions are organized in such a way that the degree of interaction amongst them determines the magnitude of national innovativeness.

Evidence from numerous studies demonstrate the application of Porter's diamond to examine competitiveness of various industries. For instance, to determine British local economy's competitiveness[12], evaluate research performance of various departments of higher education institutions in the UK[13], assess competitiveness of Armenia [14], explore competitive advantage of Irish software industry[15], investigate competitive advantage of Silicon Valley of USA [16] and Chinese automobile industry[17].

### **Advanced factor conditions**

Advanced Factor Conditions (AFC) are resources specific for an industry that are important for its competitiveness. They normally include capital resources, human resources, physical, scientific, technological and infrastructure. Sometimes, an industry creates the factor conditions such human skills, technology, science and innovations. When nations and firms face a challenge such as high land costs, lack of natural resources or labour shortage they tend to innovate and upgrade in order to be competitive. A context for firm strategy and rivalry includes competition between local competitors, openness in business and free trade agreements. This leads to the formulation of the following hypothesis:

H1: Advanced Factor Conditions have a positive influence on BI use for technological innovation in the universities in Kenya

H2: Income, education and gender together influence TI in the universities in Kenya

### **Related and supporting industries**

Related and Supporting Industries provide the access energy, communication, transport services, and collaboration. Universities rely heavily on telecommunication networks to deliver educational content and to administer student examinations. Lack of adequate funding is a barrier to adoption and utilization of broadband in education. Although computer availability and ownership rates have steadily increased over the past few years, a significant number of users remain without sufficient computer resources. As a result, many educators have yet to integrate technology into their curricula. Public-private partnership between participating institutions, national government, non-profit organizations may focus on digital literacy, computer manufacturers, and broadband service providers to increase broadband access and usage. Digital media literacy education such as online safety training, discounted desktop, laptop, or other computer devices that can access the internet and discounted home broadband service to institutions and households may help solve some of these problems. Through a national broadband plan, this can ensure that users are technologically literate regardless of their geographical location or disability. On this basis the following hypothesis was created:

H3: Collaboration conditions (COL) have a significant impact on BI use for TI in institutions of higher learning

### **Consumer demand conditions**

Demand Conditions concern the demand for products and services that firms produce in the home market. Demand can create pressure to meet high standards, innovate, and respond to tough challenges.

There are numerous uses in which BI is utilized by universities to be innovative. Administrators use BI to deliver tools and services for use by students and educators. Course management platforms are used for the creation of online learning environments and facilitating the administration of education processes. Provision of open content on the Web enables access to educational information. Online learning is made possible through provision of BI. Mobile learning utilizes handheld devices for teaching and learning purposes. BI enables research through access to research material, publication journals and other data repositories. The table below summarises the uses and impacts of BI for innovation purpose.

**Table 1.** Uses and impacts of BI for innovation

<b>Users</b>	<b>Uses</b>	<b>Impacts</b>
Educators	Access critical curricular & professional development resources, Participate in professional development, Planning, Web 2.0 tools	Enhanced curricula, Resource sharing, Increased effectiveness, More interactive classrooms
Administrative purposes	Streamline back office functions, Outsource data processes, Aggregate, store, and analyze student data	Enhanced efficiency in completing tasks, Cost savings by moving to cloud computing, More collaboration
Students	Gaming, Online learning, Blended learning, Mobile learning	Increased number of learning environments, Enhanced opportunities for disabled students, Personalized instruction, Enhanced learning outcomes and skill development

Source: Charles M. Davidson Michael J. Santorelli. A report to U.S Chamber of commerce 2010 on the impact of broadband on education

This lead to the formulation of the following hypothesis:

H4: Consumer demand conditions (CDC) influence BI use for TI in institutions of higher learning

### **Competition conditions**

Competition is healthy in any business environment. It encourages adoption of more sophisticated methods of operation and service delivery in order to have a competitive edge from other business rivalries. Universities compete amongst themselves to increase enrolments in order to improve their capital base. They achieve this by increasing the number of programs they offer as well as improve the quality of services they provide. Competition also arises among technologies and among broadband Internet service providers. Technologies competing for BI provision in Kenya include; satellite, Digital Subscriber Line((DSL), cable mode provision and wireless. Broadband internet service providers operating in Kenya include safaricom, orange Telkom, airtel and essar. Others include Jamii Telecom, liquid Telcom, access Kenya Group, Kenya Education Network (KENET), Wananchi Group, Internet solutions and MTN. Competition brings down the costs of BI, improves BI penetration levels, improves the quality standards of services delivered and improves cooperate governance standards. This has the effect of encouraging foreign investments, better salaries and incentives as well as encourage intellectual property protection laws. This lead to formulation of the following hypothesis:

H5: Competition conditions (CCO) have an impact on BI use for TI in universities in Kenya

### **Policy regulatory conditions**

Policy formulation and implementation on the use of BI is the responsibility of the regulatory authorities vested with powers to run institutions in consultation with the national government. Every institution is expected to have an ICT policy document which includes the use of BI for educational purposes. University authority is required to foresee the implementation of this policy to encourage innovation. These institutions can achieve this in many ways. They can improve BI infrastructure through increasing the number of computers, purchasing more broadband and constructing research and teaching laboratory facilities in order to provide access to BI for innovation. To encourage research by investing in research and development as well as provide training for all users. The following research hypothesis came up:

H6: Institution policy (IPO) on BI usability influences TI in institutions of higher learning in Kenya

### **Research methodology and data collection**

This research uses a case study of universities in Kenya. The case study approach is appropriate for areas that are unique and require intensive and in-depth study as suggested by [18]. A modified Porter's Model is used to compare the determinants of innovation in education sector. University policy is included in the modified model as a determinant of innovation. University policy is important to support BI infrastructure development and encourage BI use at implementation level. In addition, changes in regulatory policy influences all the factors in Porter's diamond model and at the same time these factors may impact regulatory policy. The diamond model adopted uses education sector as a unit of analysis because firms within a sector practise innovative activities to survive under competitive pressure [19]. University collaborative nature and linkages with other industry players have a strong relationship with competition and innovation. Technological innovation can therefore be considered as a functional relationship between five interactive determinants namely: Consumer/Demand Conditions (CDC), Advanced Factor Conditions (AFC), Competition Conditions (CCO), Collaboration conditions (COL) and Policy regulatory conditions (IPO) at university level. A study conducted by [20], found out that Advanced Factor Conditions

(facilities for research, levels of education, and communication networks) determine sector dynamics to achieve high levels of innovation and competitiveness. BI infrastructure is an influential factor of the level of innovation. It contributes to business expansion, new product development and creativity [21] in addition the collaborative communication network formation provide platforms for exchanging ideas critical to innovation[22].

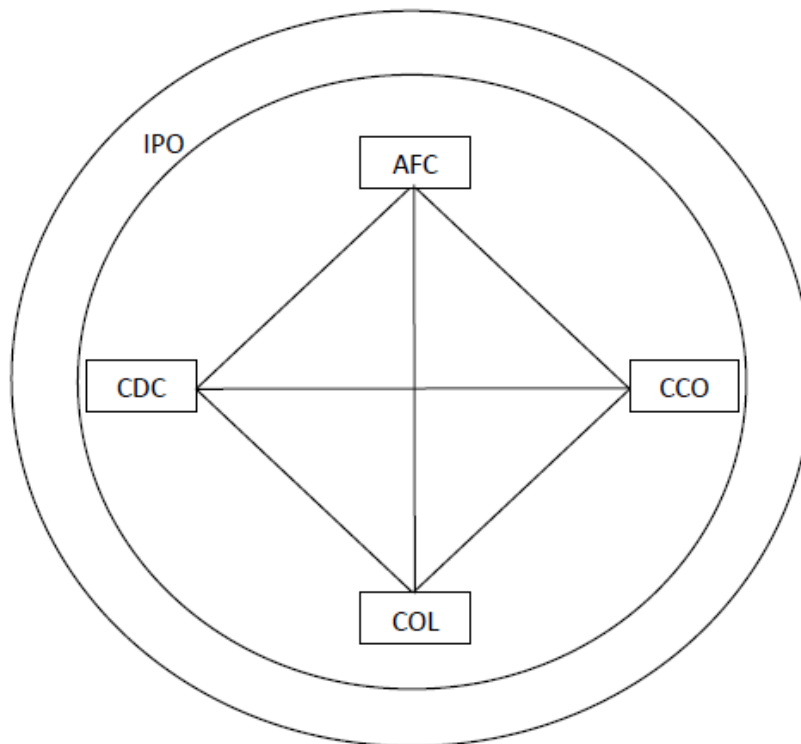


Figure 1. Conceptual framework

**The Empirical model**

To examine influential factors of technological innovation, this study employs a regression model. The study formulated the following regression model:

$$\ln TI_i = \beta_0_i + \beta_1 CDC_i + \beta_2 AFC_i + \beta_3 CCO_i + \beta_4 IPO_i + \beta_5 COL_i + \delta_i Z_i + \varepsilon_i \dots 1$$

In the model, dependent variable  $TI_i$  is technological innovation in university  $i$  in a particular year. Data transformation with logarithm was employed in this regression because the distribution of the dependent variable is rightly skewed. Independent variables used in the proposed research model were consumer demand conditions (CDC), advanced factor conditions (AFC), competition conditions(CCO), collaboration conditions (COL) and institution policy (IPO).  $\beta_0_i$  is constant,  $Z_i$  represents university dummies, and  $\varepsilon_i$  is the error term.

**Measures of proposed determinants of the model**

**Consumer/Demand conditions**

Consumer/demand conditions are determined by quantity and quality aspects of consumer demands[19]. In order to understand consumer demand of broadband internet for TI, this study will utilize BI consumer's characteristics and behaviour.

For this determinant, a survey was conducted to gather quantitative as well behavioural characteristics of BI users. A Likert scale was employed to analyse these categorical data. Principal component analysis was employed to reduce the user demands for BI and arrive at the items that had the greatest impact for this measure.

### **Advanced factor condition**

BI infrastructure, skilled manpower and the number of e-learning programs are measures that can be used to represent advanced factor conditions [19]. BI infrastructure can be measured by finding the internet penetration level, the number of web sites/World Wide Web hosts and the ratio/number of broadband Internet connections among total Internet users. The amount of overall broadband available both fixed and mobile is an indicator that can be used to measure both the potential and extent of access to a wide array of online services. The number of Internet hosts can be used as an indicator to measure Internet infrastructure development[24]. BI literacy levels is an indicator that can be used to represent the level of Internet content development at the intuitional level[25].

### **Competition conditions**

BI competition among broadband service providers at national level affects usability of internet within institutions of higher learning[26]. For this determinant, the study will review competition among competing technologies (mobile, DSL, cable etc) and the competition among broadband Internet service providers. The study will examine the pattern of broadband Internet market share of competing technologies and the top five firms' ratios as is currently in the market. The study will also review the price of broadband Internet access.

### **Institutional policies**

The study will examine ICT policy documents, government publications, press and marketing research reports to determine how BI related policies and regulation of telecommunication providers influence BI market. A survey study will be conducted among users to identify and determine how institutions encourage and promote the use of BI.

### **Measurement development**

The items used for measurement in this research were either developed based on the literature review, adapted from previously validated measures or derived through consultation with ICT experts to ensure that they are valid and reliable. A five-point Likert scale arranged in order of magnitude was employed to assess responses. A representative sample was randomly chosen and used to conduct a pilot test of the measures. Partial least-squares (PLS) analysis technique was applied to test the measurement model to determine the internal consistency reliability and construct validity of the study variables. The technique was also used to test strength and direction of the relationships between variables used in the model[27] [28]. There are only 67 universities in Kenya which represents a small sample population. Therefore PLS was preferred for the research. PLS is applicable for testing and estimating small sample sizes as it converges quickly even for large models with many variables and constructs[27].

### **Validation of the measurement scale**

In order to assess the reliability and validity of the measures before using them in the research model, the study applied a two-step approach as suggested by[29]. Analysis of the measurement model was conducted first before testing the structural relationships between latent constructs.

$$\text{Composite Reliability} = (\sum_{i=1}^n x_i)^2 / ((\sum_{i=1}^n x_i)^2 + (\sum_{i=1}^n y_i)) \dots\dots\dots 2$$

$$\text{Average Variance Expected} = (\sum_{i=1}^n x_i^2) / n \dots\dots\dots 3$$

Where x is the factor loading, y is error variance and n is the number of indicators

**Table 2.** Constructs and their psychometric properties

	Construct	Metric Code	Loading	t-value	Composite reliability	Cronbach's alpha ( $\alpha$ )	Average Variance (AV)
1.	Advanced factor condition(AFC)	AFC1	0.712	43.824	0.921	0.938	0.671
		AFC2	0.876	44.680			
		AFC3	0.860	43.450			
2.	Consumer demand conditions(CDC)	CDC1	0.912	32.102	0.985	0.849	0.721
		CDC2	0.812	31.282			
		CDC3	0.820	30.231			
3.	Competition condition(CCO)	CCO1	0.850	54.780	0.875	0.875	0.739
		CCO2	0.901	53.910			
		CCO3	0.828	60.450			
4.	Collaboration (CSI)	CSI1	0.760	55.940	0.872	0.850	0.715
		CSI2	0.780	54.650			
		CSI3	0.980	52.340			
5.	Institutional policies(IPO)	IPO1	0.870	44.780	0.880	0.920	0.613
		IPO2	0.750	45.340			
		IPO3	0.721	42.581			

Table 2 shows reliability measures above the recommended level of 0.70 as an indicator for adequate internal consistency[30]. convergent validity is adequate when constructs have an average variance extracted (AVE) of at least 0.5[28] or when items loading on their associated factors are above 0.5 [30]. Furthermore AVE from the construct should be greater than the variance shared between a particular construct and other constructs in the model[31]. Therefore, the constructs used in this study illustrated satisfactory convergent and discriminate validity. Table 3 illustrates the discriminate validity of constructs, with correlation among constructs and the square root of AVE on the diagonal.

**Table 3.** Constructs and their discriminate validity

Constructs	AFC	CDC	CCO	SCI	IPO
AFC	<b>0.819</b>				
CDC	0.811	<b>0.849</b>			
CCO	0.794	0.493	<b>0.859</b>		
COL	0.668	0.188	0.805	<b>0.846</b>	
IPO	0.802	0.760	0.391	0.322	<b>0.783</b>

### Examination of research hypotheses

This section discusses the results of analysing the structural model and the hypotheses formed for each determinant factor. The structural model can be assessed by examining the path coefficients beta weight ( $\beta$ ) which illustrates the strength of the relationships between the dependent and independent variables. The model also computes the ( $R^2$ ) value. This value shows the amount of variance explained by each independent variable. Both of this measurement construct and the path coefficients indicate how well the model is performing. The  $R^2$  value shows the predictive power of the model which should be interpreted in the same way as  $R^2$  in any regression analysis[32] suggests that the path coefficients should be significant and consistent with expectations. Partial Least Squares technique was used to perform the assessment of the research model. Table 4 tabulates the results of statistical analysis of the research.



**Table 4.** Structural model assessment

Hypothesis path	R <sup>2</sup>	B	p-value	support
AFC → TI	0.325	0.425	0.000***	Yes
Gender → TI	0.008	-0.072	0.282	No
CDC → TI	0.053	0.651	0.000***	Yes
Income → TI	0.002	-0.003	0.132	No
COL → TI	0.128	0.753	0.000***	Yes
CCO → TI	0.216	0.352	0.000***	Yes
IPO → TI	0.531	0.426	0.000***	Yes
Education → TI	0.005	-0.082	0.120	no

\*\*\*level of significance at <0.001

Five variables emerged with significant statistical support. Both AFC and IPO together explain 86% of the variance in TI. Both paths had positive effects, having coefficients of 0.325 and 0.531, respectively. The two determinants had the greatest influence on TI. CDC, COL and CCO had a coefficients of 0.053, 0.128 and 0.216 in that order respectively. The hypotheses that they have a positive impact on TI was also supported. Gender, income and education had negative coefficients and therefore no effect on TI. Hypotheses that income, education and gender influence TI were not supported according to the model.

### Discussion of findings and recommendations

Generally, although the five independent variables influenced TI, the amount of variance explained by each individual variable was small. IPO had the greatest impact and explained 53% of TI variance. This shows the strength of policy implication in TI in Kenyan universities. Policies on BI use introduced in Kenyan universities play a very important role in university's capacity to innovate. Most of the universities investigated had ICT policy documents. Some universities had implemented online student results submission and had made it compulsory for all course providers to use this method. For those that did not, there was strong indication and intention to adapt the procedure. In the other determinants with positive impacts on IT, the capacity by which they explained the variance was small. This was an indication that there was a lot more room for improvement. For instance, more broadband was required because the demand outweighed supply. Universities require to purchase more BI to improve both download and upload speeds. The fact that income and level of education did not have any impact may have been as a result of the fact that many users are already literate in BI and the fact that BI purchase is the responsibility of the university. Users may purchase broadband (mostly mobile BI) from time to time depending on their personal use. Otherwise, for official use BI is freely available at the place of work.

### Conclusion and recommendations for further research

Generally, this research was a pilot study and the amount of data used was small. This is attributed to the fact that the researcher had no official permit to collect data. Most of the data utilised in the study was collected from a sample of 4 universities. A more comprehensive study that incorporates all the 67 universities in Kenya is recommended.

For CDC determinant measure, the study investigated only the basic user demands for BI for TI. Further research could extend this uses. Universities should improve BI infrastructure in order to increase its usability for purposes of innovation. Collaboration and external linkages with the universities is generally lacking. This is an area where more emphasis could be made to help universities improve their financial capacity to provide more services. In Kenya the demand for higher education far outstrips supply. There is little competition in higher education provision which discourages innovation. The government should increase the number of universities and middle colleges to provide high education to consumers. There is a close relationship between this study and technology adoption studies. Further research could study both the factors that influence BI adoption and link it up with this study.

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