CONFIRMATORY STRATEGIC IT IMPLEMENTATION FOR BUILDING INFORMATION MODELLING ADOPTION MODEL

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Abstract
Information technology (IT) developments in the construction industry require a proportionate response by construction professionals. Building information modelling (BIM) requires strategic changes to regular ways construction is carried out. Building information modelling adoption in Malaysia is elevating by recent efforts to sensitise construction professionals on the need to change towards strategic IT implementation. This paper builds on the theory of business process re-engineering and computer integrated construction section for BIM adoption model. Data was collected from 352 construction professionals (Architects, Quantity Surveyors, Engineers and Contractors). The data was analysed using SPSS v18 for descriptive and AMOS v18 for structural equation modelling. Descriptive results showed a high prevalence in the need for BIM competent professionals. Multivariate results revealed a high value in correlation within the measurement model for business process re-engineering and computer integrated construction. The second order confirmatory model showed that business process re-engineering and computer integrated construction exhibited high impact on strategic IT Implementation. Overall, the model explored, validated the conceptual framework on the impact of strategic IT implementation perception of construction industry professionals in Malaysia on the adoption rate of BIM. The result denotes the first part of the full adoption model which can be compared with adoption rate in other countries. Subsequent research focuses on the mediating effect of collaboration to BIM adoption and diverse sample selection.

Keywords: Adoption, Building Information Modelling (BIM), Construction, Information Technology (IT), Malaysia.

Introduction

Building information modelling (BIM) presents ample advantages for construction professionals which invariably leads to improvement in efficiency and client satisfaction. Smith and Edgar (2008) and McCuen and Suermann (2007) defined BIM as a digital representation of physical and functional characteristics of a facility serving as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life-cycle of a facility to insert, extract, update or modify information in the model to support and reflect the roles of that stakeholder. The model is a shared digital representation founded on open standards for interoperability. BuildSMART (2010) was of the opinion that "BIM is a new approach to being able to describe and display the information required for the design, construction and operation of constructed facilities. It is able to bring together the different threads of information used in construction into a single operating environment thus reducing, and often eliminating, the need for the many different types of paper document currently in use".

Building Information Modelling Adoption

Malaysian construction industry has experienced a tremendous growth since the implementation of the vision 2020 and currently ICT policies under the Tenth Malaysian Economic Plan has given a further boost to the construction industry. Building Information Modelling (BIM) implementation policies are in the formulation stages. Although Moh-Nor et al. (2009) highlighted the low knowledge levels of complex IT tools which acts as a catalyst to resisting a rapid pace of BIM adoption. In tertiary training, frameworks have been developed to help improve BIM skill set training for future Quantity Surveying graduates in Malaysia with recommendations towards increased awareness and initiating of proficiency training among staffs (Ali et al., 2015). Uncertainty in terms of legal liability for professionals involved in a BIM model also presents a hurdle (Rosenberg, 2006) with only improvement in legal maturity and contractual management need to overcome such uncertainties (Rezqui and Zarli, 2006;

Liu, 2010). The Standards and Industrial Research Institute of Malaysia (SIRIM) formulated a strategic IT plan to improve productivity within the construction industry under the auspices of the Economic Planning Unit (EPU) (EPU, 2009; SIRIM, 2009; Haron, 2013). Chong et al. (2014) through a mixed method approach developed a conceptual framework which forecasts future BIM development tending towards new initiative and regulation by government. Irrespective of all the perceived policies, implementation of ICT within the construction professionals remains at disproportionate levels (Ali et al., 2013; Haron, 2013; Enegbuma et al., 2014). Internet usage was found to increase efficiency and cost saving amongst Malaysian construction firm with construction professionals spending productivity time on the internet for email and information search which with BIM, such time could be channelled to model updates and collaboration (Mui et al., 2002; Haron, 2013). Similarly, research on ICT implementation in Malaysian construction firms found a slow pace in implementation (Jaafar et al., 2007; Haron, 2013). Among engineering consulting services firms, low trained personnel, adoption guidance and inadequate government support were found to adversely affect BIM adoption (Rogers et al., 2015). Effective strategic implementation is inadequate in Malaysian construction industry which invariably limits the proper implementation of building information modelling (Haron, 2013). This improper strategic outlook in the long run leads to failure in implementation as most ICT implementations are as a result of peer pressure (Li et al., 2000; Mui et al., 2002; Haron, 2013). Among contractors, cost of software was a barrier to adoption including staff resistance and inadequate knowledge. Consultants were of the opinion that cost and system stability are hindrances. Government agencies are sceptical about the compatibility and interoperability while academicians remained worried of the low pool of BIM experts in the industry (Harris et al., 2014). Adoption of BIM upgrades a firm's differentiation competitive strategy, ensuring survival and increase in productivity (Abidin et al., 2014). The first government project to fullly utilise BIM was launched in 2010 to build the National Cancer Institute (NCI) in Sepang (Ismail, 2014). In 2013, the National BIM Steering Committee was established by CIDB assisted by seven sub-committees namely; standards and accreditation, incentives, education and awareness (academia), national BIM component library, BIM guidelines, BIM special interest group and research and development (Ismail, 2014; CIDB, 2014; Enegbuma et al., 2014). In 2014, the Malaysian Chapter of BuildSMART international was officially registered in support of open BIM platforms and policy push for BIM (Ismail, 2014). This awareness drive by the government provides a positive leadership towards collaboration and improvement in BIM adoption (Vroom and Jago, 2007; Ofori and Toor, 2012). This paper aims at assessing the connection between business process changes experienced in the construction industry. The drive for better computer integrated construction and the theoretical position of collaboration in the construction industry is also assessed. To achieve this aim, previous literature were assessed to identify the factors affecting BIM adoption, an asseessment of the perception of cosntruction professionals and significance of the relationship between this factors. The subsequent section addresses the hypotheses standpoint. The methodology, results and discussion are presented and the implications of the research examined.

Business Process Re-engineering

Betts (1999) opined that business process redesign, process innovation and business process re-engineering (BRP) form an integral part of the same theories which are separated in terms of nomenclature. IT plays a vital role in BPR and thus several researchers have argued that expenditure on IT will yield benefits of productivity increment, improved efficiency and effectiveness, if there exists a focus shift on the technology to a rather critical analysis of its usage. To avoid the pit falls of implementing new IT over old processes, new processes to match IT such as organizational structure, procedures, practices and tasks should be adopted (Drucker, 1988; Schnitt, 1993; Liang and Cohen, 1994). The modus operandi of the construction industry is forced to transform and improve to meet the growing pressure from external politics, economic and various considerations (Amor and Anumba, 1999). Integrating IT systems with business processes reshapes and facilitates the organisational culture, performed task and coordinated activities (Davenport and Short, 1990; Hinterhuber, 1995; Hammer, 1990; Willcocks and Smith, 1994; Tapscott and Caston, 1993; Klenke, 1994; Alter, 1993; Davenport, 1993; Alshawi, 2007; Enegbuma and Ali, 2012; Enegbuma et al., 2013a,b). Cultural change of modifying the traditional standard process present great challenges (Sánchez and Valencia, 2011), where only a selected number of professionals utilize the BIM model (Iguarán, 2010). This denotes an adamant resistance to change towards new systems in the construction industry. The phenomenon known as people managers shows the importance of people effects towards how organisations adapt to new IT technologies. Hence, understanding ways to tap into individual creative energy, intelligence and initiative, managing change and allay fears to change is critical to implementation success (Towers, 1996, Cooper and Markus, 1995; Kennedy, 1994; Arendt et al, 1995; Alshawi, 2007). Several conflicts and apprehensions arose during BIM usage in Hong Kong, amongst issues noticed were the need for BIM interoperability which is significant for the smooth interoperability among the participants in the BIM model. Although BIM is accepted both a new tool and a new process, changes to people, processes, communication and work culture is unavoidable. Other conflicts includes computability of the design data, the information exchange and clashes among the BIM components, technical barriers - poor library, low running speed of the system and lack of table customization. Also, early contractor input is still lacking in Hong Kong with most design work done independently by architects or engineers. At industry level, innovative technology such as BIM requires more efforts and time to implement, thus faces resistance in current project processes and the prevalent fast track culture. Thus, business process re-engineering in the industry has an effect on BIM adoption and hypothesised that:

H1: There is a significant relationship between business process re-engineering (BPR) and BIM Adoption (BA)

Computer Integrated Construction

The concept of integrated computer environment research has been a subject of interest since the early 1990's, technology uptake has been seemingly slow due to the rapid development of IT systems and their inadequate effective implementation by the construction industry. Researchers and industrialists attempted to utilise IT as an enabling technology to reduce the problems of communication and information sharing within the construction industry (Alshawi and Faraj, 2000; Aouad and Wafai, 2002; Sarshar et al, 2004; Sarshar and Christianson, 2004; Arayici et al, 2005; Enegbuma and Ali, 2013). Someya (1992) opined that gradually, computer integrated construction (CIC) overcomes the challenges of immaturity in computer technology of hardware and software. This is aimed at improving effective and quick customer design and technological capability, integration of production and information, shorter development cycle for efficiency and strategic management to react to external changing environment. Similarly, Clifton and Sunder (1997) opined that CIC helps the industry share, exchange and manage knowledge through neutral knowledge interchange format. Bjork (1999) further fuelled the growing trend in information technology in construction (ITC) stressing for the need to define such discipline in research such as defining domains and boundaries, analysing the actual effects of IT in the overall construction process and tools testing beneficial to potential process re-engineering. Koskela and Salagnac (1990) in comparing CIC development across France, Finland, Japan and US, the perceived transformation need; the scale of the output of the construction industry; the degree of anticipatory action in the construction industry and overall R&D in construction are determinants in developing computer integrated construction. Clifton and Sunder (1997) supported the infusion of CIC in the reports of National Institute of Standards and technology for computer integrated knowledge system (CIKS) to cater for construction material, components and systems. Goh and Chu (2002) highlighted the positive lunch of the national code of practice, SS CP80:1999 by Construction Industry IT Standards Technical Committee (CITC) in Singapore after its establishment in 1998. CITC was tasked with establishing an industry-wide framework for the development and adoption of IT standards in the construction including effective facilitation of CIC and information standardisation in Singapore. To accomplish this task, a cultural change and adjustment in standards of practice is necessary. A mental focus shift from inherent dependence on government-driven initiatives and cost of change to be borne by government. The code was developed through a blend of international standards and adaptation to local industry practice. Thus, CIC presents effects BIM adoption and correlates to the aforementioned construct of business process change in the industry leading to the hypotheses that:

H2: There is a significant relation between computer integrated construction (CIC) and BIM adoption (BA)
H2a: Business process re-engineering (BPR) and computer integrated construction (CIC) are correlated

Collaborative Processes

Jayasena and Weddikkara (2013) emphasised on the need for collaborative processes in the construction industry which they posit helps in assessing BIM maturity. "Collaboration can further be seen a working together in a seamless team for common objectives that deliver benefit to all.

Collaboration is more effective when undertaken at the project inception stage" (Anumba and Newnham, 2000). Yeomans et al. (2006) also argues that there is no resulting disadvantage from adopting collaboration practices in the construction industry. The driving force to collaborate is dependent on the commitment of the project team, merger of collaborative ideals with procurement systems and developing a means to capture and report the benefits. Sommerville and Craig (2006) argued that the increase usage of IT in business processes resulted from the increased awareness of the benefits of open collaborative efforts by project teams in the construction industry. The push for effective collaboration will inadvertently provide higher productivity and returns on investments for clients increased demands. Arayici et al. (2011) and Arayici et al. (2012) argued that active collaboration and learning by carrying out practical tasks during BIM implementation improved BIM adoption between practitioners and researchers. This approach was utilised under the auspices of knowledge transfer partnership (KTP) in John McCall Architects (JMA). Yeomans et al. (2006) expressed the need for certain project teams to provide extra effort towards achieving collaboration, however, in Malaysia current literature is inconclusive as to which project team members should engage more for a push towards effective collaboration. The apprehension of distrust and litigation processes often leads to ineffective collaboration. The non-collaborative nature of the construction industry is fuelled by the rampant silo working mode, where all intelligent, coordination and agility advantages gained in a collaborative environment are corrupted or lost (Owen et al., 2010; Jayasena and Weddikkara, 2013; Enegbuma et al., 2014). Thus, collaborative processes serves to mediate between business process re-engineering and computer integrated construction to improve BIM adoption and hypothesised that:

H3: There is a significant relationship between collaborative processes (CP) and BIM adoption (BA)
H4: There is a significant relationship between collaborative process (CP) and business process re-engineering (BPR)
H5: There is a significant relationship between collaborative processes (CP) and computer integrated construction (CIC)

Insert Figure 1

Methodology

Stemming from a quantitative approach, the research epistemology is driven by the positivist view. This targets examining and deriving an explanation for BIM adoption in Malaysian construction industry. To derive the relationship between the variables of this paper, alternate hypotheses were stated as opposed to the null hypotheses (Creswell, 2008). Appropriate representation within the population requires adequate sample frame, selection and size (Fowler, 1993; Paschke, 2009). A random sampling frame to collect data from a subset forming a representative data for the group was utilized (De-Vaus, 2002). The sample frame from previous research in IT and BIM were studied and a frame developed covering medium to large construction organization in addition to CIDB Class-A contractors (Son et al., 2012; Lowry, 2002; Peansupap and Walker, 2005; Davis and Songer, 2008; Jacobsson and Linderoth, 2012; Peansupap and Walker, 2006; Miller et al., 2009; Brewer and Gajendram, 2011; Samuelson, 2011; Davies and Harty, 2013; Son et al., 2014; Xu et al., 2014). The aforementioned previous studies possessed an average sample size range of 255 respondents. Hair et al. (2010) specified a sample a minimum sample size of 200 for structural equation modelling (SEM). The primary respondents were construction professionals (Architects, Quantity Surveyors, Engineers and Contractors) possessing knowledge on challenges faced in BIM adoption. 352 responses were screened following the steps for structural equation modelling (SEM) outlined by Hair et al. (2006, 2010). A total of 292 were usable and fell within the minimum threshold for SEM multivariate analysis (Hair et al. 2006, 2010; Awang, 2012). The research instrument contained four section measuring BPR, CIC, CP and BA with items in Table 1.

Insert Table 1.

The measure of reliability for all items were first carried out before the test for content and discriminant validity. The measurement model was tested to meet the required model indices and subsequently the structural model was assessed.

Results and Discussion

The demographic result in Table 2 showed that designation of respondents is Architects (37.3%), Quantity Surveyors (17.8%), Engineers (32.5%) and Contractors (12.3%). The major age bracket fell within 25-35 years (55.1%). Private sector accounted for 65.5% of the construction professionals. A total of

52.6% held a position of junior management in their respective firms while 59.4% possess a bachelor degree. 54.6% of the professionals were equipped with a minimum of 6-10 years working experience in the construction industry and subsequently registered with various professional affiliations. 45.1% of the professionals expressed the opinion that they fell into the beginners' category of experienced BIM users.

Insert Table 2.

With the adoption of BIM the industry continues to see an upward shift in the adoption of BIM. Architects utilise more of Autodesk Revit for design purposes while the BIM collaborative element still need improvement in line with other construction professionals. The lower age bracket of professionals predominant in this study highlights an increasing rate of skill acquisition towards BIM. However, the experience in the industry plays a vital role towards policy formation and drive to collaborate in practice. The private sector push for BIM within the sample highlights need for a competitive advantage in project bid and execution. This will in the long run complement the recent involvement by the government sector.
The Instrument pool generate for all the constructs were measured for internal consistency and showed that all constructs were above threshold of >0.60. Items which failed to meet the criteria were screened at the instrument cleaning stage. In the one factor congeneric model, all constructs showed discriminant validity and convergent validity (Hair et al., 2010). The measurement model examined by covariance of all constructs, a prelude to the attributes of the structural model showed that all Fit indices were within the acceptable thresholds as shown in Table 3.

Insert Table 3.

The next step after measurement model examination for fit indices was the assessment of the structural model. The major aim is to examine the validity of the relationship within the structural model. The hypotheses of the structural model was exhibited previously in Figure 1 indicating the direction of impact and relationship between all constructs. The examination of the goodness of fit indices in Figure 2 indicates a mode fit in accordance with the data from respondents and aligns with BIM theory. The indices showed that X2/df is 2.4 which fell within the acceptable threshold of ≤ 2-5 (Hair et al., 2010). The CFI and GFI are 0.90 and 0.91 respectively which also fell within the acceptable threshold (Hair et al., 2010).

Insert Figure 2.

The next step assesses the strength of the relationships to denote the overriding hypothetical standpoint on this research. The path coefficient is determined by the regression weights shown in Table 4. Constructs with critical ratio (C.R) above 1.96 are considered to be statistically significant in the model (Hair et al., 2010). Out of the 5 hypotheses generated, 4 were statistically significant while one construct the impact of computer integrated construction on BIM adoption was found to be statistically insignificant in this model. The results suggest the construction professionals currently feel overburden by the need to upgrade IT systems in their daily work practice. Although, IT promises to automate and improve for a more efficient construction process, the reactions by the construction professionals to match the rapid development in BIM calls for more proactive hands-on experience.

Insert Table 4.

Previous research posited that business process re-engineering has an effect on BIM adoption (Alshawi, 2007; Betts, 1999; Davenport and Short, 1990; Hinterhuber, 1995; Hammer, 1990; Willcocks and Smith, 1994; Tapscott and Caston, 1993; Klenke, 1994; Alter, 1993; Davenport, 1993) and this was confirmed by the findings of this research. This suggests that the current process change in the industry falls within the perception of the construction professionals in Malaysia. This alignment will invariably lead to improved BIM adoption. A strong direct impact (51%) was exhibited by this construct on BIM adoption.

The correlation of the two construct argued by this research resulted in linking business process re-engineering and computer integrated construction which was confirmed by a strong value (0.58). This implies that the future alignment of business process re-engineering and computer integrated construction will continually improve BIM adoption as theorized by the authors. Contrary to previous research (Alshawi and Faraj, 2000; Aouad and Wafai, 2002; Sarshar et al., 2004; Sarshar and

Christianson, 2004; Arayici et al., 2005; Someya, 1992) computer integrated construction exhibited a statistically insignificant effect in this study. Hence, it suggests that the construction professionals are yet to align with this perception. Collaborative process was found to have a statistically significant effect on BIM adoption which was in line with previous research (Jayasena and Weddikkara, 2013; Arayici et al., 2011; Arayici et al., 2012; Yeomans et al., 2006; Owen et al., 2010). However, business process re-engineering and computer integrated construction both had a statistically significant effect on collaborative processes. This fortifies the initial hypotheses arguing towards the need to examine this constructs as mediated by collaborative processes in the construction industry. Overall, the variance extracted (0.30) accounted for the explanation of the features of BIM adoption in Malaysia while collaborative process (0.05) portrayed a significantly low figure which will be improved as the industry drive towards improved collaboration among construction professionals .

Conclusion

This paper set out to examine the relationship between several constructs affecting BIM adoption in Malaysia. This was achieved through an assessment of the SEM model fit indices and strength of relationship within the constructs. The argument for correlation and mediation of constructs derived from past research informed the model formation which assesses BIM adoption. The goodness of fit of the structural model preceded by the measurement model further strengthened the hypotheses developed. The significant relationship were established with four statistically significant relationships. From the findings, it is recommended to improve grey areas such as the standard forms of contract to improve collaboration in the construction industry among the construction professionals. Addendum and clauses which improves and encourages collaboration should be added as observed in other more matured BIM construction industry. Continual formulation of BIM favorable policy is encouraged. The model can be utilized for future research in assessing the perception from other key stakeholder in the construction industry.

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Table 1. Items Measuring Constructs

BPR1	Malaysian construction industry is changing its business process to suite building information modelling
BPR2	Malaysian construction industry provides support for building information modelling training
BPR3	Malaysian construction industry policy encourages recruitment of building information modelling proficient staffs
BPR4	Malaysian construction industry provides adequate research and development into IT in construction
BPR5	Malaysian Construction Industry has a clear implementation framework for Building Information Modelling
CIC1	I feel IT drives for full automation in the construction industry
CIC2	I feel more research into IT integration in construction should be encouraged

CIC3	I feel construction industry has adapted quickly to IT improvements
CIC4	I feel division of project teams affects IT usage and development in construction
CIC5	I feel BIM provides an intelligent IT solution to the construction industry
CIC6	I feel information technology (IT) usage is dependent on the project size
CP1	I feel current communication is adequate for collaboration
CP2	I feel current standard forms of contract encourage Collaboration
CP3	I am comfortable with the current stage of work where collaboration is introduced
CP4	I feel collaboration aligns the project objectives and teams
CP5	I feel there is sufficient building Information Modelling collaboration protocol documents in the industry
BA1	Building Information Modelling will expose me to new ways of reasoning for projects
BA2	I will be comfortable with collaboration with project teams
BA3	Greater communication will be achieved amongst project team members
BA4	Building Information Modelling draws the construction industry closer to the set Construction Industry Master Plan (CIMP)
BA5	Cost saving will be achieved through Building Information Modelling
BA6	Overall client satisfaction will be achieved with Building Information Modelling

Table 2. Demographic of Respondents

		N	%
	Architect	109	37.3
Designation	Quantity Surveyor	52	17.8
	Engineer	95	32.5
	Contractor	36	12.3
Gender	Male	225	77.1
	Female	60	20.5
	Below 25years	23	8.7
Age Bracket	25-35years	146	55.1

	35-45years	95	35.8
	Above 45yrs	1	0.4
Construction Sector	Public Sector	96	34.5
	Private Sector	182	65.5
	Executive	25	9.2
Position in Establishment	Senior Management	104	38.2
	Junior Management	143	52.6
	1-5years	113	40.4
Years of Experience	6-10years	153	54.6
	11-15years	13	4.6
	16-20years	1	0.4
	Beginner	129	45.1
Level of BIM Involvement	Novice	127	44.4
	Intermediate	27	9.4
	Advanced	2	0.7
	Expert	1	0.3

Table 3. Goodness-of-fit Indies for measurement model

Fit Index	**Acceptable Fit**	**Indices for data**
χ^2		234.08
df		97
p	<0.05	0.00
χ^2/df	≤ 2-5	2.41
RMR	<0.06	0.03
CFI	≥0.90	0.90

GFI	≥0.90	0.91
RMSEA	≤0.05-0.80	0.70

Table 4. Structural Model Estimates and Hypothesis Testing

			Estimate	S.E.	C.R.	P	Label	Hypotheses
CP	<---	BPR	0.715	0.341	2.094	0.036	par_15	Significant
CP	<---	CIC	-0.435	0.188	-2.314	0.021	par_16	Significant
BA	<---	BPR	0.677	0.199	3.410	***	par_14	Significant
BA	<---	CIC	0.026	0.085	0.302	0.763	par_17	Insignificant
BA	<---	CP	-0.086	0.031	-2.740	0.006	par_19	Significant

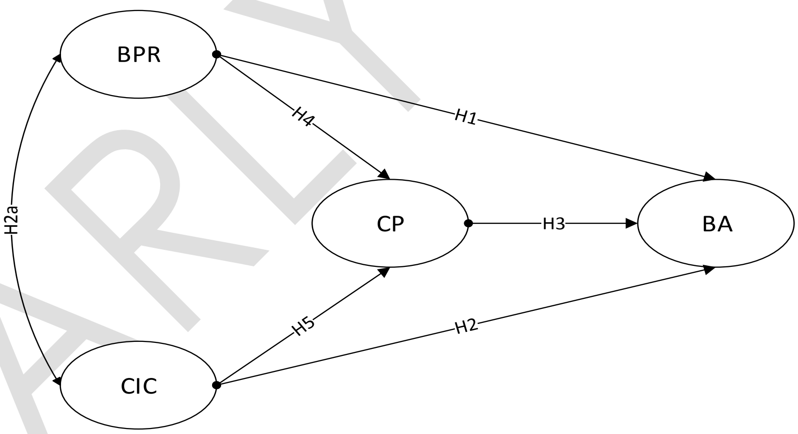

Figure 1. Hypothesised Model

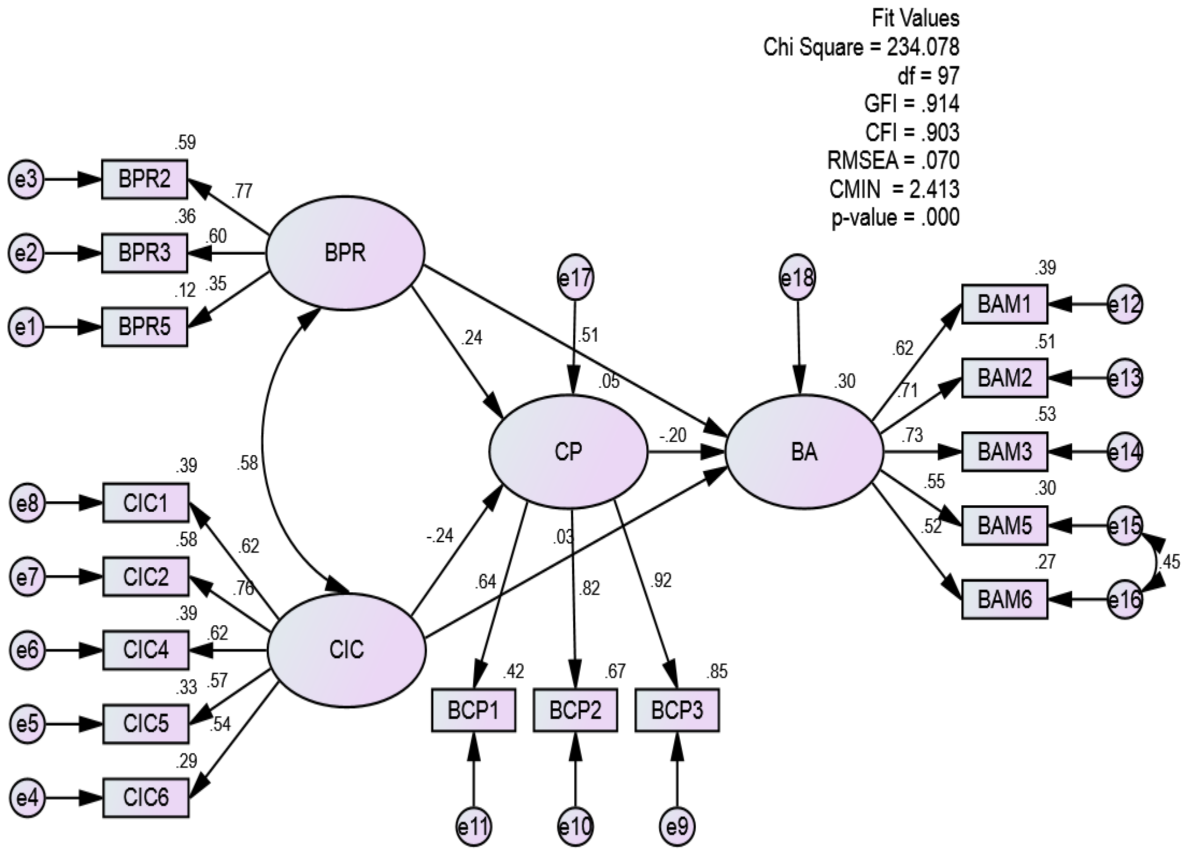

Figure 2. Structural Model