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BIM BUSINESS VALUE GENERATION THEORY: A GROUNDED THEORY APPROACH

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SUMMARY*: Theoretical developments in the Architectural Engineering and Construction (AEC) industry have been deficient, especially for the operations and use phase. The need for asset owners to understand the Building Information Modelling (BIM) process and to realise business value from BIM implementation cannot be over emphasised. This study investigates a BIM-based Asset Management (AM) system to examine how business value can be created for the asset owner. The BIM-based AM system is evaluated from the Transformation-Flow-Value (TFV) generation view to define the characteristics and functions. This is followed by the grounding of data to develop a novel explanatory theory through the development of conceptual categories. A qualitative research approach based on a grounded theory methodology is utilised to generate a proposition on how BIM can create value in an AM system. The study involves a five-stage research design using interviews and document analysis to inform the phenomenon of BIM business value creation in AM. The paper highlights that BIM business value generation in AM is dependent on three main categories, which are: development of the information requirements, creation of the information content and management of the information content. From the grounded data, the study finds that it is crucial for asset owners to develop their information requirements since the information requirements development category guides the data creation, data management and value generation. Furthermore, the development of a sound rationale that appropriately translates the organisational business objectives is critical to value generation. The paper studies how BIM can create business value in an AM system using a grounded theory methodology. The results show that the rationale for developing BIM-based information requirements determines the value that will be generated by the AM system. The key contribution of the paper is that it presents a novel theory for BIM-based AM. One of the contributions of this study is the demonstration of the application of grounded theory within the AEC industry. Also, the study demonstrates the relationships between concepts and how they emerge from the grounded data.*

KEYWORDS: *BIM, Asset, Management, Business, Value, Theory*

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1.0 INTRODUCTION

Theoretical developments in the Architectural Engineering and Construction (AEC) industry have been deficient, especially for the operations and use phase. The AEC industry is based principally on the transformation view of production (Rooke et al., 2012). However, this theory of production has many drawbacks. One is its inability to characterise complex production processes. Koskela (2000) argues that the chronic production problems in the AEC industry are mainly due to the lack of applicable industry-based theories to implement methods of flow and value management. Similarly, Antunes and Gonzalez (2015) state that the AEC industry lacks the history of applying theoretical approaches to managing production. Therefore, there is a need for more theories that will help to solve the complex production problems in the AEC industry.

Furthermore, the need for asset owners to understand the Building Information Modelling (BIM) process and to realise value from BIM implementation cannot be over emphasised. BIM and Asset Management (AM) systems are changing the way built assets are operated and these systems can potentially impact the value proposition of asset owners (Love et al., 2014; Mirarchi et al., 2018). Thus, estimating the business value of BIM is not enough, as asset owners should focus more on how the complex mechanisms of production create value (Love et al., 2014).

Although, there have been some research efforts to apply manufacturing practices to the AEC industry, few studies have focused on understanding the critical mechanisms of production in the AEC industry (Antunes and Gonzalez, 2015). Hence, without understanding the complex mechanisms in production, the realisation of value will certainly remain elusive. More studies have to be conducted in BIM business value generation in AM to develop models that will support the asset owner to create value from their business processes (Ouertani et al., 2008; Love et al., 2014; Love et al., 2015). Furthermore, to understand the complex mechanisms in production, it is important to understand the asset owners' perspectives towards value and what motivates them to use the systems (Kujala and Väänänen-Vainio-Mattila, 2009).

This study proposes to investigate how business value can be created for the asset owner in a BIM-based AM system. Therefore, to develop a theory, there is a need to understand what a theory is. A theory essentially represents reality by acknowledging certain phenomena whilst disregarding others (Rooke et al., 2012). Whetten (1989) highlights that many theorists do not clearly emphasise the contextual limits of their theories. In order for a theory to be fit for purpose, it must contain three fundamental elements. Thus, the theory has to demonstrate: which factors should be considered as part of the explanation of the phenomenon; how the factors are related; and why the proposed factors are justified to form causal relationships (Dubin, 1978; Whetten, 1989; Koskela, 2000).

1.1 Theoretical Developments in the AEC Industry

Traditional views of production in the AEC industry have been the transformational view, where it is viewed as the processing of input to output (Koskela, 2000). The main principle of this theory is that improving all the sub-processes can optimise the performance of the whole process of production. However, Koskela (2000) argues that the application of the transformational concept to, and management of, productive operations may be false or misleading. In comparison, flow theory, which is another view of production in the AEC industry, views the transitions between transformations as complex flows. The flow theory is built around the principle of reducing waste and includes a time dimension as one of its attributes (Rooke et al., 2012). An additional perspective of production is the value generation theory, which focuses on the interaction between a customer and a supplier or producer (Koskela, 2000). The basic principle of the value generation theory is to address: requirements capture, requirements dissemination, requirements completeness, subsystems capability and value measurement (Koskela, 2000; Rooke et al., 2012). Nevertheless, Koskela (2000) presents a Transformation-Flow-Value (TFV) generation model, which is a synthesis of the three aforementioned approaches. It views the production process as a transformation that also flows and generates value. However, Bertelsen and Bonke (2011) contest that TFV may not be the most suitable approach to practical production in the AEC industry.

Some of the other theories currently applicable to the AEC industry are: Theory of Constraints (Goldratt, 1997); Queuing theory (Gross and Harris, 1985); V–model (Forsberg and Mooz, 1998); and Transformation-Flow-Value generation model (Koskela, 2000). Goldratt (1997) introduces a five-step method to address system problems as a result of the constraints, which is applied on a continuous improvement basis. The steps are: identify the system's constraint; exploit the constraint; adjust the setting of other activities to the constraint; alleviate the constraint; if the constraint is broken in any of the steps, go back to step one. However, this theory focuses on process improvement and effecting change programmes in systems and not value generation. Gross and Harris (1985) propose queuing theory which is a mathematical model that can be used to predict queues or waiting times.

Nonetheless, this focuses on operations management and does not apply to value realisation in AM. Forsberg and Mooz (1998) suggest the V–model for project lifecycle development in systems engineering activities. Although, the V-model has aspects of product development that may be applicable to AM, it does not focus on value realisation. However, these theories are generic and although they may apply to some aspects of AM, they are not specific to its activities. Therefore, further research is needed to develop theories that are unique to AM. As the previously described TFV (Koskela, 2000) may be partially useful in understanding the BIM-based AM system in question. Therefore, this study adopts the TFV to describe the inner mechanisms of the AM system.

1.2 Value and Value Creation in AM

Organisational values are perceptions of what is favourable and detrimental for an organisation from a business perspective. Schwartz and Bilsky (1987) define value as a cognitive representation of needs. However, asset owners perceive value differently due to varying organisational values, needs, preferences and financial resources. Organisations have prevalent value systems with the tendency to prefer certain states of affairs over others (Hofstede et al., 2010). Furthermore, the Information Systems (IS) value within organisations is always a matter of context and perception (Bakis et al., 2006). Cockton (2004) suggests that quality-in-use and fit-to-context are dependent variables when achieving IS value. Boztepe (2007) asserts that value is the outcome that is created through user-product interaction. Similarly, Kujala and Väänänen-Vainio-Mattila (2009) offer a concept of understanding user values. The framework presents the critical dependency of users, such as asset owners' values, needs, goals and limitations as central factors in the interaction with the product properties in achieving value.

Value creation in an organisational context is simply the process of generating benefit by producing outputs that are more valuable than the inputs used. Windsor (2017) reviews three value generation theories in organisations. Firstly, the agency theory of value creation denotes that value is created in a market economy through economic exchange. Secondly, the managerial stakeholder theory of value creation views stakeholders as central to value generation. Finally, creating shared value and the co-creation of value is concerned with the dimension of organisations that simultaneously produce shared values that are not mutually exclusive. Kraaijenbrink (2011) views value creation from the philosophical perspective by presenting economic, social and cognitive mechanisms as a means of creating value. Economic mechanisms relate to production, whilst social mechanisms pertain to communication, and cognitive mechanisms centre on people's interpretations. Murman et al. (2002) consider value creation from a procedural perspective suggesting that it is composed of three phases: value identification, value proposition, and value delivery. Rojas and Liu (2015) view value creation from an organisation capability perspective and present two dimensions of value creation: independent and co-create. Independent value creation refers to the process of creating value by a single organisation or stakeholder to deliver what has been requested of them without the need of external stakeholders or organisations. Co-create value generation involves the collaboration of stakeholders or organisations to create value. Furthermore, Rojas and Liu (2015) present a framework for a value creation process in construction projects and the relationship between stakeholders. However, this does not cover aspects of AM. Some studies have presented frameworks for evaluating business value of BIM in AM (Love et al., 2014; Sanchez et al., 2016; Munir et al., 2018). Still, they do not cover value generation from the AM system perspective. All the reviewed studies indicate that little work has been done in relation to value generation theories in AM and BIM. Furthermore, there is a need for further research that focuses on value and the involvement of users in identifying their value in BIM-based AM processes (Kujala and Väänänen-Vainio-Mattila, 2009).

1.3 Nature of Asset Owners and Business Models

There is a need to define the scope of the client in this study. In this context, we refer to the client as an asset owner or owner-operator. Masterman (2002) suggests two client sectors- public and private - and includes other characterisations, such as primary, secondary, experienced, and inexperienced clients. Galbraith (1995) identifies groupings for AEC industry clients, which are based upon organisational factors. These are classified under traditional professions, newer professions, the industrial sector and average industry clients. As the aforementioned factors are influencers, clients consequently acquire distinct characteristics.

There is a variety of business models in AM. Thus, business models that are owner-operators may include owner-occupier, rented property, real estate traders and real estate brokers. Only the owner-occupier and rental tenants are classified as dwelling and office stock. Furthermore, Malone et al. (2006) classify all business models into 16 archetypes, as shown in the Figure 1:

BASIC BUSINESS ARCHETYPES	TYPE OF ASSET INVOLVED			
	FINANCIAL	PHYSICAL	INTANGIBLE	HUMAN
CREATOR	Entrepreneur	Manufacturer	Inventor	Human Creator
DISTRIBUTOR	Financial Trader	Wholesaler/ Retailer	IP Trader	Human Distributor
LANDLORD	Financial Landlord	**Physical Landlord**	Intellectual Landlord	Contractor
BROKER	Financial Broker	Physical Broker	IP Broker	HR Broker

Figure 1: Business model archetypes (Malone et al., 2006)

The purpose of this study is to develop a theory of how BIM can generate business value for clients in an AM system. Therefore, the study identifies the Physical Landlord business model as the generic classification that may be applicable to owner-occupier and real estate tenant clients. Furthermore, the study reviews various organisations with business models that incorporate AM in their activities. The study further classifies business models that fall under the Physical Landlord type from the ONS (2007) classification list. A number of owner-operator business models are identified (Items G, H, I, K, L, P, Q, and R), which are shown in Appendix A.

Morledge and Smith (2006) assert that clients' characteristics and experiences are critical factors in determining client attitude and their dealings with other stakeholders in the AEC industry. Due to the fact that there are diverse asset owners in the AEC industry, there cannot be a one size fits-all model or theory to address client requirements and values. The information requirements, business processes, organisation values, organisational strategy and management structure of every asset owner are distinct. Thus, even similar organisations performing the same business functions and competing in the same market have different methods to perform the same task.

1.4 Asset Management (AM) and Building Information Modelling (BIM) Systems

An asset is generally viewed as an economic resource. Similarly, AM is a methodology for the control of assets over a lifecycle. It is expected that the profitability of assets will increase over time through the adoption of best practices in managing and maintaining assets (Schneider et al., 2006). An AM system is a combination of three elements; technology, work processes and expertise (Mehta and Reddy, 2015). Moreover, AM systems support asset planning, acquisition and maintenance including other support systems such as IT, financial and legal services (Hastings, 2009). New technologies in AM systems support asset managers to predict events, diagnose causality and create value using historical or real time data to reduce the cost and risk of failure (Parlikad and Jafari, 2016). Mehta and Reddy (2015) suggest eight key drivers for AM systems, which include: reliability, quality, increased production, man-power reduction, cost reduction, understanding customer requirements, environmental health and safety, and value creation.

BIM is one of the most recent aspects of change to impact the AEC industry (Eastman et al., 2011). It is defined as 'a set of interacting policies, processes and technologies producing a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle' (Succar et al., 2007). BIM includes geometric and non-geometric data (Guillen et al., 2016). Similarly, the term 'Modelling' is usually interchanged with 'Management' in 'BIM' to describe a methodical approach to managing asset information throughout its lifecycle (Parsanezhad and Dimyadi, 2014). This study views BIM from the perspective of Building Information Management where all relevant information is integrated or linked within one consistent dataset. That is, the application of BIM in an AM system, which, in essence, is the lifecycle perspective. BIM can be seen to deliver the required datasets for asset managers executing their business processes.

2.0 METHODOLOGY AND RESEARCH QUESTION

This section presents the methodological approach adopted for this study as well as the rationale for the selected methods and strategies. The aim of this study is to research an AM system and to develop a theory on how BIM can create business value.

2.1 Research Question

The study aims to address the following research question:

- How can BIM create business value in a BIM-based Asset Management System?

2.2 Research Methods

The study adopts an inductive approach to understand the context of value generation or the creation of BIM in an AM system. Inductive logic refers to the process of concurrently collecting and analysing data to generate a theory (Strauss and Corbin, 1998). To achieve this, a constructivist grounded theory methodology is utilised (Charmaz, 2013). Grounded theory is a set of developed concepts that are linked through statements that form an integrated framework to predict a phenomenon (Strauss and Corbin, 1998). Charmaz (2013) argues that grounded theory has proven to be a credible methodological approach in its own right, and not a preceding activity to develop quantitative instruments. One of the advantages of grounded theory is that it aids creativity, gives the researcher the potential to conceptualise ideas and provides data depth and richness (Glaser and Strauss, 1967; Strauss and Corbin, 1998; Saunders et al., 2012). Furthermore, Strauss and Corbin (1998) highlight that grounded theory studies typically present data at an abstract level since their goal is to explain phenomena through the conceptualisation of ideas. The ontological and epistemological stance of this study is relativism and interpretivism respectively. Ontology refers to the researcher's view of reality, whilst epistemology is the relationship between the researcher and subject of study (Saunders et al., 2012). Epistemologically, the use of a constructivist grounded theory presumes that multiple realities exist, which are constructed by researchers based on meanings and interactions with the research context (Charmaz, 2013). The research methodology is shown in Figure 2.

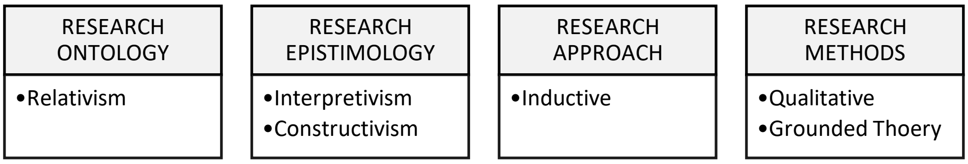

Figure 2: Research Methodology

Charmaz (2013) suggests guidelines to perform grounded theory research, and views such research as a set of principles and practices, rather than as methodological rules. Eisenhardt (1989) highlights that random sampling is neither desirable nor necessary when building a theory from a case because the number of cases that can be studied in any research project is limited. This study adopts purposive and theoretical sampling techniques for the data collection (Glaser and Strauss, 1967; Strauss and Corbin, 1998; Saunders et al., 2012). The case is purposefully selected for theoretical, and not statistical reasons, in order to extend the emergent theory (Glaser and Strauss, 1967). Theoretical sampling is most suitable for grounded theory research because it gives the researcher the flexibility to collect, code, and analyse data, and to decide where to collect more data from as the theory emerges (Glaser and Strauss, 1967; Strauss and Corbin, 1998).

This is a grounded theory study that was carried out in four departments in a large multinational building design, consultancy and software company that manages asset information for over 1,000 clients globally. The AM system is licensed proprietary software that was developed for asset owners to execute AM tasks efficiently. This case is selected to research the business value of BIM in an AM system. Seven sets of interviews were carried out and the interview participant profile is shown in Table 1. The following criteria were considered in the participant selection for the study:

- The selected participants interfaced with different types of client ranging from public to private.
- Participants were senior ranking members of the selected departments who interfaced with clients.
- Participants had an advanced level of knowledge and understanding of BIM in asset operation and management.

Table 1: Interview participant profile

S/NO	JOB DESCRIPTION	EXPERIENCE IN BIM (YEARS)	EXPERIENCE IN AM (YEARS)	EXPERIENCE IN BIM AND AM (YEARS)
1	Director Manager Services	14	14	14
2	Senior Technology Consultant	5	20	5
3	Technology Director I	20	15	5
4	Technology Director II	10	5	5
5	Software Development Manager Services	10	10	2
6	Development Manager	14	14	14
7	Business Director Digital Real Estate	5	5	5

The study was conducted in five stages, which were partly carried out concurrently. The first was the initial theoretical sampling where preliminary interviews were conducted and a write up of the first draft was carried out. The second was the literature review and the third was the data collection. The study utilised semi-structured interviews and document analysis to collect data. Interviews were used to probe participants to identify how BIM creates business value in an AM system. Furthermore, document analysis was used to analyse the inner workings of the system, that is, the requirements, data interpretation and value generation. The fourth stage was the data analysis, and the fifth was the theory formulation. Figure 3 shows the research process. Validity was ensured through participant validation by sharing the preliminary findings with the participants to confirm whether the data were representative of their views (Saunders et al., 2012).

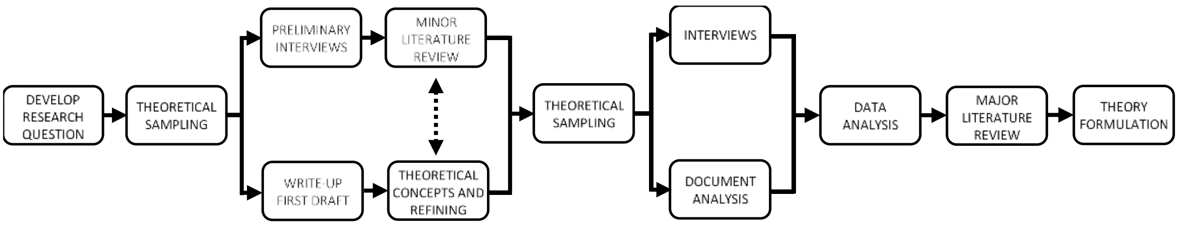

Figure 3: Research process

There is considerable debate that when adopting grounded theory, researchers should not review literature in order to avoid prejudicing the results (Glaser and Strauss, 1967; Strauss and Corbin, 1998). As a result, Glaser and Strauss (1967) encourage researchers to conduct a literature review after completing the data analysis. However, other authors encourage a review of literature before, during and after the data analysis in order to enhance the researcher's theoretical sensitivity, gain an improved insight into the data, and to position the study within the context of related literature (Stebbins, 2001; Charmaz, 2013). For these reasons, a preliminary literature review was conducted at the initial stages to develop the study's theoretical construct and at the later stages to focus the research on the context of its contribution and the related literature. Furthermore, the study utilised an abbreviated grounded theory research method whereby theoretical sensitivity and theoretical saturation were carried out within the available texts analysed (Willig, 2013). Theoretical sensitivity refers to the ability of the researcher to generate concepts and to relate them to the normal models of theory development by interacting with the study data (Glaser and Holton, 2004). Theoretical saturation is the point at which no new properties or theoretical insights emerge concerning the developing grounded theory (Charmaz, 2013).

2.3 Data Collection and Analysis

A qualitative approach to data collection and analysis is utilised in this study. Qualitative research refers to any type of research, which produces findings that are not arrived at by statistical or other means of quantification (Strauss and Corbin, 1998). Similarly, grounded theory provides a sound intellectual justification for using qualitative research to develop theoretical analysis (Charmaz, 2013). Qualitative data is usually collected by three main methods; interviews, observations and document analysis (Patton, 2002). The study obtained data using interviews and document analysis. Preliminary interviews were conducted because, in grounded theory, the process of data collection and analysis continues until theoretical saturation is achieved (Strauss and Corbin, 1998). In this phase, data was coded to identify the initial codes and concepts in draft manuscripts as further refining took place. Furthermore, the second set of interviews were later conducted and analysed. The study utilised the NVivo software within the transcription, coding, and data analysis activities (Bazeley and Jackson, 2013). Coding is the analytic process through which ideas are identified and their dimensions are discovered in the data (Strauss and Corbin, 1998). Significant themes were identified using codes, which helped to increase the focus of the data analysis, and informed the further collection of data. The data was rearranged in categories whilst sub-categories also emerged, which are referred to as dimensions. Coding in this study was done in four stages; initial coding, focused coding, axial coding and theoretical coding (Charmaz, 2013). This is shown in Figure 4.

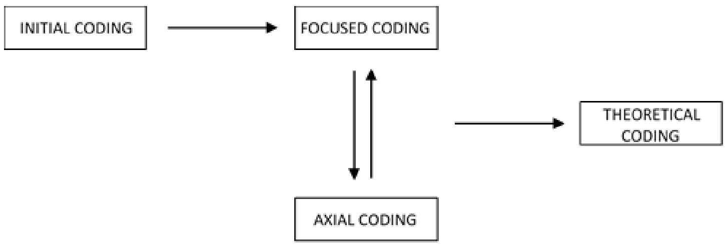

Figure 4: Coding structure of the study

The literature review was conducted to enable a better insight into the data in terms of theoretical sensitivity. Also, internal documentation was reviewed to provide more data about the context within which the participants operate (Strauss and Corbin, 1998). These documents were analysed to reveal certain meso and macro conditions of the system under investigation. Conceptual ordering was carried out to organise the data into selective sets of categories, and to classify relationships between the data (Strauss and Corbin, 1998). Lastly, the relationships between the categories were used to identify and develop the core category. The systematic approach for developing the codes and categories is shown in Figure 5.

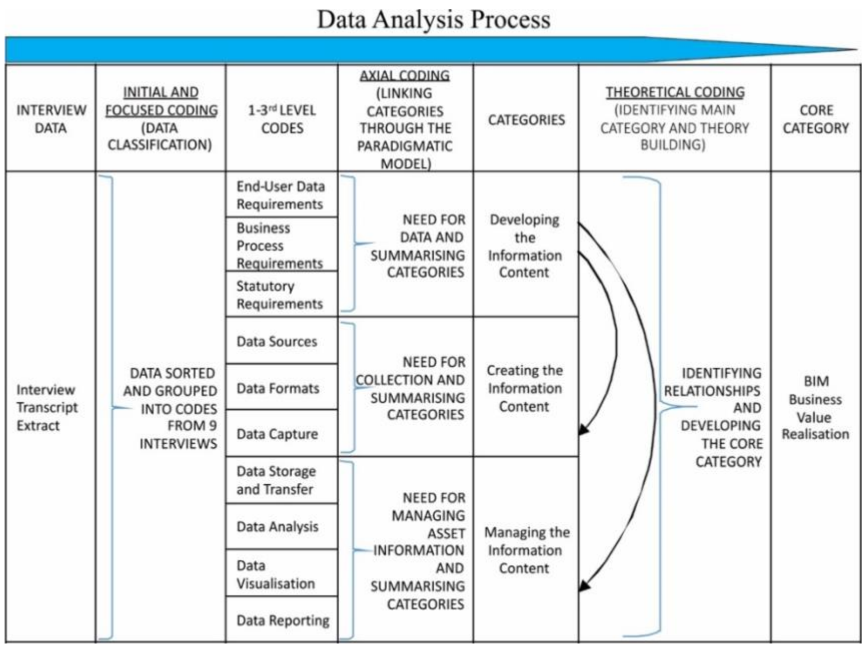

Figure 5: Data analysis process

3.0 CHARACTERISTICS OF THE BIM-BASED AM SYSTEM

This section presents the characterisation of the AM system from the document analysis process. The BIM-based AM system under study can be described from the transformation model perspective (Koskela, 2000).

3.1 Definition of the System

A system is defined as a collection of interrelated components that make a whole such that a change in any component may lead to or result from a change in some other component (Curtis and Cobham, 2008). A basic description of the system is shown in Figure 6:

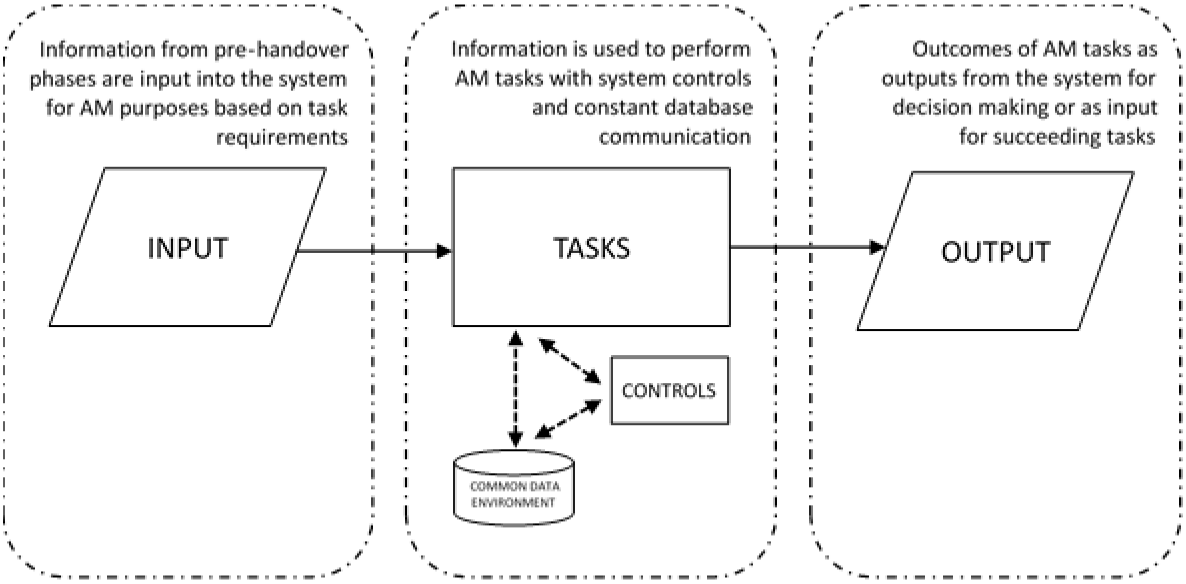

Figure 6: BIM-based AM Input-Output system

The AM system utilises data from the pre-handover phases, which are inserted into the system for AM tasks. These business processes are then executed to provide data for decision making and other AM tasks. AM personnel rely on the outputs of preceding activities as sources of data for their daily processes. The system consists of sub-systems or sub-processes that are interrelated by means of their inputs and outputs.

3.2 Functions of the System

The systems model has to be decomposed to reveal the inner workings of the AM system in terms of the sub-tasks carried out by the system. Hence, the TFV production view (Koskela, 2000) is used to describe the functions of the BIM-based AM system. This is illustrated in Figure 7.

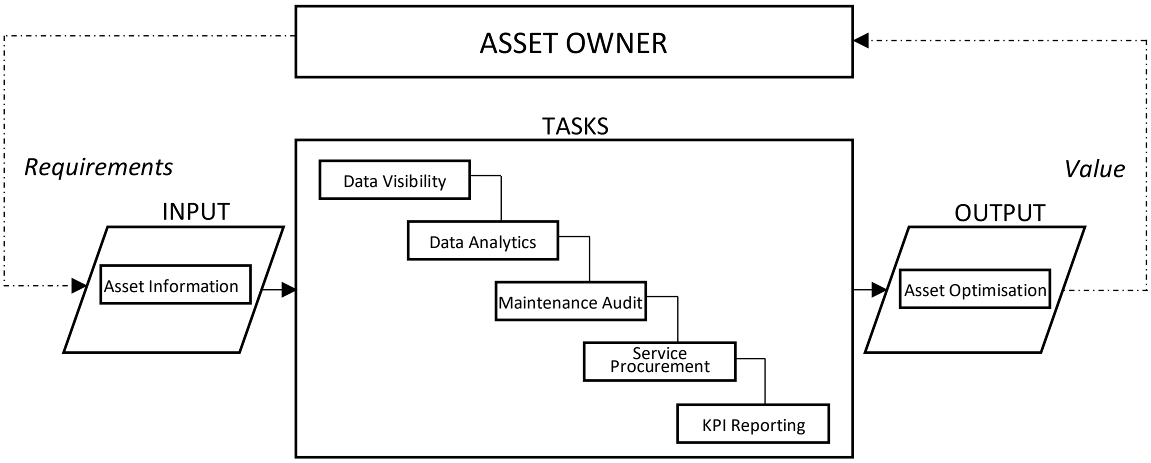

Figure 7: Functions of the system

The system performs many different functions such as:

- **Strategic maintenance:** The system has the capability to develop schedules for asset maintenance within the facility.
- **Energy analysis:** The system utilises a global database of weather information to calculate the total energy usage and carbon emissions on an hourly, daily, monthly or annual basis.
- **Thermal performance:** The system can monitor and analyse the effects of occupancy, internal gains, infiltration and equipment, including the heating and cooling loads of the facility.
- **Water usage and cost evaluation:** The system can estimate and monitor the water usage of a facility.
- **Indoor environmental quality:** The system has the capability of monitoring the air quality and noisy areas within the facility.

4.0 RESULTS: BIM BUSINESS VALUE GENERATION

This section presents the outcome of the data collected and analysed from the interview process. The data analysis starts with a process of finding relationships between codes, which make up the categories. The relationships between the main categories are conceptualised to show the prerequisite processes for developing the core category, which creates BIM Business Value (Figure 8). Three different categories are identified through the data analysis, which are: development of the information requirement; creation of the information content; and management of the information content. From the data, these categories are understood to represent the strategy for asset owners to create business value from BIM.

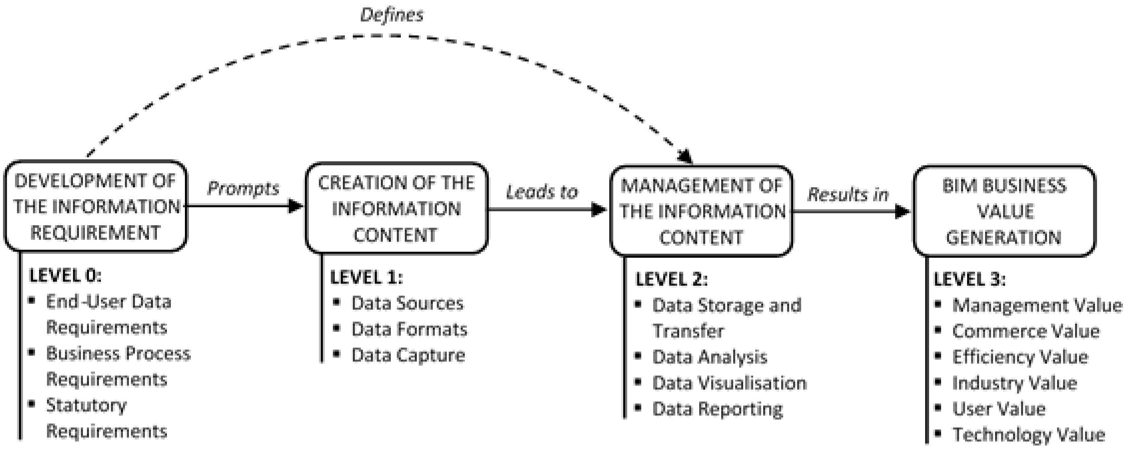

Figure 8: Development of the core category

Here, the information is developed in levels (as explained in the following sections) and the relationships are indicated.

4.1 Level 0: Development of the Information Requirement

Firstly, this category includes aspects relevant to the definition of requirements. Asset owners are diverse with different business models whilst even those with the same business models may have differing strategies and approaches. The respondents point out that defining the requirements guides the design process needed to produce the required data for use in the operations and use phase. The set of activities within this category helps to define the whole process. It sets the targets, context and sometimes the value that a business expects to generate by the end of the process. The respondents assert that the client or asset owner specifies the development of the information requirement. Furthermore, three guiding principles govern the process of developing the information requirement: end-user requirements, business process requirements, and statutory requirements. In essence, it states the rationale for the BIM process. The respondents highlight that the information requirement should answer the following four key questions Figure 9:

- Why is the data needed?
- How should the data be created?
- Who needs the data?
- What will the data be used for?

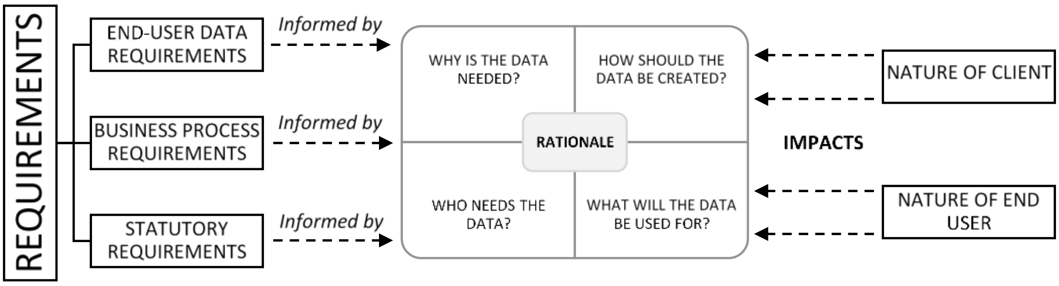

Figure 9: Development of the information requirements

4.2 Level 1: Creation of the Information Content

This category involves three dimensions that are responsible for creating the information through BIM-based AM systems, they are: data sources, data formats, and data capture (Figure 10). The first concerns the definition of the main sources of information, which comprise static and dynamic information. Static information refers to the data, which come from a source where the information seldom changes. Static information comes from documents such as operation and maintenance manuals and Industry Foundation Classes (IFC) models. In comparison, dynamic information comes from a source where the data is characterised by continuous change or activity. Dynamic information comes from data generated through Application Programming Interfaces (API) by Internet of Things (IoT) sensors and building automation data. Thus, the data formats supported by the system are diverse. The data capture dimension involves the action of collecting data from the assets. The respondents mentioned that this is done from a variety of sources. Data is captured from sources such as, but not limited to, energy meters, energy sensors, lighting sensors, IFC, and the manufacturer's product information. The respondents explain that placing a software layer over the building management systems captures the data. These data are then sent to the cloud services in batches.

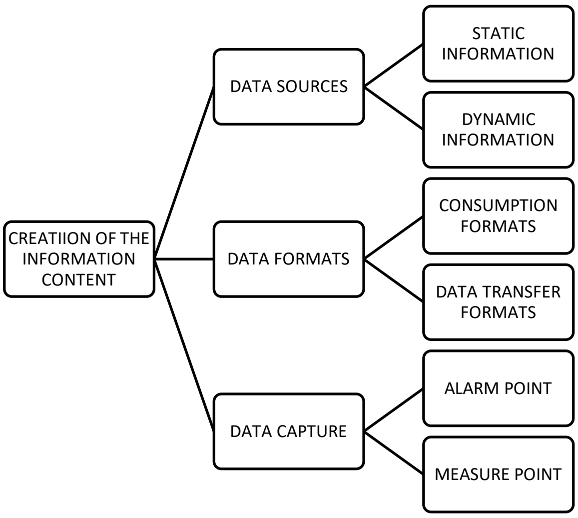

Figure 10: Relationships within the data capture category in the creation of the information content

4.3 Layer 2: Management of the Information Content

The next level involves a category that manages the information created in Layer 1. The dimensions within this category are: data storage and transfer, data analysis, data visualisation, and data reporting. The first dimension is data storage and transfer, which concern the easy access to data, and the sharing of information within organisations and across the supply chain. The respondents assert that the system supports tens of different formats for the consumption data transfer. The data transfer method follows the same approach as the building performance monitoring. Therefore, once the data are captured, they are transferred to the cloud service for the analytics. The next dimension comprises the data analysis. The analytics department uses tools to analyse the captured data and make estimations in order to identify deviations based on the client's requirements. The respondents state that data can be analysed at the sensor, room, floor, zone, building or portfolio level. Data visualisation as a dimension involves the activity of conception after data analysis. The respondents assert that the same data analysis can be visualised in many different ways depending on the nature of the end-user. Also, the same data can be presented to different end-users, from which they would infer based on their role in the organisation. The respondents highlight the need to correctly define the rationale and capture requirements for the execution of this activity. The next dimension is data reporting, which involves the production of summaries on the asset performance at the operational, tactical and strategic levels. Key Performance Indicators (KPI) of operational tasks are reported monthly or quarterly depending on the service level agreements with clients or asset owners. This is shown in Figure 11.

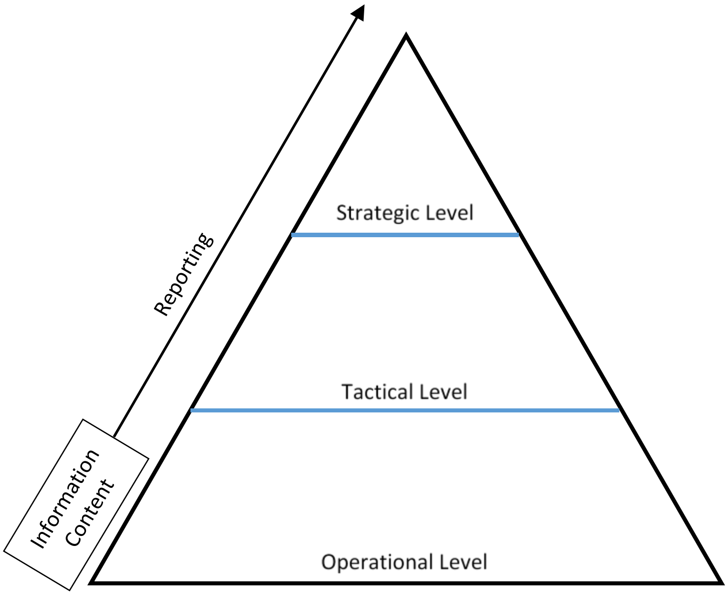

Figure 11: Strategic reporting of the asset information content

4.4 Layer 3: BIM Business Value Generation (Core Category)

The final category is the core category, which involves the creation of BIM business value. The respondents note that there are six dimensions to BIM business value from the perspective of their clients, which are: management, commerce, efficiency, industry, user and technology value (Figure 12).

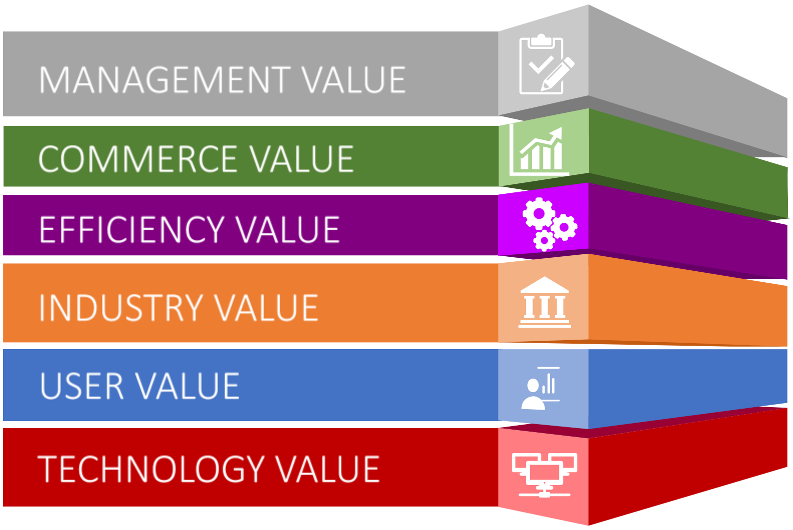

Figure 12: BIM business value

Management value is where the asset owner derives BIM business value as a result of data visibility, utilisation, planning and enhanced task management. Commerce value refers to the benefits derived by the asset owner as a result of the cost savings and cost avoidances that emerge from the BIM-based processes. Efficiency value concerns the productivity benefits to the asset owner as a result of the enhanced asset optimisation and utilisation effected by the BIM-based processes. Industry value refers to the business value derived by the asset owner as a result of collaboration with other stakeholders in the AEC industry through BIM-based processes. User value centres on the end-user benefits and relates to user incentives, data applications and task performances as a result of the BIM-based processes. Technology value is where the asset owner derives BIM business value as a result of the technological functionality that BIM provides to the organisation. This refers to real-time data, data visualisation, connectivity and precision.

5.0 VALUE GENERATION THEORY OF BIM-BASED ASSET MANAGEMENT

The theory presented in this section is derived from data, which are systematically gathered and analysed throughout the research process. Frameworks and conceptual diagrams show the relationships between concepts and provide a trail that demonstrates how conclusions are drawn (Strauss and Corbin, 1998). During the analysis, significant patterns emerged. Therefore, from the relationships that emerged within the data, the following theories were drawn (Figure 13):

- Creation of the Information Content *depends on* Outcomes of the Development of the Information Requirement.
- Management of the Information Content *depends on* Output of the Creation of the Information Content.
- BIM Business Value Generation *depends on* Outcomes of the Management of the Information Content.

Therefore, it is inferred that:

- BIM Business Value Generation *depends on* well-defined parameters that are set during the Development of the Information Requirement.

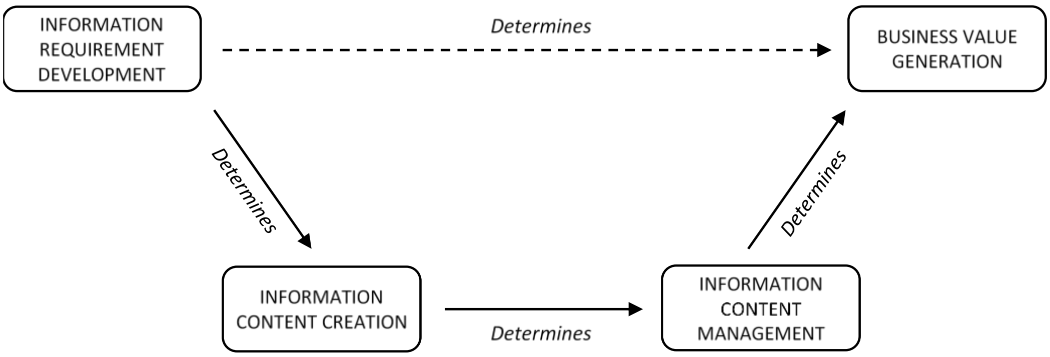

Figure 13: Relationships within categories

Similarly, these relationships have been expressed in Section 5. Furthermore, data in Section 4.1 suggest that the development of the information requirement category is conditioned by the rationale. This is expressed in Figure 14:

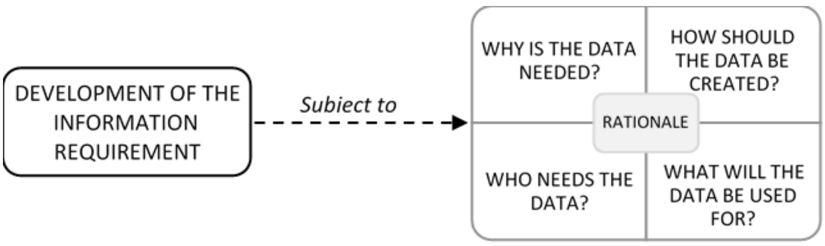

Figure 14: Dependency of the development of the information requirement category

Finally, based on the phenomenon under study, it is inferred that (Figure 15):

- The rationale for BIM-based Asset Management *determines* the outcome and BIM Business Value generated in an AM system.

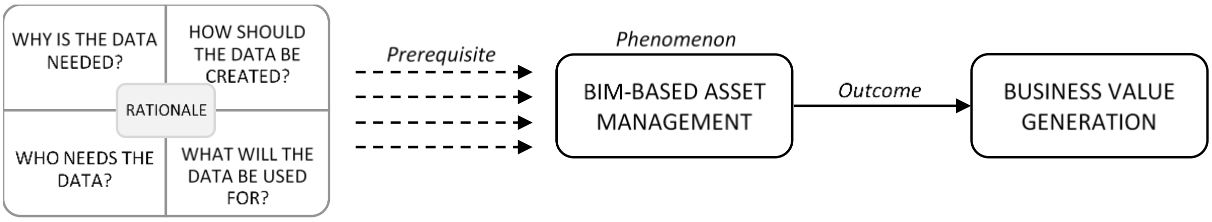

Figure 15: Value generation theory of BIM-based AM

6.0 DISCUSSION

The present study adds to existing literature by identifying key strategic (management) and functional (operational) phenomena that facilitate BIM business value realisation in AM. The main aim of the study is to investigate how BIM can create business value in an AM system and the results show that generating business value is an outcome of many organisational BIM-based processes. The core category identified in this study is *BIM Business Value Generation*. The three categories discussed under Section 4 are seen as important activities for asset owners to realise BIM business value. Therefore, the study discusses related literature on BIM value realisation in the operations and use phase of facilities.

Few studies have attempted to develop theories that explain the phenomenon of BIM business value for asset owners (Love et al., 2014; Sanchez et al., 2016). Also, a number of studies have developed frameworks that help to identify the business value of information technology or systems (Barlish and Sullivan, 2012; Sanchez et al., 2016). Furthermore, many studies have attempted to develop theories to understand the business value of information technology or systems (Ward et al., 1996; Andersen et al., 2000; Thorp, 2001; Lin and Pervan, 2003; Melville et al., 2004; Bakis et al., 2006). On the whole, these studies have used restricted approaches and have not viewed business value from the perspectives of management and operational business processes or from a theory of production perspective. An original contribution of this study is the use of the TFV production system to study an AM system and to generate a theory of how documented phenomena can derive BIM business value. In particular, this concerns the business processes of: the development of the information requirement; the creation of the information content; and the management of the information content; leading to the core category of *BIM Business Value Generation*.

Generating theory from data would imply that concepts and categories are systematically worked out from the collected data. Whilst the data was collected, it was observed that each department within the organisation contributed to various business processes that facilitated the generation of business value. In relation to the first category, which is the development of the information requirement, some studies have suggested the importance of developing owner information requirements for BIM-based processes and aligning these with the asset owner's AM strategy (Ashworth et al., 2016; Cavka et al., 2017). The substantive grounded theory offered explanations of such connections by presenting findings that linked the AM rationale (strategy) to the types of business process requirements, and linked the AM rationale (strategy) to the nature of the asset owner, client or end-user. Establishing relationships between these variables was central to the development of the grounded theory, which has led to a better understanding of the phenomenon, which is BIM-based AM.

Researchers have advocated a better organisational focus in methods of information sharing and the exchange of BIM data, such as the multi-dimensional nature of formats, storage and exchange (Isikdag et al., 2007; Pishdad-Bozorgi et al., 2018). This study extends the knowledge base by highlighting the generic classifications of data sources, formats and capture points in buildings. The substantive grounded theory offered explanations to such connections by presenting findings that linked information content creation to the preceding activity of information content definition, and linked information content creation to information management and the subsequent realisation of BIM business value.

Other studies have highlighted the need to effectively manage BIM data during the entire lifecycle of a facility (Vanlande et al., 2008; Miettinen and Paavola, 2014; Pishdad-Bozorgi et al., 2018). An important contribution of this study is the demonstration of levels of data management that facilitate effective data administration within the organisation. The level at which an organisation can create, transfer, store, analyse and manage asset information is highly contingent on the need and organisational rationale for such information. A clear definition of information requirements by the asset owner will eventually lead to the effective application of BIM-based AM in the right organisational context. The substantive grounded theory offered explanations for such connections by presenting findings that link information management to the preceding activity of information content definition via information content creation and links information management to *BIM Business Value Generation*.

Finally, interesting new knowledge generated from the substantive grounded theory includes the strategic and functional roles that the three categories play in the creation of BIM business value in an AM system. The present study suggests that it is important for asset owners to have a robust rationale for BIM-based processes in AM in order to derive business value. Furthermore, there should be consistency and synergy in organisational management and operational business activities to ensure a positive outcome of BIM business value.

7.0 CONCLUSION

This study aimed to investigate how BIM can create business value in an AM system by using a grounded theory methodology. Therefore, this study presents a novel theory for BIM-based AM. One of the contributions of this study is the demonstration of the application of grounded theory within the AEC industry. The results show that the rationale to develop BIM-based information requirements determines the value that will be generated by the AM system. The four categories discussed in Section 4 are crucial for asset owners to realise the value from BIM. The data are presented as required by the guidelines of Charmaz (2013), which ensures that the data speaks for the participants in a clear and representative manner. The theory in this study has proved to be fit for purpose because: it has answered the research question; expressed the factors considered part of the description of the phenomenon under study; described how the factors are related; shown what constitutes the theory; and demonstrated how the factors form causal relationships (Dubin, 1978; Whetten, 1989; Koskela, 2000).

The results presented lead to four main conclusions. Firstly, there cannot be one single data requirement template that is designed to fit all clients. Asset owners will have to undergo the meticulous process of defining their particular information requirements due to the fact that every organisation’s business process is unique. Secondly, BIM business value creation is dependent on three main categories, which are: development of the information requirement, creation of the information content, and management of the information content. Thirdly, considering that the grounded data has indicated that the information requirement development category guides the data creation, data management and value generation, the study finds that it is crucial for asset owners to develop their information requirements. Lastly, the development of a sound rationale that appropriately translates the organisational business objectives is critical to any value generation.

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APPENDIX A

IDENTIFIED BUSINESS MODELS

1. Wholesale and Retail Trade (Section G)
    a. Retail trade (SG:47)
        i. Retail sale in non-specialised stores (SG:47.1)
        ii. Retail sale of food, beverages and tobacco in specialised stores (SG:47.2)
        iii. Retail sale of automotive fuel in specialised stores (SG:47.3)
        iv. Retail sale of information and communication equipment in specialised stores (SG:47.4)
        v. Retail sale of other household equipment in specialised stores (SG:47.5)
        vi. Retail sale of cultural and recreation goods in specialised stores (SG:47.6)
        vii. Retail sale of other goods in specialised stores (SG:47.7)
2. Transportation and Storage (Section H)
    a. Warehousing and support activities for transportation (SH:52)
        i. Warehousing and storage (SH:52.1)
        ii. Support activities for transportation (SF:52.2)
3. Accommodation and Food Service Activities (Section I)
    a. Accommodation (SI:55)
        i. Hotels and similar accommodation (SI:55.1)
        ii. Holiday and short-stay accommodation (SI:55.2)
        iii. Camping grounds, recreational vehicle parks and trailer parks (SI:55.3)
4. Financial and Insurance Activities (Section K)
    a. Financial service activities, except insurance and pension funding (SK:64.2)
        i. Activities of holding companies (SK:64.20)
        ii. Trusts, funds and similar financial entities (SK:64.3)
5. Real Estate Activities (Section L)
    a. Real estate activities (SL:68)
        i. Renting and operating of own or leased real estate (SL:68.2)
6. Professional, Scientific and Technical Activities (M)
    a. Activities of head offices; management consultancy activities
        i. Activities of head offices (SM:70.10)
7. Education (Section P)
    a. Education (SP:85)
8. Human Health and Social Work Activities (Section Q)
    a. Human health activities (SQ:86)
9. Arts, Entertainment and Recreation (Section R)
    a. Creative, arts and entertainment activities (SR:90.0)
        i. Operation of arts facilities (SR:90.04)
    b. Libraries, archives, museums and other cultural activities (SR:91)
        i. Libraries, archives, museums and other cultural activities (SR:91.0)
    c. Sports activities and amusement and recreation activities (SR:93)
        i. Sport activities (SR:93.1)
        ii. Amusement and recreation activities (SR:95.2)