Maturity model of building maintenance management for New Zealand's state schools

An Thi Hoai Le[a,c]*, Niluka Domingo[a], Eziaku Rasheed[a] and Kenneth Park[b]

[a]School of Built Environment, Massey University, Auckland, New Zealand; [b]College of Engineering and Physical Sciences, Aston University, UK; [c]Faculty of Construction Economics and Management, National University of Civil Engineering, Vietnam

Address Correspondence to An Thi Hoai Le, email: a.lethihoai@massey.ac.nz; anlth@nuce.edu.vn

Abstract

In New Zealand (NZ), state school properties are owned by the Ministry of Education and operated by school managers with the assistance of external consultants. This study aims to explore relationships of key stakeholders to propose a set of improvement actions for building maintenance management (BMM) in NZ's state schools. The research employed a sequential mixed-methods approach encompassing interviews with school managers at the exploratory stage and questionnaire surveys completed by school managers and the Ministry staff to identify the maturity level of BMM. The interviews' findings were used to map roles and responsibilities of people involved in BMM and develop the measurement model used in this study. Based on data from the questionnaire, relationships among key stakeholders in BMM were examined using Partial Least Squares Structural Equation Modelling (PLS-SEM). The research hypotheses of correlation among the stakeholders were tested and validated. The questionnaire results were also analysed to identify the maturity level of stakeholders' responsibilities in BMM. Suggestions were made for improving BMM for NZ's state schools focusing on training programmes, reporting system, performance evaluation, and lesson sharing. The results could assist stakeholders to review their current BMM and identify the areas in need of improvement.

Keywords: building maintenance, maturity model, school buildings, New Zealand, PLS-SEM

INTRODUCTION

School buildings and infrastructure are not only supposed to provide a pleasant and safe environment for staff and students but are also clearly visible representations of the education system's quality (Abdelhamid, Beshara, & Ghoneim, 2013; Trachte & Herde, 2015). Therefore, it is important to ensure that school properties are well maintained. School managers, practitioners, authorities, and researchers have become aware of the links between building standards and learning outcomes. As a result, academic and practical interest in maintenance management for schools has increased substantially (Akasah, Amirudin, & Alias, 2010; Ampofo, Nassè, Amoah, & Peprah, 2020; Bennett et al., 2019)

In addition to addressing technical issues of building maintenance management (BMM), it is also essential to explore how key stakeholders in this field collaborate. After all, managing school buildings often requires an interdisciplinary team to work together towards a common goal. This is especially true in the context of state schools, where school managers are managing the property on behalf of another party (state, local council) but lack professional knowledge in maintenance management, so that they often have to rely on external consultants or service providers (Le, Domingo, Rasheed, & Park, 2020). Because collaboration arises when stakeholders have limited abilities to complete a given task which requires them to combine their abilities with the knowledge and skills of others to ensure the completion of tasks (Kalay, 2001); the collaboration is more important in managing school property.

Previous studies have explored the importance of collaboration of key stakeholders to ensure the achievement of maintenance management goals. Some researchers focus on communication among key stakeholders (Au-Yong, Ali, Ahmad, & Chua, 2017; Fliervoet & van den Born, 2017; Reymen, Dewulf, & Blokpoel, 2008), while others center on differences of information form including feedback system for collaboration in BMM (Ismail & Shah, 2010). However, few attempts were made to establish models to examine relationships among key stakeholders in relation to promoting the improvement of BMM. This lack of an established model to study the relationships means that the stakeholders' involvement in BMM and their relationships with one another are not yet fully described. Given these gaps, this study investigates roles and responsibilities of key stakeholders in BMM and develops a measurement model to examine their relationships. This research also presents a maturity model that can be used to assess current maturity levels of the stakeholders' responsibilities in BMM. Recommendations are made based on the identification of the weaknesses in the current process.

LITERATURE REVIEW

Building maintenance management (BMM) practices

Buildings are long-lived products, which are typically designed to last 50-60 years, and approximately 75%-80% of buildings' total life-cycle costs occur in the use and maintenance stage (Madureira et al., 2017). Regardless of type, size, or location, buildings are required to be maintained properly to perform their functions and meet users' expectations. Gradually, building maintenance has been considered a major activity in the construction industry and comprises more than 50% of total construction outputs (Falorca, 2019; Nita Ali, Sun, Petley, & Barrett, 2002); therefore, it has received the attention of stakeholders including owners, users, policy-makers and researchers.

Due to the importance of building maintenance, public authorities and organisations have established sets of guidelines, standards, policies, and academic studies focusing on maintenance management of public buildings such as government offices, social housing, hospitals, and educational buildings (Falorca, 2019). In 2011, the British Standards Institution (BSI) published European Standard BS EN 185531: 2011 which outlines the criteria and methods for planning, management and control of building maintenance in consideration with legal requirements, owners' objectives, users' expectations and the required quality of maintenance (BS EN 15331:2011, 2011). More recently, the International Standard Organisation launched a series of standards, ISO 55000, in 2014, which provide a framework of requirements for managing of the use of physical assets (ISO 55000, 2014). The framework contains guidelines on "what you must have" to ensure that their system complies with the standards, but the organisation needs to determine the best way "how to achieve" the standards themselves. Last year, BSI published BS 8210:2020 (Guide to Facilities Maintenance Management) to help top management to understand how to manage facilities maintenance including maintenance strategies and policies, and the impacts of different facilities maintenance approaches to the core business of the organisation (BS 8210:2020, 2020). This standard can apply to most types of building-related facilities such as health care, education, housing, communication and transportation. However, like the ISO framework, this standard does not give recommendations on how to carry out the services. In the housing sector, Queensland's Department of Housing and Public Works (DHPW) issued a

Maintenance Management Framework as a high-level direction to manage public buildings in the State. The framework contains 14 policies which are categorised into three groups: planning, implementation and information & systems providing principles and practices to manage public assets in an effective and efficient way (DHPW, 2017).

More specifically, in relation to maintenance management of school buildings, authorities, researchers and community agree that effective school maintenance maximises capital investment, ensures health and safety of staff and students, and supports learning and teaching activities. US Government authorities introduced "Planning Guide for Maintaining School Facilities" to help schools understand why and how to develop, implement and evaluate a facilities maintenance plan (Education, 2003). This guideline also contains best practice and examples of evaluation questions to help school stakeholders improving facilities management programs. With the same purposes, the Australia's Victoria State Government provided a "school policy and advisory guideline", which is web-based with a set of policies to support property and asset management in schools. The guideline has been structured with different topics such as "planned maintenance program", and "asset information management system". Each topic has three sub-tabs - advice, guidance and resources - that provide necessary information for managing school property projects. Similarly, the Department for Education in England have introduced a web-based manual "good estate management for schools" in 2018 and updated in 2020 (Department for Education, 2018). The manual provides advice, tools and checklists for schools and responsible bodies to manage their land and buildings effectively.

Findings from the review of the above standards and guidelines reveal that BMM can be divided into different phases; however it is usually grouped into two parts: defining the strategy, and implementing the strategy (Crespo Márquez, Moreu de León, Gómez Fernández, Parra Márquez, & López Campos, 2009). In the strategy part, maintenance strategy usually involves establishing guidelines for how to develop the maintenance objectives, policies, plans, procurement and evaluation (55001:2014, 2014; DHPW, 2017). Having established the maintenance objectives for a building portfolio, the next step is to consider how to achieve the objectives. This usually involves creating a strategy to determine what maintenance works need to be done, when, , the budget, and how the work can be done safety (RICS, 2009). There are two typical maintenance strategies: preventive and corrective (Madureira, Flores Colen, Brito, & Pereira, 2017; Ruparathna, Hewage, & Sadiq, 2018). Izobo-matins and Olotuah (2018) stated that an appropriate maintenance strategy is fundamental to ensuring the success of BMM.

The selected strategy (preventive or corrective) starts with conducting a condition assessment to evaluate the physical, functional and service aspects of building facilities and services. Without this information, one could not formulate maintenance activities and estimate costs (Straub, 2003). The use of condition assessment is typical means to collect relevant data for a comprehensive inventory (55001:2014, 2014) . It is suggested that the more regular a condition assessment is conducted, the better for maintenance planning. However, the cost is one of the challenges and redundant information also wastes resources. Therefore, the assessment should be carried out in combination with other important activities such as during maintenance and operation (Dejaco, Cecconi, & Maltese, 2017). Publications have been introduced as guidance on methods for building condition assessment in different countries including UK, Portugal, Dutch, Australia (António Costa Branco de Oliveira Pe, Ângelo Vasconcelos de Paiva, & José Dâmaso Santos Matos Vilhena, 2008; Government, 2017; Straub, 2009; Wilson & Bellis, 2019). Once the condition assessment is complete, a maintenance plan with prioritised projects/tasks is developed in consideration with the resource available. The procurement process follows involving contractor selection and implementing the maintenance plan.

Key stakeholders involved in BMM usually include top management (owners/public authorities), maintenance and property departments, service providers, and users. They all have specific roles and tasks to perform at different stages of the maintenance management cycle (Ampofo et al., 2020; Au-Yong, Ali, Ahmad, et al., 2017). The top management position is usually held by building owners and has the highest responsibility for BMM. With the assistance of maintenance managers, service providers and consultants, top management establishes maintenance strategy, policy, and procedures that align with organisational objectives. The policy usually defines roles and responsibilities of the different stakeholders and develops communication protocols for the people involved in the process.

Previous research has been established that the BMM framework has been developed with guidelines, standards, policies, and process. However, issues and challenges still exist. Yin (2008) emphasised the gaps between the strategic and operational levels such as communication between top management and maintenance team preventing BMM efficiency. Other researchers stated that the lack of capacity and capability of people involved is a key challenge in BMM (Au-Yong, Ali, Ahmad, et al., 2017; Le, Domingo, Rasheed, & Park, 2019). It is common that public authorities employ external service contractors to perform maintenance projects/tasks. In this situation, researchers agree that it requires great collaboration of stakeholders to minimise issues in information exchange and communication (Falorca, 2019; Hauashdh, Jailani, Abdul Rahman, & Al-fadhali, 2020). However, there has been little attempt to explore the stakeholders' maturity level of responsibilities or to examine their BMM relationships.

Maturity model for assessing stakeholders' relationships

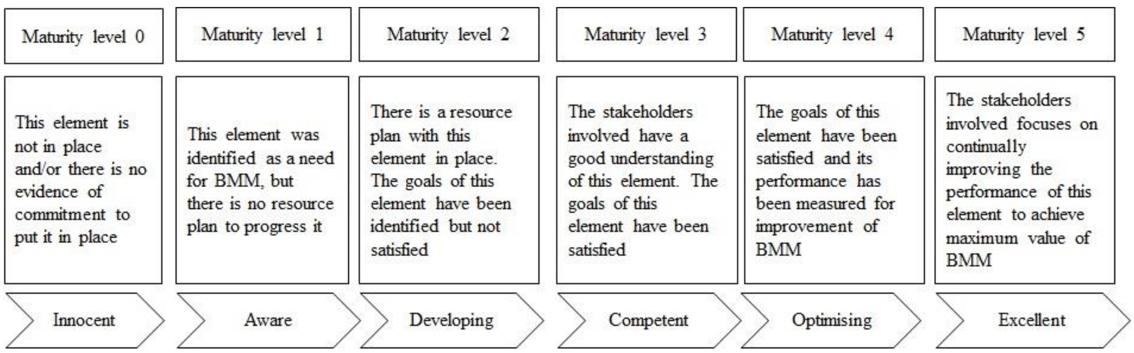
"Maturity model" is a conceptual framework, initially used in software engineering, that describes current maturity levels of an organisation's services or specific tasks whereby organisations can develop improvement actions to achieve the higher levels of the model (Project Management Institute, 2013). In areas of building asset maintenance management, The Institute of Asset Management (2015) introduced a self-assessment methodology (SAM) for use with the International Standards of Asset Management (ISO 55000). There are six levels of maturity in the model, covering a total of 39 indicators for asset management based on ISO 55000 requirements. This model has been adopted by Australia Asset Management Council (2017) to develop an asset management maturity assessment tool for public assets, which helps organisations to benchmark their current maturity level and develop targets to reach the next level. Similarly, in NZ, Treasury has developed an asset management maturity assessment based on ISO 55000 which helps reveal the extent of differences between current and target levels of asset management maturity for each government agency (The Treasury

NZ, 2017). This literature review of existing models concludes that maturity model frameworks can be adopted to assess maturity level in BMM.

The maturity model framework has been widely adopted in assessing stakeholders' relationships in business processes. Meng, Sun, and Jones (2011) provided a literature review on the use of the maturity model concept in assessing relationships in the supply chain sector. The model focuses on relationships between customers and suppliers rather than the whole supply chain. Later, (Gimenez, Labaka, & Hernantes, 2017) established a maturity model that captures the involvement of stakeholders in order to develop a path for the evolution of the city resilience building process. Most recently, Santos, Mota, and Alencar (2021) also introduced a maturity model for the supply chain strategy in order to improve the capabilities of the supply chain management process. `

The maturity model used in this study was adapted from the structure, definitions, and distribution of the ISO 55000 assessment model to assess relationships of stakeholders in BMM. As shown in Figure 1, there are six levels of maturity in this model. Characteristics of each maturity level were defined to capture the understanding, goals, and resources for each stakeholder activity. Results of the assessment allow the stakeholders to review their current maturity and demonstrate improvement actions to reach higher maturity levels.

Figure 1: Maturity Model for BMM



Case study for maturity level and stakeholders' relationships in school building maintenance management in New Zealand

In New Zealand, the MoE manages all state school property, which encompasses over 2,000 schools with over 15,000 buildings and 35,000 classrooms situated on approximately 8000 hectares (Ministry of Education, 2020). Each NZ state school is required to develop a short-term and long-term property plan to identify capital projects and maintenance work to ensure that the school property is well maintained and fit for purpose. As stated by MoE, managing each school property involves multi-layered relationships among schools' stakeholders, which include the MoE property board (PO), property regional advisors (PA), school board of trustees (SC), external consultants referred to as project managers (PM), and property planners (PP). PO has the role of top management, while PA are property department staff. PP and PM serve as external consultants who help schools plan and implement property projects. SC act as users and are responsible for the day-to-day operation of school buildings and infrastructure. PO, PA, SC, PP, and PM are required to work together to fulfil the BMM objectives. Due to the multi-layered relationships, it is important to clearly define their responsibilities, and explore their relationships in BMM to improve the overall performance of schools' BMM.

RESEARCH METHODOLOGY

This study has been led by a combination of inductive and deductive approaches. Initially, inductive reasoning was used to build patterns and theories on the relationships of key BMM stakeholders and then a deductive approach was used to test the hypotheses, leading to the confirmation of the theories. Based on this combination of inductive and deductive approaches, a sequential mixed methods approach was employed.

The data collection started with inductive approach by semi-structured interviews to develop the research hypothesis. Due to geographical issues, time, and resource limitation, purposive sampling was used to select the participants for the qualitative data collection stage. This aims to produce a sample that can be logically assumed to represente the whole population (Lavrakas, 2008). An invitation was extended to school principals or administrators with a request that it be sent to those responsible for property matters at the school, and 13 stakeholders agreed to participate. To refine the information provided from those stakeholders affiliated with the schools, ten Ministry advisors were also contacted and two accepted the invitation. As each Ministry advisor managed 35-50 schools, these two advisors can be considered sufficient to validate the information provided by the school-based participants.

The interview questions were designed to gain information on the current processes in BMM, including activities, procedures, roles, and responsibilities of the people involved. Apart from questions about participants' background, the interviews included three main questions: (1) who are key stakeholders in BMM, (2) what are their roles and responsibilities, and (3) how do they work together to achieve the BMM goals and objectives. Interviews were conducted at participants' offices and usually took about 45 to 60 minutes to help the researchers understand the practice of BMM. After the 15th interview, all the questions were explored in detail and no new idea or theme was found to emerge, indicating saturation had been reached. Therefore, the qualitative data collection was considered completed at this stage. Each interview transcript was read several times to ensure that all relevant information from the interviews was identified and was analysed following the same steps and procedures to ensure consistency. The interview findings s were used to build patterns and propose a hypothetical model linking the relationships among the people involved in BMM.

In the second stage of data collection, a questionnaire with structured questions was devised to derive relationships between the responsibilities of the key BMM stakeholders. The questions were grouped into three main sections. First, participants were asked questions about their backgrounds and schools' information. The second section of the questionnaire was designed to identify the current maturity level of BMM, with five sub-sections focusing on the capabilities of PO, PA, PP, PM, and SC as presented in Table 1. Each question asked the respondents to assess a maturity feature on a scale between 0 and 5. Based on the answers to the questionnaire, it was then possible to calculate all the maturity indexes of the process areas. The questionnaire was designed to collect data on the maturity levels of all processes involved in BMM and therefore participants were needed that were familiar with all processes.

Based on this consideration, the choice fell on SC and PA, who are involved in all BMM processes. Due to time and resource constrains, the questionnaire was only sent to a half the schools on the list which is available on the Ministry’s website (every second school). Regarding the sampling for PA, there were 48 PA listed on the Ministry's website and their contacts were extracted. The invitation email was sent to all PA directly. There were 148 valid responses, including 140 respondents from schools and 8 Ministry advisors.

FINDINGS

Findings from qualitative data analysis

Among 15 interviewees, seven were principals/deputy principals who took the highest responsibility for the property management in their schools. Six participants were responsible for property management in their schools, namely one property manager, two executive officers, and three business managers. Nine of these school-based participants had been working for over ten years in the field of school property management, and others had at least two years’ experience in their current position. Five participants were working for primary schools while eight were serving at secondary schools. Among the two Ministry advisors, one had worked in this field for more than 15 years, while the other had two years’ experience. All participants were experienced at middle and strategic management level positions, which ensures the credibility of the qualitative data. The consistency in the answers among the participants proves the reliability of the interview process.

The interviewees were asked about the current involvement of stakeholders in BMM, including information on who is involved in the process, their roles, and their responsibilities in each process. The information provided by the participants and findings from the literature review are summarised in Table 1. At the top management level, the MoE has a leadership and management role for the BMM. The MoE provides policy initiatives, a regulatory environment, and funding for the BMM. There is a property board at the Ministry to organise and maintain the property management system, including information management, monitoring process, training, and communication. The PA are based in regional offices to help schools manage their day-to-day property matters. PP and PM are external consultants who are pre-approved by the Ministry to assist schools in developing property plans and implementing property projects. PP engage with SC to prepare the 10YPP and PM are employed to help schools manage and perform the approved projects. Schools, with advice from PA, PP, and PM, decide how to use the PMG to maintain their properties. In-depth discussions were held during the interviews to investigate the specific roles and responsibilities of PO, PA, PP, PM, and SC in the BMM.

Based on the information provided by the participants, Figure 2 below illustrates the hypotheses that are investigated in this study. PO has the highest responsibility for BMM, so it was hypothesised that PO influences all other stakeholders. Similarly, PA works as the advisor staff dealing with all requirements from school and external consultants, so PA are considered to impact the maturity level of responsibilities performed by PP, PM, and SC. Since PM is responsible for the management and implementation of the approved property projects and for recording interventions of school buildings and infrastructure, it is hypothesised that

PM affect the performance of PP and SC. Finally, PP, who prepare the 10YPP for schools, are believed to impact on the maturity level of SC.

Figure 2: Organisational structural in BMM

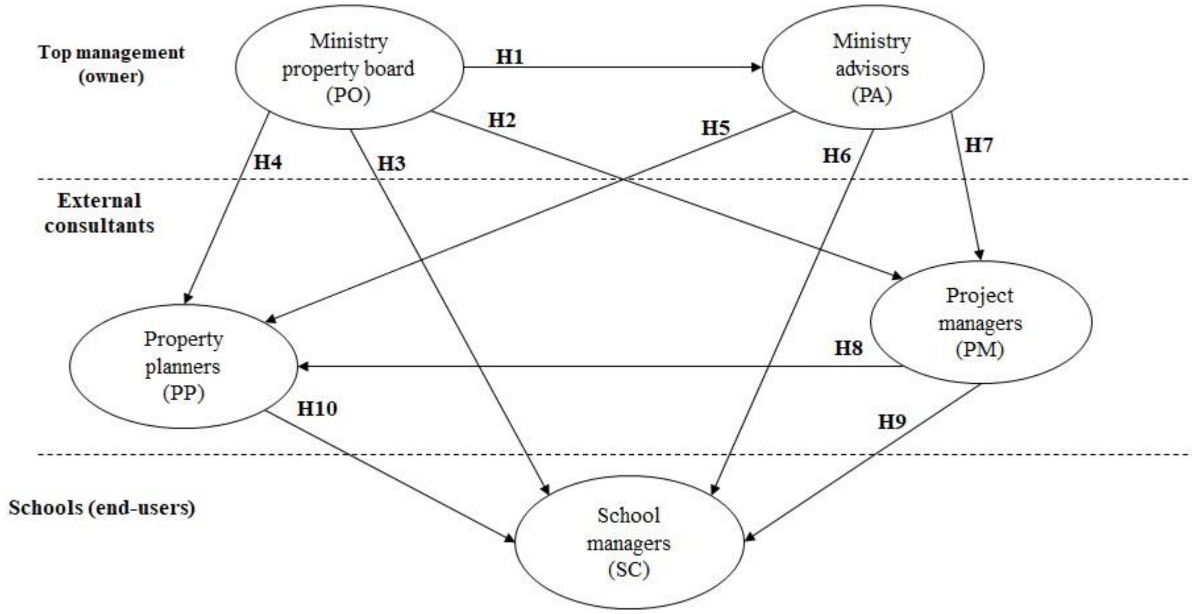


Table 1: Roles and responsibilities in BMM

Code	Roles and responsibilities
PO	***Ministry property boards***
PO1	Planning long-term strategies for BMM
PO2	Providing policies for delivery of BMM
PO3	Providing a communication platform for people involved in BMM
PO4	Defining responsibilities of people involved in BMM
PO5	Providing training programs for people involved in BMM
PO6	Establishing a performance evaluation framework for BMM
PO7	Calculating and paying funding for BMM
PO8	Establishing a reporting system for collecting feedback and required information
PO9	Reviewing the BMM system against the long-term strategy
PO10	Enhancing improvement actions for better delivery of BMM
PA	***Ministry property advisors***
PA1	Understanding their roles and responsibilities in BMM
PA2	Co-ordinating completion of 10YPP for schools
PA3	Supporting schools to complete their property plans
PA4	Connecting schools to top management
PA5	Monitoring school property projects
PA6	Sharing knowledge and lessons to help schools resolve property issues
PA7	Helping schools improve their property maintenance outcomes
PP	***Property Planners***

PP1	Understanding their roles and responsibilities in BMM
PP2	Conducting condition assessment
PP3	Preparing 10YPP
PP4	Estimating the required funds for the plan
PP5	Ensuring asset condition information is updated in the MoE's property condition database and shared with the schools
PM	***Property Managers***
PM1	Understanding their roles and responsibilities in BMM
PM2	Selecting appropriate contractors for the approved projects
PM3	Ensuring project implementation in an effective and timely way
PM4	Helping schools prioritise maintenance tasks for the constructed facility
PM5	Ensuring required information is updated in the MoE's property database and shared with schools
SC	***School Property Board***
SC1	Understanding their roles and responsibilities in BMM
SC2	Understanding staff and students' needs for school buildings and infrastructure
SC3	Ensuring property projects align with school activities and objectives
SC4	Complying with legal and MoE requirements for BMM
SC5	Engaging with PP and PA to prepare property plans
SC6	Ensuring day-to-day maintenance of school property
SC7	Ensuring their school follows the approved property plan
SC8	Recording and managing required information for BMM
SC9	Collecting and sharing lessons for improvement of BMM

Development of a structural and measurement model

For the purposes of this study the maturity level is measured based on the roles and responsibilities of those involved in BMM. This allows for the development of clear measurement criteria that are not affected by activities and processes being performed by different people. SC, PO, PA, PM, and PP are constructs or latent variables which are not directly measured or observed but are inferred from the questionnaire indicator scores using factor analysis. Therefore, the five exogenous constructs (presented in Figure 3) were measured to evaluate the overall maturity level of BMM. The study hypothesised that the stakeholders' performances influence one another and thereby contribute to the overall performance of BMM. Figure 3 also represents the direction of the hypothesised influences in the structural model:

H1: PO significant positively influences maturity level of PA

H2: PO significant positively influences maturity level of PM

H3: PO significant positively influences maturity level of SC

H4: PO significant positively influences maturity level of PP

H5: PA significant positively influences maturity level of PP

H6: PA significant positively influences maturity level of SC

H7: PA significant positively influences maturity level of PM

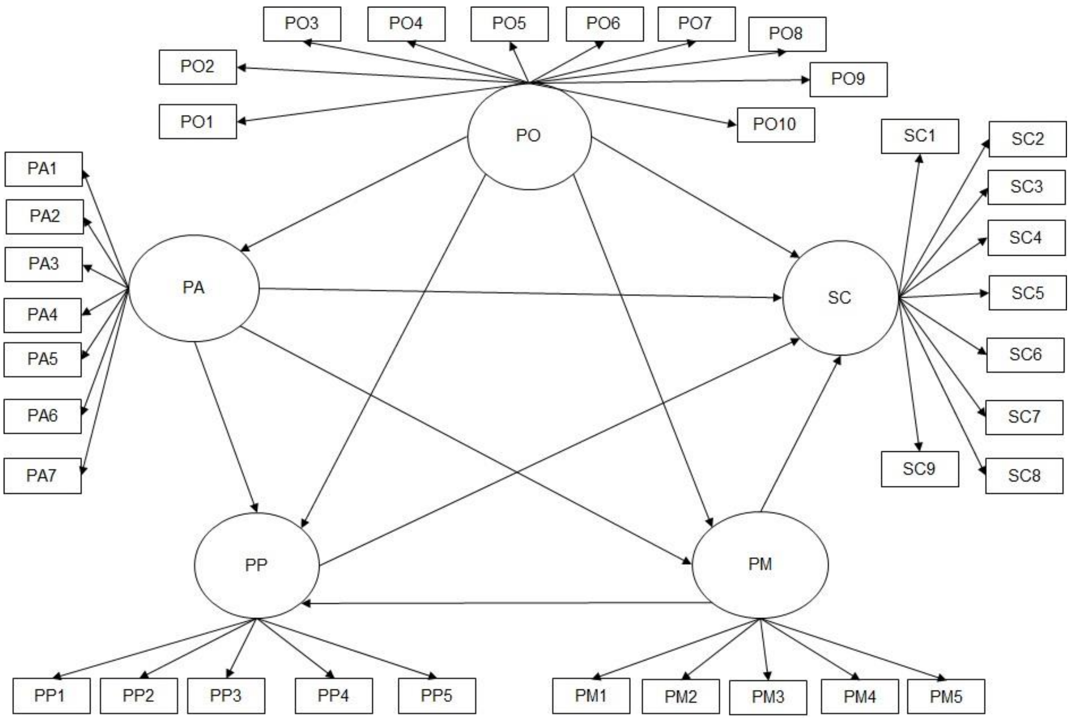
H8: PM significant positively influences maturity level of PP

H9: PM significant positively influences maturity level of SC

H10: PP significant positively influences maturity level of SC

In line with the general aim of this study to determine the maturity level of BMM, the measurement model was developed with reflective indicators as shown in Figure 3. The data analysis uses PLS-SEM to examine the relationships amongst the constructs to predict the hypotheses of this study. The measurement model examines the relationship between the constructs and their corresponding indicator variables using factor analysis.

Figure 3: Measurement model of this study



Findings from quantitative data analysis

The demographic data were analysed to provide general information of the participants, aiding understanding of the other results. Among 140 SC, 107 were working in primary schools and

33 were from secondary schools. Approximately three quarters (73.6%) are principals/deputy principals who are responsible for their school property management matters. In terms of working experience, 45.3% had over ten years working in this field. Principals/ Deputy principals comprised the majority of the respondents who had over 10 years of experience (55/67). Nevertheless, some respondents with other job titles also had over ten years of experience, particularly school board members and executive officers. Approximately 70% of respondents had been in the field for over five years. This level of experience meant that their responses to the questionnaire can be considered reasonably reliable.

Maturity level of BMM

Figure 4 presents the maturity level of the process areas and Figure 5 illustrates mean scores of each indicator in the measurement model. The maturity level of each process area was calculated by the average of the mean scores of its indicators. The results show that all indicators' mean scores are less than level 4, reflecting that the responsibilities have not been performing effectively and should be improved.

Further analysis as illustrated in Figure 5, shows that the respondents evaluated five out of ten of PO's indicators as between level 2 and level 3 (PO5, PO6, PO8, PO9, PO10), indicating that they have been introduced but their goals have not been satisfied. There are also three out of seven PA's indicators which have a maturity level below level 3. The results indicate that respondents were satisfied with the performance of SC, PP and PM, with most indicators having mean scores between level 3 and level 4, except PP4 (but almost achieving at level 3), and SC9. This could be interpreted to suggest that PP, PM, and SC have fulfilled their job in BMM. Based on the maturity level, the weakest points in BMM have been identified. However, the relationships between the indicators and the constructs and among the constructs should be examined to provide comprehensive recommendations for the improvement of BMM. PLS-SEM was used to examine the relationships.

Figure 4: Maturity levels of process areas

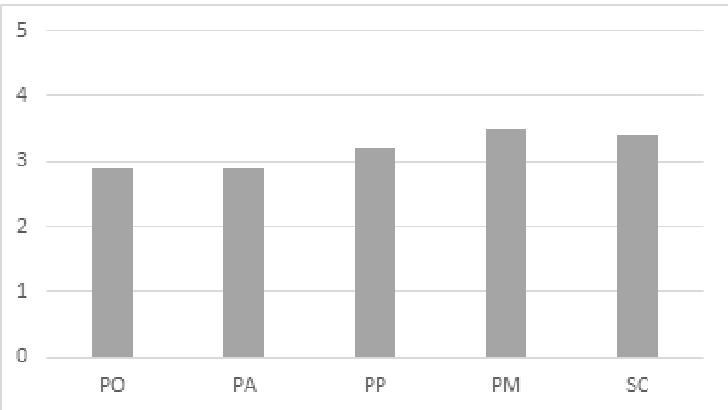
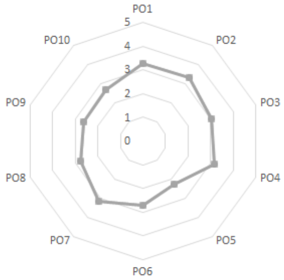
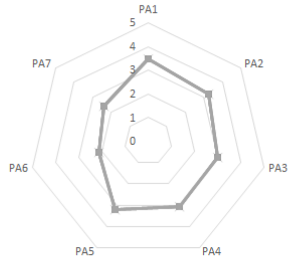


Figure 5: Maturity level of indicators

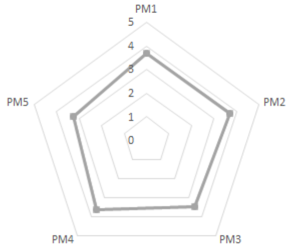
Indicators	Mean	Std.Deviation
PO1	3.28	1.194
PO2	3.32	1.050
PO3	3.05	1.211
PO4	3.16	1.149
PO5	**2.25**	1.228
PO6	**2.70**	1.104
PO7	3.14	1.137
PO8	**2.75**	1.211
PO9	**2.63**	1.252
PO10	**2.66**	1.308
Average	2.89	



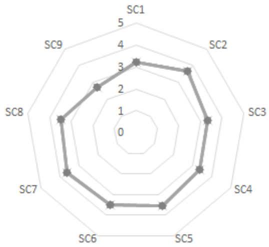
Indicators	Mean	Std.Deviation
PA1	3.49	1.079
PA2	3.23	1.207
PA3	**2.99**	1.317
PA4	3.07	1.297
PA5	3.19	1.225
PA6	**2.14**	1.383
PA7	**2.41**	1.385
Average	2.93	

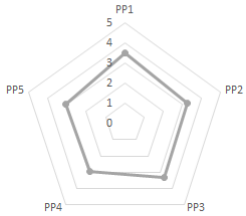


Indicators	Mean	Std.Deviation
PM1	3.71	1.168
PM2	3.71	1.083
PM3	3.44	1.208
PM4	3.61	1.221
PM5	3.25	1.319
Average	3.41	
PP1	3.51	1.158
PP2	3.28	1.250
PP3	3.34	1.275
PP4	**2.96**	1.360
PP5	3.06	1.213
Average	3.36	



Indicators	Mean	Std.Deviation
SC1	3.24	0.978
SC2	3.68	0.990
SC3	3.32	1.162
SC4	3.36	1.038
SC5	3.55	1.045
SC6	3.48	1.109
SC7	3.61	1.014
SC8	3.48	1.072
SC9	**2.72**	1.365
Average	3.38	





Application of partial least squares structural equation modelling (PLS-SEM)

Partial least squares structural equation modelling (PLS-SEM) is considered an appropriate method to test the hypotheses for this research study. PLS-SEM is a technique that can analyse structural equation models involving multiple-item constructs with direct and indirect paths(Hair, Hult, Ringle, & Sartedt, 2017). PLS-SEM has become increasingly popular in research involving the analysis of questionnaire data due to its advantages of testing theories that are not well-developed in the literature review (Hair et al., 2017). This study employed PLS-SEM to determine the standardised factor loadings and structural model path coefficients needed to examine the relationships between constructs and their indicators as well as the relationships among the constructs.

According to Hair et al. (2017), the minimum sample size should be considered against the background of the model and data characteristics. As a rough guideline, the minimum sample size in a PLS-SEM analysis should be 10 times the largest number of structural paths directed at a particular construct in the structural model (10 times rule) (Hair et al., 2017) . As presented in Figure 4, SC has the most directed paths (4); thus, 4*10 = 40 represents the minimum number of observations needed to estimate the PLS path model in Figure 4. Cohen (1992) recommended that for multiple regression analysis a construct with 10 variables would need at least 91 observations to detect a coefficient of determination of around 0.25. Therefore, the response for the questionnaire for this study (140) was considered satisfactory for the purpose of PLS-SEM approach for data analysis.

Many researchers use the PLS-SEM approach for exploratory studies to establish a new structural relationship for multi-variables (Alshibly, 2015; Gamil, Rahman, Nagapan, & Nasaruddin, 2020). The PLS-SEM analysis involves a two-step procedure: measurement model assessment (relationships between constructs and their corresponding indicators), and structural model assessment (relationship among constructs). This study aims to explore the relationships among key stakeholders in BMM. Therefore, PLS-SEM was applied to validate the constructs used in this study and to test the research hypotheses.

Evaluation of measurement model

The evaluation of the measurement model assesses the validity and reliability of the instrument. Convergent validity is assessed with the Average Variance Extracted (AVE) and Composite Reliability (CR). CR assesses the correlation between the indicators measuring the same construct. The composite reliability varies between 0 and 1, with higher values indicating higher levels of reliability, generally between 0.60 and 0.95 (Hair et al., 2017). Convergent validity is adequate when constructs have an AVE greater than 0.50; the variance shared with a construct and its measures are higher than the error (Hair et al., 2017). The model was run by Smart-PLS version 3 (results presented in Appendix 1).

The results indicate that composite reliability values and Cronbach's alpha scores are between 0.910 and 0.947, which demonstrates that all five constructs have a high level of internal consistency reliability. The lowest AVE value of the constructs is 0.580, confirming that the measures of the five constructs have high levels of convergent validity. All the indicators for the five constructs are equal or above the minimum acceptable level for outer loadings. The indicators' outer loadings should be higher than 0.70. Indicators with factor loadings between 0.40 and 0.70 should be considered for removal only if the deletion leads to an increase in composite reliability and an AVE above the suggested threshold value (Hair et al., 2017). Figure 5 displays the relationship between the constructs and their indicators (outer loadings). All outer loadings are above 0.70, except PO7 (0.699). As recommended by Hair et al. (2017), 0.699 is considered close enough to 0.70 to be acceptable. Therefore, all of the indicators for the five constructs are equal or above the minimum acceptable level for outer loadings.

Finally, the Fornell-Larcker criterion results show the square roots of the constructs' AVE are higher than the correlations of these constructs with other latent variables in the model. Therefore, the constructs meet the discriminant validity assessment by the cross loading. After confirming the reliability and validity requirements of the measurement model, the structural model was evaluated to confirm the hypothesised relations between constructs in the structural model.

Evaluation of structural model

The purpose of structural model assessment is to study the relationships among constructs. This is achieved by hypothesis testing for the t-value of the estimated path coefficients (β), and coefficient of determination (R^2) (Hair et al., 2017). The squared multiple correlations R^2 for endogenous constructs were initially examined to test the significance of the structural paths. According to the results of the standard estimation model as shown in Figure 6, R^2 and corresponding path coefficients were checked to confirm the hypothesised relations between constructs in the proposed model. Coefficient of determination R^2 is a measure of the amount of variance in endogenous constructs that is explained by the predictor constructs. According to Wynne (2009), R^2 values of PA (0.463), PP (0.483), and SC (0.507) can be considered moderate, whereas the R^2 value of PM (0.279) is rather weak. And Falk and Miller (1992) suggested that an R^2 value of 0.10 as a minimum is acceptable. Therefore, the R^2 values in the exploratory study are adequate.

The next step is to test the path model hypothesis as presented in Figure 3. According to Hair et al. (2017), the t-value has to be more than 1.96 and the p-value has to be less than 0.05 to accept the hypothesis. Table 2 summarise the results of the structural model test. The results show that H1, H2, H3, H5, H7, H8, and H10 are significant at a 5% level, while H4, H6, and H9 were rejected. These results suggest that PO directly affected the maturity levels of PA, PM, and SC; PA has influences on the maturity levels of PP, PM, and SC; and both PP and PM influence the maturity level of SC.

Table 2: Significance testing results of the direct effects ($p \leq 0.05$)

Relationships	β	t values	p values	Decision
H1: PO => PA	0.68	11.583	0.000	Supported
H2: PO => PM	0.205	2.151	0.032	Supported
H3: PO => SC	0.269	2.793	0.005	Supported
H4: PO => PP	0.047	0.594	0.552	Not supported
H5: PA => PP	0.215	2.448	0.015	Supported
H6: PA => PM	0.168	1.735	0.083	Not supported
H7: PA => SC	0.367	3.795	0.000	Supported
H8: PM => PP	0.531	6.148	0.000	Supported
H9: PM => SC	0.158	1.632	0.105	Not supported
H10: PP => SC	0.283	3.102	0.002	Supported

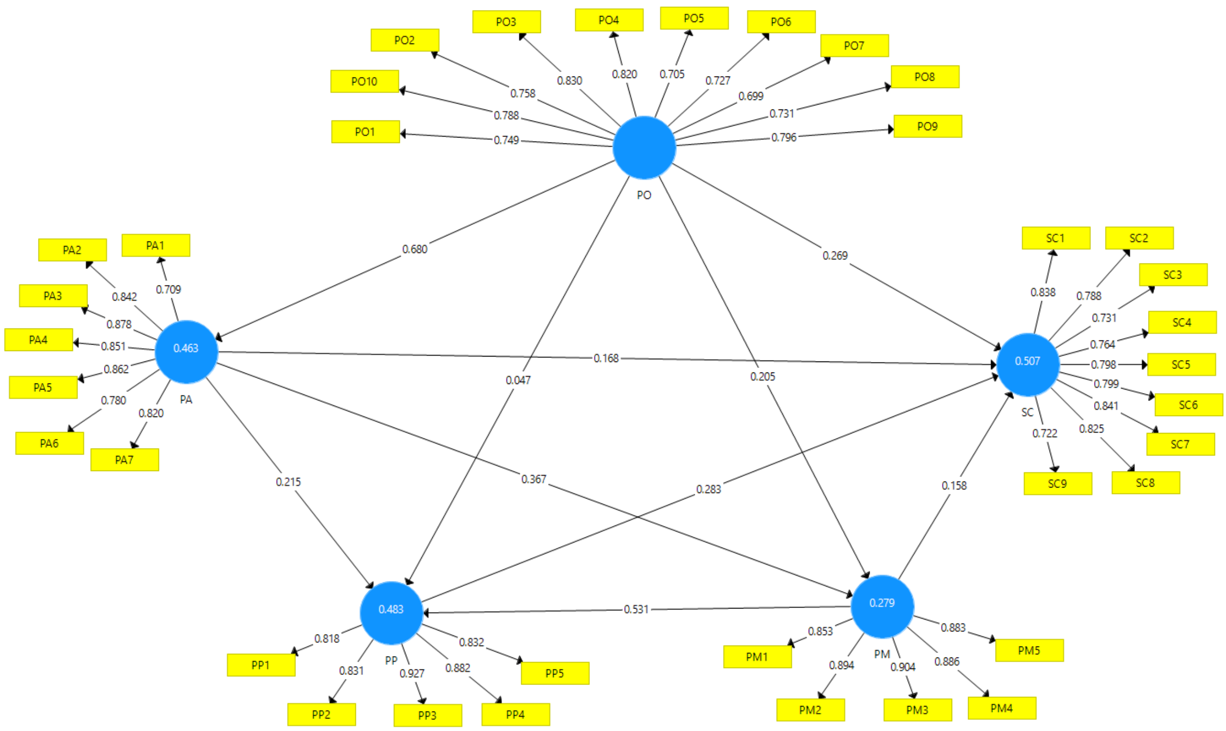
Alongside the direct effects, Hair et al. (2017) recommended examining indirect effects in the structural model to identify moderating effects on the latent variables. The sum of direct and indirect effects is referred to as the total effects which help explore the influences of mediating and moderating variables on the latent variables. The indirect effects were evaluated, and total effects were calculated (refer to Table A3, A4, A5 in Appendix 2).

When considering the indirect effects, all the hypotheses are supported as shown in Table 3. The results reveal that PO has the strongest total effects on PA, PM and SC, while PM has the strongest total effects on PP. In addition, PP has the strongest direct effects on SC and PA has the strongest total effects on SC. The results highlight that the different stakeholders influence each other, which provides further evidence for the suggestion that the relationships between stakeholders are crucial for the success of BMM. The interrelationships should be considered when proposing the most needed areas for improvement.

Table 3: Significance testing results of total effects ($p \leq 0.05$)

Relationships	β	t values	p values	Decision
H1: PO => PA	0.68	11.583	0.000	supported
H2: PO => PM	0.455	7.028	0.000	supported
H3: PO => SC	0.578	10.271	0.000	supported
H4: PO => PP	0.435	6.137	0.000	supported
H5: PA => PP	0.409	4.597	0.000	supported
H6: PA => PM	0.342	3.584	0.000	supported
H7: PA => SC	0.367	3.795	0.000	supported
H8: PM => PP	0.531	6.148	0.000	supported
H9: PM => SC	0.308	3.943	0.000	supported
H10: PP => SC	0.283	3.102	0.002	supported

Figure 6: Coefficient of determination



Most needed improvement areas in BMM

When considering the maturity level scores alongside relationships among the indicators and the constructs, priority levels for improvement can be recommended. Indicators which have mean scores below Level 3 of PO are suggested to be high priority for improvement. Moderate priority for improvement is suggested for indicators with mean scores below level 3 of PA, PP, PM, and SC and indicators with mean score between level 3 and level 4 of PO. Low priority for improvement is recommended for indicators with mean scores between level 3 and level 4. Therefore, the most needed areas for improvement include:

- Providing training programs for people involved in BMM (PO5)
- Establishing a performance evaluation framework for BMM (PO6)

- Establishing a reporting system for collecting required information (PO8)
- Reviewing the BMM system against the long-term strategy (PO9)
- Enhancing improvement actions for better delivery of BMM (PO10)

The moderate priority for improvement focuses on activities relating to policy and strategy (PO1, PO2), communication (PO), engagement (PO4, PA3, PA7), sharing lessons (PA6, SC9), and preparing funding for BMM (PO7, PP4). Appropriateness of these recommendations will be discussed in the next section.

DISCUSSIONS

The findings of this research contribute to the theory of relationships of stakeholders engaged in maintenance management. The structural model assessment results reveal that the stakeholders affect each other and that the top management plays an important role in BMM. These findings are supported by (Aragonés-Beltrán, García-Melón, & Montesinos-Valera, 2017) and (Au-Yong, Ali, & Ahmad, 2017) who have proved that there is a significant relationship between key stakeholders' involvement and maintenance performance. The findings also highlight relationships between the stakeholders and their corresponding indicators (responsibilities). This means that improvement of the maturity level of an indicator could impact the overall maturity level of BMM.

Furthermore, this research introduces a new continuous representation maturity model to identify the maturity level of the responsibilities in BMM. Most maturity models developed in this field used to be stage representation which has only one predefined path that must be followed to reach a predefined series of goals to progress to the upper level (Galar, Parida, Kumar, Stenstrom, & Berges, 2011; Macchi & Fumagalli, 2013; Meng et al., 2011). This study developed a continuous representation which provides a recommended order for approaching process improvement within each process area. In the school context, the budget for BMM is limited, so using a continuous presentation approach enables the budget to be allocated more effectively and efficiently by focusing only on those areas that most need improvement.

Regarding the high priority improvement areas, this study clearly demonstrates the need to evaluate the current processes, engage in lesson analysis, and promote improvements for BMM (PO6, PO9, PO10, SC9). These findings are consistent with research by Ismail and Shah (2010) and Newig et al. (2008) who highlighted that monitoring and evaluating the performance ensures that processes have been carried out as planned and that outcomes meet the stakeholders' expectations. The information collected in the monitoring and evaluation processes can generate lessons to improve the management effectiveness.

The findings also emphasise the importance of engagement and communication between the people involved in BMM (PA3, PA7, PO3). These findings are supported by Reymen et al. (2008) who found that the success of a process depends on the level of cooperation between the actors. Stakeholder communication plays a crucial part in ensuring maintenance strategies are carried out as planned (Azlan, Shirley, & Badariah, 2016). This view is also shared by Lang, Dickinson, and Buchal (2002) who argue that the success of collaboration requires effectiveness of communication. Lee and Scott (2008) acknowledged that interactions between top management at strategic levels and maintenance personnel at operational levels are powerful for influencing the performance of maintenance activities. Therefore, communication between key stakeholders in BMM should be improved.

The results highlight the requirement to establish a centralised information system and a feedback loop that help the MoE understand what schools most need, and allow schools to respond to MoE's requirements (PO8, PA6). ISO 55000 (2014) and (John, Kirsty, Geoffrey, & Ann, 2005) suggest that information is essential at all stages of asset management. Accurate and adequate information about the property condition and its performance enable managers to make informed and practical decisions in the planning stage. There is a need to provide clearer guidelines for gathering reports, providing feedback, and sharing lessons learnt during and after each project. The standard reports can confirm what type of information should be shared and outline the criteria used for evaluations.

Such an information management system would also help SC review their maintenance conditions and budget spent with neighboring schools to help them find cost-effective solutions. At school level, it is important that schools continuously record and update their maintenance information and report the information to the MoE (SC8). Relating information is important to perform maintenance tasks properly (Gómez-Chaparro, García-Sanz-Calcedo, & Aunión-Villa, 2020) and make decisions for future renewal alternatives such as renovation or refurbishment. Therefore, both the MoE and schools should pay attention to the information management of all maintenance work and provide the information for other stakeholders if required.

These findings also strongly suggest that an improvement of the training programmes for people involved in BMM (PO5) is needed. Quality of workmanship, including training, awareness, and competence of employees have a significant influence on the effectiveness and efficiency in the built environment (Adeyeye, Piroozafar, Rosenkind, Winstanley, & Pegg, 2013). Understanding the individual roles of the partners (PO4) and their abilities were shown the be critical factors for the success of collaboration. Therefore, organisations should determine the necessary competence of staff and provide appropriate education and training to acquire this competence.

CONCLUSION

This study developed a maturity model to assess the current maturity level of stakeholders' responsibilities in BMM. The model also examined relationships among the key stakeholders in BMM and the results highlighted that the maturity levels of stakeholders' responsibilities are interrelated. Consequently, an improvement in the maturity level of one indicator could impact the overall maturity level of BMM. The study shows that the most-needed improvement areas in BMM for state schools in NZ are the reporting system, performance evaluation, staff training, lesson sharing, communication, and continuous improvement. Although the data collection was subject to a few limitations, the findings provide an opportunity for the stakeholders to review their current practice and identify improvement actions for BMM in NZ's state schools.

There are opportunities to extend the outcomes of this research through further investigations. The first proposed approach could be developing a comprehensive framework for all BMM processes that also includes processes for monitoring, evaluating, and improving existing processes. It would be important for such a framework to highlight the need of data collection and analysis to generate lessons learnt. The framework should also promote ongoing staff training and development to ensure all the stakeholders understand their roles and responsibilities in BMM and perform effectively. Second, the maturity model and research approach of this study can be applied for studies on schools in other countries or other types of public buildings in which maintenance typically is managed on the behalf of another party or entity.

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Appendix 1: ***Evaluation of PLS-SEM measurement model***

Table A1: Consistency Reliability and Convergent Validity

	Cronbach's α	Composite reliability	AVE
PO	0.919	0.932	0.580
PA	0.919	0.936	0.676
PM	0.930	0.947	0.782
PP	0.910	0.937	0.737
SC	0.925	0.937	0.625

Table A2: Fornell-Larcker Criterion

	PA	PM	PO	PP	SC
PA	0.822				
PM	0.506	0.844			
PO	0.680	0.455	0.762		
PP	0.516	0.661	0.435	0.859	
SC	0.577	0.553	0.578	0.591	0.791

Appendix 2: ***Evaluation of PLS-SEM structural model***

Table A3: Specific Indirect Effects

Relationships	Effects
PA => PO => PM	0.249
PO => PA => PP	0.146
PO => PA => SC	0.144
PO => PM => SC	0.032
PO => PP => SC	0.013
PO => PM => PP	0.109
PO => PA => PM => PP	0.132
PO => PA => PM => SC	0.039
PO => PA => PP => SC	0.041
PO => PM => PP => SC	0.031
PO => PA => PM => PP => SC	0.038
PA => PM => PP	0.195
PA => PM => SC	0.058
PA => PP => SC	0.061
PA => PM =>PP => SC	0.055
PM =>PP => SC	0.151

Table A4: Total Indirect Effects

	PA	PM	PO	PP	SC
PA				0.195	0.174
PM					0.151
PO		0.249		0.387	0.309
PP					
SC					

Table A5: Total Effects

	PA	PM	PO	PP	SC
PA		0.367		0.409	0.342
PM				0.531	0.308
PO	0.680	0.455		0.435	0.578
PP					0.283
SC					

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