Theory derived conceptualisations for high level interpretations and descriptions of informational systems and data linkages

(Working Paper 004)

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This paper is issued as an authored “working paper” and is an excerpt of the work in progress being undertaken by the lead author towards fulfilling a PhD candidature. As a working paper, this document has been subject to a limited peer review. The views expressed in this paper are those of the authors alone and do not represent the views of the University of Melbourne. Any comments on the paper may be sent directly to the lead author, Ilsa Kuiper, via ikuiper@student.unimelb.edu.au.

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Abstract
This working paper aims to describe theoretical perspectives of information as an interpretative basis for research into building information modelling (BIM) and public procurement of infrastructure projects. Theoretically deduced concepts derived from Burgin’s (2010) general theory of information (GTI) are developed and explored as a solution towards identifying and analysing systems based propositions relative to information. Termed elemental expression, network infrastructure and transitions of state, these interrelated concepts are described by clustering the ontological principles offered by GTI. In effect these concepts offer a high-level approach to delineate potential informational characteristics of systems, and which may lead toward more detailed analyses of information system dynamics.

For public procurement of infrastructure projects, the offered interpretation provides a new way to identify or target potential changes and design to better support the relative stakeholders towards achieving intended objectives. Whilst this may include seeking alternative value propositions derived from information dynamics for any context, it may equally apply in terms of defining or bound what BIM could mean.
Key outcomes of this working paper not only illustrate the different informational systems that can be associated within the definition and applications of BIM. But the research further considers possible public procurement implications that may arise in the context of BIM due to the conceptual differences between data (including types of data) and information.

Keywords: Burgin’s general theory of information; building information modelling; BIM; BIM data; informational systems
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Introduction
This working paper presents a descriptive overview of three informational conceptualisations derived from the ontological principles described by Burgin (2010) as part of the general theory of information (GTI). The proposed concepts include: elemental expression; network infrastructure and transitions of state. These conceptualisations have been developed as a methodological means or basis for determining informational perspectives of given contexts. This working paper also forms part of a wider PhD research program into BIM and public procurement being undertaken by the lead author.

To consider the application of these conceptualisations within the context of researching BIM and public procurement of infrastructure projects (see background (Kuiper & Duffield, 2018a, 2018b, 2018c)), potential research issues are identified for discussion. This includes highlighting guiding factors and qualifications, limitations or areas of concern, and potential interpretative implications for example.

The following sections of this working paper are set out in two parts. The first includes a theoretical overview drawing the Burgin’s GTI and the proposed conceptualisations. This is followed by a discussion of the potential issues and considerations these conceptualisations may raise for research on BIM (and where relevant in the context of public procurement of infrastructure projects). The paper concludes with commentary on the key outcomes from this work.

Theoretical perspectives on information
This section introduces the ontological principles as described by Burgin (2010) as part of his discussion on GTI. It further introduces and describes the concepts (termed elemental expression, network infrastructure and transitions of state) that are directly derived from these principles.

Ontological Principles of General Theory of Information
In giving form to GTI, Burgin (2010) describes a series or system of ontological and axiological principles that go towards formalising the nature and behaviour of information. Based on parametric definitions of information, the ontological and axiological principles also provide a potential means to
qualify, quantify and measure informational features. To this extent, Burgin’s approach is acknowledged to retain and use a multi-functional approach to information and provide a mathematical-categorical perspective (Brenner, 2014a), and as distinct from other philosophical orientated pursuits. It further permits model development “for information and its flow, as well as for computers, networks and computation”, notwithstanding insight limitations of discerning “information as a real process” (Brenner, 2014b).

For this working paper, however, only Burgin’s (2010) (pp. 92-129) ontological principles of GTI are profiled and reviewed (and as opposed to also considering the axiological principles, see (Burgin, 2010) (pp. 138-144)). This stance aims to provide the preliminary step of framing or describing the nature and behaviour of “information” rather than attempting to measure or quantify information attributes. Although the latter arguably warrants examination, including as another next step for information orientated research.

Table 1 sets out Burgin’s (2010) ontological principles (prefixed “O”) of GTI, including a summary of the described principles. The table comprises further general descriptions of the features and conditions as another offered interpretation of the principles.

<table>
<thead>
<tr>
<th>Ontological Principles (O)</th>
<th>Summary description of principle</th>
<th>Interpreted feature or condition descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1 Locality</td>
<td>“Information” is distinguished and relativised for a system (R) and from the context of abstract absolute information</td>
<td>Connoting the relativity and apportioning for information (possibly akin to or a type of grounding or situational effect)</td>
</tr>
<tr>
<td>O2 General transformation</td>
<td>Information for a system is a capacity (ability or potency) to cause change in a system, permitting subjectivity and apportionment of information (as part)</td>
<td>To enable function of and for change, including that may be within an information space (via the operator, IF)</td>
</tr>
</tbody>
</table>

3 In terms of BIM, it is anticipated that there may be examples that do this and that already exist. This is notwithstanding the potential for differences in terminology, positions and perspectives taken, methods used and informational features measured.
Ontological Principles (O) | Summary description of principle | Interpreted feature or condition descriptions
--- | --- | ---
O2a Special transformation | Information of a system (in a strict sense) is a capacity to change structural infological elements from an infological system $IF(R)$ of a system $(R)$ \(^4\) | To enable function of and for change, but relative to, in or of parts
O2c Cognitive transformation | A system can comprise a cognitive infological system in which cognitive information for the system is a capacity for change. Cognitive infological systems $CIF(R)$ contain knowledge of a system to which it belongs and is a source of knowledge change | To enable function of and for change in respect of referential basis (possibly akin to awareness)
O2g Relativised transformation | Information for a system (relative to the infological system) is a capacity to cause change in the system. Infological systems can have capacity to store information, comprise elements as infological elements | To enable function of and for change for hosting
O3 Embodiment | For any portion of information (denoted as $I$) there is a carrier (denoted $C$) of this portion of information of a system | As a means or basis for hosting and types
O3m Material embodiment | For any portion of information, there is some substance that contains information (that can be defined as carrier classes including material, mental and structural) | 
O4 Representability | For any portion of information there is always a representation (as a carrier) of this portion of information (denoted as $I$) for a system | To enable form, implying O3
O5 Interaction | A transaction, transition, transmission for information (either directly or indirectly) goes on only in some interaction of the carrier (denoted $C$) with respect to the system (denoted $C \rightarrow R$) | Hosting related functionality (possibly depicted as or akin to engagement)
O5a Structured interaction | A system receives information only if some carrier of information transmits information to the system or the system extracts this information from the carrier, including as reflective of a processing of information | Hosting related functionality as enacting or affecting change (as transaction, transition or transmission)
O6 Actuality | Information becomes actual only when it is transmitted to and comprehended by a recipient (subject to transformation which results in a system acceptance of a portion of information) | As function for change of state (possibly akin to affecting realisation)
O7 Multiplicity | One and the same carrier can contain different portions of information for one and the same system | Hosting related functionality

It is further noted, that whilst these principles are offered, this reflects an interpretation and recognises the potential scope for further application, examination and research. This includes whether consolidating these theoretical perspectives, “tweaking” them or rejecting them outright.

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\(^4\) By way of further explanation, an infological system is a free parameter enabling consideration of different information types, and that comprises infological elements (Burgin, 2010) (pp. 55, 113). One example is where a human is considered a system, and the mind is determinative of an infological system, and a memory is an example of an infological element.
Detailed descriptions of General Theory of Information derived conceptualisations

From the ontological principles of Burgin’s (2010) GTI set out in Table 1, three interdependent concepts (as interrelated variables) are proposed. This was achieved by clustering or grouping ontological principles whilst recognising the necessary interplay of these concepts as contributing to determining or discerning information. As set out in Figure 1, the concepts are termed: elemental expression (EE); network infrastructure (NI); and transitions of state (ToS).

These concepts represent an interpretive configuration or translation, as a step toward establishing the respective connectivity to more general forms, structures and language noted and referred to in the research literature. In effect, they provide an option for high-level interpretation only. It is anticipated that these concepts could be applied to provide a first pass review of a given circumstance and complexity (e.g. comprising multiple parts, layers and/or interconnectedness). The objective of this type of approach is to identify possible informational characteristics and features. This may also include determining the respective or extent of potential systems, systems of systems or relevant relationships. As an interpretive process, it further aims to balance and link theoretical generalisations and real world contexts (Neuman, 2011) (p. 63).
Each of the concepts are described in further detail in the following paragraphs.

Elemental expression (EE)

One of the foundational characterisations of Burgin’s (2010) (p. 87) discussion of GTI encompasses the relationships or structure between the conceptual triadic dimensions of:

- an object (as of the worldly reality, including a thing, activity);
- a sign (as a representation or expression); and
- interpretative capacity for meaning.

Whilst this can lead to an end state, as a determination, interpretation or realisation, Burgin’s (2010) GTI supposes it reflects a derived part of a potentially infinite or indeterminate landscape of information or absolute information (O1 Locality). Burgin (2010) (p. 93) further draws the distinction to suppose that whilst information may be considered infinite or open in an abstract way, practically its realisation is predicated on certain transformations and pretexts or conditions. This includes Burgin’s (2010) (p. 127) reference to information serving as an indicator of the transformation of a respective system (O6 Actuality), including any responsive and subsequent actions. Conditional references further infer linkages to other transformations and the carriage of information. This includes being relative to assignment or labelling of objects (O4 Representability) that may also be predicated on inherent, subjective or determined reference or classification sets, or capabilities, as well as those that may be new\(^5\) or different (Burgin, 2010) (p. 124). By way of another example, Burgin (2010) (p. 198) notes that a representation may, by virtue of its features:

- be any structure (i.e. a pattern, picture, model);
- be abstract or concrete, or symbolise some other structure; or
- contain informational parts or elements,

\(^5\) Given the potential for “new” realisations (derived from informational processes), there may be an argument to suggest one part or branch of innovation definitions may have source roots in this function or feature (even as a prior step to material or product based innovations).
that help the receiver to infer meaning from a sender.

Appreciably, however, such transformations may be multifaceted and complex, whether layered or comprising voluminous or concurrent actions and structures, and predicated upon the base system identified for analysis. The concept of elemental expression may further attribute to distinguishing other characteristics, including, for example, in terms of commonality or friction (relative to objectification connections) or sufficiency (as a tipping point for information).

**Network infrastructure (NI)**

Network infrastructure descriptions allude to a form or supporting structure, including that can comprise carrier forms (O3 Embodiment) (Burgin, 2010) (p. 120). That is, a form that can “carry” or host for information and which is or can be embodied by a material or substance. As such carrier classes can include material, mental and structural forms (Burgin, 2010) (p. 120) (O3m Material embodiment). Carriers may also comprise certain capacity (whether for different portions of information (O7 Multiplicity) (Burgin, 2010) (p. 128), and that may be subject to certain informational orientated limits or limitations. This may be particularly evident if these carrier characteristics are akin to channel capacity or entropic considerations, including as Burgin (2010) (pp. 5, 6) (in view of (Shannon, 1948)) notes as “quantity of information”.

Whilst an infological system can perform or have carrier functionality (depending on the function performed), this system characteristic is not reciprocated for a carrier. Likewise, (Burgin, 2010) (p. 122) notes that an information representation is always a carrier but that information carriers are not always an information representation. An infological system is also perceived as one that is being of or having capability of discerning “different kinds of information, e.g., social, personal chemical, biological, genetic, or cognitive, and combines all existing kinds and types of information in one

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6 The material embodiment principle as discussed by Burgin (2010) is denoted as “OM3”. For consistency across the principles, “O3m” has been adopted for this paper.
general concept of ‘information’” (Burgin, 2010) (p. 54). This may also be determinative or an example of the carrier nature (in terms of O7 Multiplicity) of infological systems (Burgin, 2010) (p. 128).

**Linkages between carriers, infological systems and systems**

Burgin’s (2010) (pp. 124-125) GTI further emphasises a carrier/system relationship determined as a relative action and basis of connectivity affecting information (O5 Interaction, O5a Structured interaction). There may be certain types or characteristics of interaction (for example direction and degrees (contribution, extraction as well as direct or indirect), points of time, as singular entities or groups, physical or digital, connected or isolated). By extending these types of engagement, it may be feasible to follow a potential or relative input-output functionality. This includes whether it is described as sending, issuing, carrying or receiving.

By bringing these features together, del Moral, Navarro, and Marijuán (2014) intimate a context for systems that may consist or comprise of an “infostructure” made up of “informational entities”. This includes for the latter possibly incorporating types, either as a carrier or a carrier/infological system hybrid. However, in adopting graph theory representations (to model relationships between objects), it may be another proposition again to configure the relevant structures relative to or including:

- carriers as a conduit illustrative of the path of connoting transformation to affect information; and
- carriers/infological system hybrid as nodal entities or units in which information can be realised or evoked.

Of note, is that Burgin (2010) (pp. 110-111) intimates the definition of an infological system is not intended to be confined to singular or nodal entities (as subsystems of systems) but may be potentially be dynamic, layered and multidimensional. Extending this further supposes collective and scalable forms depicting a whole (comprising of parts) can be delineated, and could lead to consider systems of systems frames, structures, types or examples.

**Possible applied componentry of Network Infrastructure**
Drawing from the synopsis for emergent information by Hofkirchner (2013) (p. 171), information evoking and utility systems are proposed to be categorised as either material (physical or chemical), living (biotic) or human (social) for the respective information types: pattern formulation, code making or a constitution of sense. This basic pretext leads to suppose informational entities (infological systems, carriers) may not only include humans (as living entities) or have human orientated dimensions (including of social contexts for human interaction). It possibly further intimates a role of technologies or machines\(^7\) (notwithstanding the originating or operational basis being human orientated or sourced)\(^8\). In terms of information, such entities would still be subject to the relative functionality and condition requirements\(^9\).

**Transitions of state (ToS)**
The concept of transitions of state effectively incorporates consideration of a system’s capacity for change or transformation for or as it concerns information. These are denoted by Burgin (2010) (p. 92) as a system having such a capacity generally (O2 General transformation). But he also notes (pp. 116, 104 respectively) of this capacity in respect of certain system parts or compositions, be it infological elements (O2a Special transformation) or the infological system itself (O2g Relativised transformation) (including as to the relative stored features, such as infological elements). This may also be inherent for emergent information as described by Hofkirchner (2013) (p. 125), particularly as it relates to any prerequisite or conditional “adjacent necessary”. Or justifiably heightened or realised due other ways of human thinking\(^10\). However, Burgin (2010) (p. 114) also distinguishes a further type

\(^7\) This also relates to other like descriptions and relationships, such as machine to machine (M2M) (OECD, 2015) (p. 36).

\(^8\) Appreciably, this potentially may engender the need to affect unique rules for and about technology, including in terms of scale and self-performance.

\(^9\) Extending this further, Dopfer and Potts (2008) note that “[f]irms exist not just to minimise operation transaction costs, but more fundamentally they exist to organise new knowledge that no individual human could coordinate”. Putting aside whether there are distinctions to this “new knowledge” (including as recognised as a desired social outcome, material production), it may lead to consider the extent to which technology, including that may be algorithm based, may fulfil this role or contribute to this. This includes the impact on the role and composition of the “firm”.

\(^10\) The focusing illusion (Kahneman, 2011) (p. 403) may be one example. Another variation may be in the way this is achieved. For example, (Dopfer & Potts, 2008) (p. 38) make the distinction between global and local novelty (possibly equating describing a new idea and the new application of an existing idea).
of cognitive infological system with transformational capacity (O2c Cognitive transformation) with ties to knowledge or self-awareness based inferences and connotations.

Using ontological principle O2 along with its versions, Burgin (2010) (p. 55) accords information with that which can exist in “nature, society, mentality of people, virtual reality, and in the artificial world of machines and mechanisms created by people”. It further points to explaining examples of self-perpetuation, where by the reception of information, such as by individuals and social groups, induces transformation.

**Inference of time**

A further inference of the concept of transitions of state arguably incorporates and considers time or the relative temporal dimensions of information. It follows underlying presumptions that change has some relativity to time, including as an irreversible, forward progression. This not only concerns of the transformation properties (including processes) that are inherent or conjured within or by a system, but also between and across systems. Thus, a further consideration for network infrastructure conceptualisations noted above relates to the state in which the relative nodes and connectors are enacted or “on”. That is, the point in which information is realised, affected, reflective of certain transformations, transitions or transfer occurring or happening. But it further infers a circumstance which may not necessary stop or cease.

This gives rise to suggest network infrastructure may be determined as a state of potential (including that may be anticipated or unexpected), at real point time or confirmed as actual or retrospective view. However, the extent to which the informational transformations could be mapped, either as or relative to potential, in real time or retrospective events presents another offering (see for example Figure 2).
By adding temporal considerations, mapping such “paths”, trajectory or trails (relative to the respective informational entities) may be subject to that which can be feasibly discerned or captured. This may be particularly relevant to historical or non-digital scenarios and circumstances. Whether this in turn is or could be determinative of “flows”, including as flows of information transactions, is also relevant. In one sense, it follows del Moral et al. (2014) reference to informational entities that “organize their permanence amidst endless flows and exchanges with the environment”. Hofkirchner (2013) (p. 114) further suggests that humans, in the context of social interaction as a form of self-organisation, will evoke further information that goes to self-perpetuating not only the nature of the self-organised form but also the direction or path taken. Whether there is or could be a critical path or trajectory determinations as it pertains to information, including in terms of reliance or optimisation, is likely to require further development.

Finding the “I” for BIM? Issues and considerations for research

In view of the GTI ontological principles and proposed concepts (EE, NI and ToS) above, there are several issues for consideration for information based research of BIM. This is discussed further below, including to:

- highlight the potential relevance of systems as a unitary basis for the analysis of information or informational orientated perspectives;
• consider existing BIM definitions through an informational lens, including in acknowledging the potential for multi-system interpretations of BIM;

• discuss the possible semantic and temporal qualifications for interpretations of BIM; and

• propose a possible approach to BIM, particularly in consideration for broad scaled applications, premised on data.

Unitary basis for analysis of information: the relevance of systems

For any given context, there may be considerable scope in which information could be profiled, either in part or from broader scaled perspectives (including as a hypothetical or future circumstance). However, one possible approach to disaggregate complex and all-encompassing perspectives could involve interpreting a context in terms of systems. This includes as informational systems (and possibly as a distinction from information systems). It is another proposition again to suggest whether systems inherently comprise context or reflect higher order, increased system complexity.

Generally, the discussion and context of BIM is not immune from systems references and orientated research in the literature (Kuiper & Duffield, 2018c). This is despite such reference focusing on systems that are technological or “machine” based in nature. However, as the intent of GTI described above does not limit the qualification of “systems”, such classifications may be more broadly defined. It points to suggest the relevance of BIM could be further discerned as relating to humans (as living forms, either as individuals or types of grouping), other technology or a mixture of both, or the respective parts or componentry\(^\text{11}\). Ecosystem based terminology and research may be a further basis for overlap or linkages\(^\text{12}\).

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\(^{11}\) Harty and Whyte (2010) allude to this mix as part of the research into the role of mixed media (including information technology) for emerging practices in construction design work, particularly through actor-network theory and the role of human and non-human factors.

\(^{12}\) See in reference to BIM and built environments (Moffat & Kohler, 2008; Starkey & Garvin, 2013) and information based perspectives (Hofkirchner, 2013) (p. 228).
A consequence of this, however, leads to infer that each system identified in the context of BIM may constitute or comprise different, potentially blended, mix of informational features (see for example as described in Table 2).

### Table 2 Potential informational systems examples raised in the context of BIM

<table>
<thead>
<tr>
<th>System</th>
<th>Information characteristics that may arise in the context of BIM</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A person</td>
<td>Knowledge states about (or lack thereof):</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• BIM (as thing or object), as well as the respective parts/portsions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• use of BIM (as software program/product)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• development of BIM (as software program/product)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• the effect or impact of BIM, including interpretation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capability, capacity to/for knowledge states</td>
<td></td>
</tr>
<tr>
<td></td>
<td>including transitioning from potential to actual, and probable referential bases</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knowledge states about other/multiple things</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emphasis on cognitive functions, including that may relate to:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• learning, creating, designing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• decision making</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• seeing, viewing</td>
<td></td>
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<tr>
<td></td>
<td>• recognition, interpreting</td>
<td></td>
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<tr>
<td></td>
<td>May relate to individuality or uniqueness of person (e.g. subjectivity)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Relativity to other systems (for example within context)</td>
<td></td>
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<tr>
<td></td>
<td>Carrier aspects may connote human physiology (e.g. eyes)</td>
<td></td>
</tr>
<tr>
<td>BIM program (a type of ICT)</td>
<td>Human based origins</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potential states (subject to interaction, including operation)</td>
<td></td>
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<tr>
<td></td>
<td>Bounding effects (subject to code)</td>
<td></td>
</tr>
<tr>
<td>Person (user) using BIM (program)</td>
<td>Translation of user knowledge to digital/machine based form</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interfaces may include human/hardware, software/hardware, other systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potential dual bounding, scope effects (code, knowledge)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Related to context, including purpose, objective or motivation, and that may have location/space dimensions (that may or may not be proximate e.g. cloud)</td>
<td></td>
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<tr>
<td></td>
<td>Likely to be relative to other systems (e.g. other model authors, technologies)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can be discerned by products/results/outcomes of interaction (e.g. model, databases)</td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td>Scope for multiple systems, carriers (including that may be technological, human)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scope for multiple interactions, including different types and at points in time</td>
<td></td>
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<tr>
<td></td>
<td>Entropic potential and range heightened (people not knowing about BIM, how to use, BIM use with others etc)</td>
<td></td>
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<tr>
<td></td>
<td>Friction potential heightened (technology incapable of interaction with BIM/outcomes, people having misaligned views of BIM, number of interactions)</td>
<td></td>
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<tr>
<td></td>
<td>Relevance of non-BIM context (as proportion of other information dynamics)</td>
<td></td>
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<tr>
<td></td>
<td>Related to context, including material forms</td>
<td></td>
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<tr>
<td></td>
<td>Differences throughout project (as a system) to which BIM may/may not be relevant, including in different forms (model, part of model, as object)</td>
<td></td>
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<tr>
<td></td>
<td>Degrees/probability of adaptation relative to representations of built environment</td>
<td></td>
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</tbody>
</table>

Notably, the above table is not limited but could include other potential systems. Perceived this way, it possibly highlights the multi-faceted complexity that can arise with systems based approaches.

Accordingly, research may also involve identifying and reconciling systems, as determinative parts,
collectives of parts (systems of systems, subsystems, elements) and intimating certain relationships (whether inward looking, external, retrospective or future orientated)\textsuperscript{13}. Viewed globally, such information landscapes are arguably overwhelmingly vast, live and continuous. By inference, however, even this breadth may be superficial. For example whether information is or could be a physical manifestation at anatomical or molecular level or scaled systems, has been raised in the research on information (Burgin, 2010) (pp. 36-37) and in other domains (for example, epigenetics (Griffiths, 2017)). But this may also accord with information/rule correlations, including generic/genetic classifications (Dopfer & Potts, 2008) (p. 6). Arguably, these still only constitute part of, albeit unattainable, absolute information.

Whilst the expanse of possible systems further point to multiple types or forms of systems that may be considered and compared for informational research or analysis, it may offer a way to identify or contextualise certain information features. Conversely, it may also highlight those features that differ between systems. However, a further interpretative step towards isolating the information relativity of systems may be achieved by applying the proposed GTI concepts (EE, NI and ToS).

**Reconsidering BIM definitions relative to informational systems**

To further consider the above discussion, systems based approaches could be contemplated in terms of BIM definitions (Kuiper & Duffield, 2018b, 2018c). Specifically, this includes considering BIM as a type of technology, as well as the activity that enables and goes to the realisation of a type of digital model. To this extent, the label of BIM as an “umbrella’ term” by Papadonikolaki (2016) (p. 42) is apt, notwithstanding the past promotional inferences of this descriptor (Miettinen & Paavola, 2014).

However, even at a superficial level, these descriptions point to potential differences in the types of systems that could apply. Relevantly, though, this further supposes that the informational features of

\textsuperscript{13} For example, mega projects arguably reflect a different type of system to traditional, smaller scaled projects. It is another matter again determining whether the characteristics of mega projects are or would be akin to larger organisational forms or modes.
“BIM” definitions can vary (refer Table 3) and which may ultimately result in different responses and considerations\(^{14}\).

**Table 3 Example variability of BIM definitions (as systems) relative to information concepts**

<table>
<thead>
<tr>
<th>BIM definition terms</th>
<th>GTI based information concepts</th>
<th>Comment on externalities, bounding attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI</td>
<td>ToS</td>
<td>NI, ToS, EE</td>
</tr>
<tr>
<td>Technology</td>
<td>State of potential</td>
<td>Human derived (i.e. software developers, marketing/sales)</td>
</tr>
<tr>
<td></td>
<td>(subject to input)</td>
<td>Organisationally purposed/ purchased (economic product, subject to use/access arrangements)</td>
</tr>
<tr>
<td></td>
<td>Software/code (subject to</td>
<td>Discrete functionally</td>
</tr>
<tr>
<td></td>
<td>adaptation)</td>
<td></td>
</tr>
<tr>
<td>Technology (store/file format)</td>
<td>State of potential (as product, further use/application)</td>
<td>Discrete set of structured data (i.e. object/relation based, concerning built environment)</td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>Intentionally future driven (i.e. created/basis for insights, including for further modelling)</td>
</tr>
</tbody>
</table>

Of note, is that this breakdown possibly has some resonance with the structure-function-behaviour based descriptions of BIM described by Turk (2016) (i.e. model-technology-modelling). Notwithstanding the generality of these distinctions, the following paragraphs set out further details illustrating the potential multi-systems perspectives that appear to fall within the existing BIM definitions.

**BIM as a type of Information and Communications Technology**

In describing BIM as a type of information and communications technology (ICT), it can be and relative to, or a direct consequence of a discrete type or set of digital tools or technological program, and

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\(^{14}\) This is particularly evident from legal considerations where issues may relate to:

- the selling and purchase of a technological product, including associated arrangements be it for sale, licensing, or distribution and that may related to consumer related concerns and protections (see (C. Merschbrock & Nordahl-Rolfsen, 2015));
- how project parties or participants (that may or may not be contractually related) (Kuiper & Holzer, 2013) work together or collaborate on the development of a design or the extent they may be liable for the design (including that arise from errors or mistakes); or
- contract compliance issues, including whether deliverables fulfil fit for purpose requirements (see (Beach, Petri, Rezgui, & Rana, 2017)).
further qualified in terms of functionality\textsuperscript{15}. At one level, this may include those systems that enable certain object/parametric based or orientated sets of data and representations about and of a built environment, and synchronised model views\textsuperscript{16} (Cerovsek, 2011).

Looking inward, though, this functionality is a consequence of the enabling software/hardware programming and code\textsuperscript{17}, with linkages to technology-human interfaces\textsuperscript{18}. In effect, this possibly depicts an informational environment comprising a collection of bounding “rules”, albeit that can change (i.e. software updates). These rules attribute to how a certain set or type of built environment representations\textsuperscript{19} are or can be configured and presented. To the extent this reflects “knowledge” “characterised by machines, blueprints and recipes” (Potts & Mandeville, 2007) generally, or in relation to BIM, may be relevant.

In contrast, however, such rules may not strictly be built environment representations themselves, despite there possibly being some relativity and overlap (i.e. terminology, pre-determined relationships). Further, such “systems” are arguably premised upon being in a state of rest or potential, and notwithstanding the originating form (i.e. a software product) being human derived or orientated. Appreciably, such systems are and will be subject to external interaction, albeit that can occur in numerous ways and that can call upon all or only some of the bounded functionality offered.

\textsuperscript{15} The is evident in the literature generally, including in terms of how BIM is used and/or the applications of BIM. For example see (Bosch-Sijtsema, Isaksson, Lennartsson, & Linderoth, 2017).

\textsuperscript{16} The aim of which enables multiple views of the same, concurrent representations.

\textsuperscript{17} This accords with the description of BIM by Linderoth (2010) “as a technology consisting of a vast amount of programs of actions inscribed”.

\textsuperscript{18} This may include or relate to, for example, standards or schema development and metrics (including in recognising the adaptation of tools) (Cerovsek, 2011) or semiotic based approaches for developing interfaces between software developers and building designers (T. Hartmann, 2014).

\textsuperscript{19} There may be scope to identify the general, determinative descriptors and characteristics (including any levels, hierarchies, changes that occur) that identify this set of representations.
**BIM as a function of modelling, models**

As intimated above, the definition of BIM incorporates other presumptive elements, whether denoted in terms of inputs, interactions or conditions. Accordingly, model reference descriptions of BIM are arguably an outcome depiction realised only due to the interaction between such tools and a user or author (or as multiple sets, other input contributions). Similarly, modelling inferences are illustrative of the active state of this interaction (as a present participle conjugation of the verb, to model and by the thing that models). Appreciably, though, these possibly reflect other, albeit different, kinds or features of informational systems again.

Distinguishing further examples, there is also the subsequent use or interpretation of built environment models derived from BIM, whether as a whole or part thereof. Whilst this may be an example that arguably tips into the “building information management” connotations of BIM, this does not detract from the potential uncertainties raised with this terminology (Kuiper & Duffield, 2018b). It is another matter again to suggest that terms such as “building information management” (or like terms) may not align or fit neatly (without further qualification) in accordance with GTI perspectives. This includes, for example, whether:

- information can feasibly be “managed”, or is determinative of an approach or management for or towards information;

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20 For example, testing whether there are (or should be) distinctions with and between BIM and “building information” (or more likely “building data”) that may be considered “non-BIM” (such as a 2D drawing that represents a building). It is another question again to suggest this may should be irrelevant or may be otherwise determined by the flow on effects of such.

To some extent, this has been considered in as part of the standard PAS 1192-2:2013 (The British Standards Institution, 2013). This UK standard distinguishes an “information model” as comprising documentation, non-graphical data and graphical model that can arise from a project (“project information model”) for subsequent use (“asset information model”). Although viewed from GTI perspectives, the “information model” is conceivably a dataset (and possibly, without further qualification, reflects existing, traditional practices, rather than as a nuanced framework leveraging “BIM”).

Further consideration may be necessary in recognising the relevance and potential persuasive attributes of the term “BIM”. This includes as a thing or mechanism that has provoked and conveyed a global narrative.

21 For example, if information is premised upon the possibility or likelihood of being realised or evoked, is or would the subject of management include focusing on the enabling context or conditions for information (and
• the prefix of “building” is sufficiently broad or has discrete meaning (be it a noun, verb) to reflect or pin point a certain type or kind of “information”;
• such terms cover all attributes and features that can go towards information collectively (for example in accordance with the proposed concepts, EE, NI or ToS); or
• the terminology used could or should be described otherwise or contrasted with other existing examples (for example as subset of or types of “data management”, “database management”, “data models”?

Acknowledging possible “BIM” qualifications
In taking a deeper look at how the term BIM is used, information orientated approaches are likely to offer further qualification. This includes around broad or far reaching interpretations of “BIM”. Whilst this can be acute in terms of some theoretical views of BIM, it may provide a way to distinguish perspectives of BIM based on subject/object distinctions and further qualifying BIM in terms of data.

Distinguishing BIM: as the subject, as the object
Another challenge from informational perspectives of BIM arises from the subtle changes to the semantic references22 to BIM. This includes those types of examples emphasising the relevance of BIM (as the object) relative to a subject, rather than being about BIM as the subject23. This distinction may

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22 Ironically, this may possibly be due to changes as part of the EE concept. This includes trying to determine what “sign” (label, description, term) is attributable to the thing or object (as a function of representability) and what meaning is attached to the sign-object relationship (as a function of actuality).

23 This may include where the premise is about BIM as a discrete object or artefact, like a model or a type of software/program and what it can enable or do. Also see the discussion by Hofkirchner (2013) (p. 156) on the subject-object dialectics and information. Viewed in terms of evolution, this may pertain to “the gradual unfolding of phenomena in a cumulative and thus path-dependent way; and, quite separately, a dynamics of system behaviour which creates change and emerging structure from variety in behaviour” (Metcalfe, 1995).
be intensified when considering the presumptive context or conditions of BIM from human and social related\textsuperscript{24} or temporal perspectives.

For these and in acknowledging the variability of systems and informational consequences that arise from BIM definitions, it may mean distinguishing BIM propositions that are technological, model or modelling orientated, or a combination of these. Viewing BIM via these frames may offer an opportunity to identify the differences in the types of implications and impacts, as well as offer alternative perspectives.

This is illustrated by considering the BIM dimension/field termed “policies” (Kuiper & Duffield, 2018c) (which appears to be premised upon the presumptive objective of the wide spread uptake, adoption and implementation of BIM). Appreciably, the intent of this objective is different to considering how markets or institutions respond (or are responding) to the introduction of BIM and how they are desired, expected to behave or work\textsuperscript{25}. Accordingly, the impact of BIM\textsuperscript{26} can also be considered in terms of the respective parts, including types of:

- organisations, such as small to medium enterprises (SME) (Dainty, Leiringer, Fernie, & Harty, 2017); or

\textsuperscript{24} For example, the definition of BIM presumably does not incorporate or extend to include issues concerning: cognitive capacity; training/knowledge of information and communication technology (ICT) programs; project workflows; organisational adoption of tools or strategic market positioning; organisational reputation; software procurement and licencing arrangements; or inter-organisational or international linkages and relationships. This is despite BIM being raised in these terms and contexts.

\textsuperscript{25} For example, this may include questioning direct or mandated references to BIM as a technology and as a socially orientated requirement. Whilst this may concern risks associated with uncertain terms or professional experience/expertise or biased, limited or presumptive uses and benefits of BIM, there may also be issues around public procurement tensions (i.e. related to competition, monopoly behaviours, transparency, inequality/fairness, innovation opportunity, relative decision making).

\textsuperscript{26} This arguably may be considered from different perspectives and may play out in discernible degrees. The type of relativity is noted by Stiglitz (2017) making reference to those “pervasive pecuniary externalities that matter; what one firm or individual does has consequences for others” in the context of asymmetries of information and incomplete markets.
• industries, professions and practice, such as for facilities management (FM) (Pärn, Edwards, & Sing, 2017) or contract/construction law (including from UK perspectives (Centre of Construction Law and Dispute Resolution, 2016; Winfield & Rock, 2018)).

The effect of such an approach also has the potential to separate out those issues that grounded from socially, cognitive or technologically perspectives, including that are attributable to the human/social decision-making about BIM, but are not “BIM” per se. This subject/object distinction may be further illustrated by examples that overlook or fail to consider the likelihood of less deterministic consequences27 that can arise using BIM, or linkages to past or previous practices and approaches. This includes using the past (or that which is “known” relative to informational system) as a basis for future considerations28 (potentially pointing to or knowing where to look).

27 For example, this may include for applications, ideas, solutions or approaches that are still yet to be formulated or identified, that can emerge or possibly attribute to innovation. But it may further extend to include those scenarios in which BIM may be rejected or perspectives change.

Appreciably, this not only plays out in terms of built environment representations (including using other technological tools) that can exist without BIM, but also of those other built environment data structures that currently have no direct, vague or tenuous connection or association with BIM. An example of the latter may include using BIM as part of the education of children, including as a basis of conveying mathematical concepts, integrating virtual and augmented reality features for example. This is also notwithstanding there may be correlations with existing programs, games and apps for children that comprise built environment elements (i.e. Minecraft), and the potential interfaces changes (including whether as new products) that may be required for children (as other and different informational systems).

28 This may follow the adjacent necessary principle (Hofkirchner, 2013) (p. 125). For example, one type of relationship with the past is arguably achieved through people (as a type of informational system). It may include or concern, not only the types of depictions or representations of the built environment that were enabled, but also the way in which this was achieved, applied or managed. To the extent this may provide a grounding or basis to identify future applications of BIM may be of interest. For example, one starting point in examining the potential breadth and contrast of BIM may lie in how societies use or have used 2D drawings of the built environment. Whilst obvious examples include the use of drawings in the AEC industry, peripheral examples may also include the use of BIM for: urban planning approval processes; dispute resolution in planning and construction tribunals, arbitrations and courts; security purposes; or for registering land and intellectual property. Relevancy may also come in the form of people know of their own immediate environment (i.e. which may be impacted by a new development but can be visually determined using BIM. This includes for community consultation processes).

It is another matter again (albeit unfeasible) to profile representations (as types of data structures) that may be associated with the built environment generally but otherwise do not reflect or require a graphical or dimensional form. This includes those representations that may be depicted by words or numbers for example (which may include standards, building codes, laws).
Another view may also involve considering “BIM” as a source point description\textsuperscript{29} in time. To the extent that BIM developments (or evolutionary processes?) may be technological, model or modelling orientated may be of interest. Whether this can be determined relative to time and scale may also be relevant, including that may:

- be a consequence of the lag of social-scientific development behind societal and technological developments (Hofkirchner, 2013) (p. 16); or
- accord with technological transitions (Geels, 2002) or other similar terminology or narratives\textsuperscript{30}.

This may further extend to developing or adopting semantic qualifications for the very term “BIM”\textsuperscript{31}. However, nor should this preclude or exclude considering aspects or factors that may be otherwise relevant, albeit that are “non-BIM” or indirectly related (for example policy\textsuperscript{32}, processes\textsuperscript{33} etc.). To the

\textsuperscript{29} This may be analogous to a point in time that results in a “burst” described by Pollack and Adler (2015) (in their extensive review of the project management literature over time), which may be perceived as discernible growth and collective focus on a particular topic.

\textsuperscript{30} One possible example of this from the research literature on BIM includes the theoretical perspectives on the “diffusion of innovation” (T. Hartmann, 2012; London & Singh, 2013; Christoph Merschbrock & Figueres-Munoz, 2015; C. Merschbrock & Munkvold, 2012, 2015; Shibeika & Harty, 2015; Singh & Holmstrom, 2015; Xu, Feng, & Li, 2014). Whilst this perspective appears to dominate the BIM literature (compared to other applied theories), it is noted there are the multiple contributions by repeat authors.

\textsuperscript{31} Again, the literal prefix “building information” of BIM potentially skews offered interpretations or componentry of BIM (Kuiper & Duffield, 2018c). This includes potentially overlooking the relevance of other (non-BIM) “building information”, or factors that attribute to evoking such information, and including how this is, could or should be realised.

\textsuperscript{32} For example, this may include recognising policy implementation challenges, whether from practical, jurisdiction based perspectives, such as Australia (Althaus, Bridgman, & Davis, 2018) or that can be discerned from implementation theory, see (Kuiper & Duffield, 2018a) referencing (Sporrong & Kadefors, 2014).

\textsuperscript{33} One example relates to building and project life cycle concepts. Another is the act of modelling. Appreciably these predate “BIM”. But due to the enabling functionality of BIM, this has resulted in changing perspectives of what these can mean, relative to past practices and for certain contexts. Although this is different in presuming BIM is the only way in which such activities can be undertaken.

Again, informational orientated perspectives of past practices and approaches may be insightful. This not only includes contrasting gaps of misalignment (or friction) but also those aspects that work or are working within the set or acceptable parameters. This includes for the situations where the introduction of BIM may not be applicable, justifiable or appropriate, and for others, necessary or essential.
extent informational based approaches can explain why less overt examples\footnote{This may include those outlier examples where the definitional connection of BIM (including in contrast to the literal or reference connection) may be less obvious or not typical (i.e. BIM and dental curricula (Kruger & Tennant, 2012)).} are related may provide alternative insights (including as cognitive function, type or way in which data is structured).

Appreciably, this may also include considering the diffusive characteristics beyond such point sources (including relative to the BIM definition variations), where the inference of “BIM” may be different, diminished, filtered or partial. Whilst this may be considered narrowly (e.g. linear, relative to time, number of informational translations, causal), changes may also be dynamic and concurrent, and potentially relative to the respective systems. This includes systems that are likely to or be subject to change over time.

Objectifying the data element of BIM

From the above discussion, however, there may be scope to distinguish BIM as a data orientated object, thing or “product” (see as profiled by Kuiper and Duffield (2018c)). But in stating this, BIM may reflect one type of data that could be considered as one contributory factor for potential information of or about the built environment.

In this sense, the pretext of “BIM” narrows. Instead the focus leverages the model inferences of BIM, albeit as reflecting one type or sort way of how the built environment is represented (structured data)\footnote{This includes how this type of structured date could be characterised, including if this is achieved via a classification hierarchy or ordering (as a type of meta data). Whether there is scope to use descriptive terms rather than a discrete allocation of a term may be the subject of further research. For example, instead of attributing the label of an object as a “door”, it is defined by an accumulation other factors (geometric shape and size, its relationship in space/other objects, the way it works) that go to the zero likelihood of it being anything else but a door.}. A potential objective becomes about the breadth or extent to which BIM affects or could affect other downstream informational systems\footnote{This includes whether by humans, technology or together, and regardless of form, or that more specifically involves or comprises computer aided design (CAD), geographic information systems (GIS), 2D paper etc.}, including for scaled applications and considerations of BIM. However, mapping the nature and behaviour of certain types of data structures is likely to provide an alternative picture. This not only includes those points at which representations enabled
by BIM are essential or less emphasised, but it may point to those circumstances in which these points may be elevated or change due to the need, motivation or desire for such representations.

Whilst the other definitional aspects of BIM (as technology, modelling (as limited to the association between users and technology)) are still relevant, they arguably concern different potential scales of economy. This includes recognising that these aspects of BIM arguably become part of an immense technological landscape, whether in terms of human derived machinery, tools or ICT and the degree to which there is connectivity and integration. Relevantly, this also supposes there may come a day in which BIM as a technology may be superseded, but the legacy data may prevail, albeit that may be in a way that ensures format accessibility or future proofing considerations.

**BIM: Data v Information?**

There appears to be a growing number of examples highlighting the economic opportunities arising or derived from data generally, including under the auspices of like terminology (e.g. “Big Data”). This later type of discussion has also been considered in the context of BIM, see (Aziz, Riaz, & Arslan, 2017; Boton, Halin, Kubicki, & Forgues, 2015; Sayed, Bew, & Penn, 2016; J. Whyte, Stasis, & Lindkvist, 2016). Whether this line of enquiry is converging or blending with data based research more generally may be relevant. This includes in conjunction with geo-spatial research and concerning other

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37 For example, the reach of data based economies, rather than those that are technology/systems based (in terms of market), are arguably magnified. Viewed another way, any person may be able to look at a model derived from BIM and interpret it, including for their purposes. However, there is only a limited market or group that has (and can afford) access to BIM technology/programs, as well as who use them to create models.

38 For example, there may be an equivalent technology orientated and mixed human-technology hybrid of systems that accords with the classification hierarchy of living systems theory posed by Miller and Miller (1995).

39 For example, the Productivity Commission (2017) (pp. 61-63) identify the economic properties of data as a form of capital (considered essential for the production of goods and services), as well as a way to address market failure (including information asymmetries) and understand risks. Data-driven innovation is another opportunity, in terms of productivity growth and in contributing to well-being, inclusiveness and development (OECD, 2015) (pp. 27-32).

40 In contrast, the potential extent and breadth of all informational translations is likely to appear boundless, despite the unattainable absolute information. “Information” is exponentially gigantean, particularly if considering every unique individual human being or technology and parts; every circumstance and interaction; and every point in time. Compared to this Big Data (as limited to a function of technology, regardless of connectedness) is relatively confined.
information systems, such as geographic information systems (GIS), see (Plume, Simpson, Owen, & Hobsom, 2015; Zhu, Wright, Wang, & Wang, 2018).

Appreciably, informational perspectives intimate or suggest that data, in isolation, only forms part of the picture. That is, that data in itself does not constitute “information”\(^{41}\). This may be attributable to or further exemplifies the definitional misalignment between data and information\(^{42}\). However, in taking informational perspectives into consideration, the premise for BIM as a type of data (including that may be grounded as relating to or concerning the built environment amongst other characteristics) may also concern or relate to:

- systems that may be able to take receipt of or benefit from these types of data structures (in whole or in part), as well as the types of systems that make use of such data;
- the way in which a system does benefit or use such data, including how this achieved, hindered or further adapted (for example via standards, automation/rates, human involvement or certain data extractions or translations); or
- contrasting BIM data relative to non-BIM equivalent types\(^{43}\) and relative to the respective systems.

\(^{41}\) This is readily acknowledged more generally. For example, the role of “spatial information” is rarely an “end in itself” and that it is “typically used to create useful information products that help organisations improve their productivity” (Smart, 2017) (p. 1).

\(^{42}\) Arguably this is also possibly due to more systemic issues surrounding the definition and conceptualisation of information, including the limitations in research generally. Boton et al. (2015) elaborate on this, noting “[t]he management of raw data (e.g. from BIM as well as from other sources) is not really conceptually formalized so far”. This is also despite examples that attempt to marry contrasting “information” and material processes as part of the construction process using information technology, along with humans, and machines and tools (see for example by Björk (2002)).

However, there may be different perspectives and propositions of “data” relative to information, if grounded as part of the EE, NI and ToS concepts (including the potential emphasis of data possibly falling within the EE concept).

Other distinctions may also include recognising differences between “information” and “knowledge” (for example, there are discussion that appear to describe informational aspects as described in this paper, see (Rooney & Mandeville, 1998)).

\(^{43}\) This may be extended to contrast data that could be qualified as non-BIM/non-built environment related but may otherwise be indirectly relevant (i.e. to reflect externalities). For example, the political environment, global financial markets, lack of/diminishing skill sets in science, maths, engineering and technology (STEM).
In effect, there may be scope to consider BIM relative to a type of or context for information production\textsuperscript{44}, including that possibly point to emerging shifts in perspectives\textsuperscript{45}. Relevantly, this may also stem from understanding the value propositions concerning or that arise from information dynamics, including that may tip into knowledge orientated considerations\textsuperscript{46}.

“Producing” information?
In considering the production of information further, three further points are presented as part of this working paper. Set out in the following sections, this includes:

- examining the informational perspectives and characteristics that relate or concern BIM and that attribute to illustrating the transitions from states of potential to actual (including as reflecting a type of transaction);
- profiling examples from the literature that look at value propositions of BIM, including to contrast to or highlight potential benchmarks and positions taken, as well as any gaps; and
- considering the possible relevance and adaptation of transaction cost economics (TCE) or evolutionary economics as a basis for relative and scalable considerations of BIM data.

Transitions from states of potential
In reiterating an overt outcome of Table 3 and further grounding the discussion premised on Figure 2, the potential of what BIM offers is different to that which is made actual. However, given the relativity of information to systems, including for emergent information envisaged by Hofkirchner (2013) (p. 107), there are arguably a myriad of ways in which these sort of transitions can occur. This includes the basis or reasons why, how or to what extent (as proportions, relative to entropic considerations) these can, do or do not occur.

\textsuperscript{44} J. Whyte, K. and Hartmann (2017) infer an aspect of this noting the need for research on “how to handle such fluid information” in design processes and insights on “transient information itself”.

\textsuperscript{45} For example, information economics (Stiglitz, 2017).

\textsuperscript{46} This may also include potential accounting for operational (i.e. applying knowledge), adaptation (i.e. learning, changing) and constituting position (i.e. social, legal, political, cultural) purposes and perspectives (Dopfer & Potts, 2008) (p. 53).
System entropy

As such, potential states of systems may be delineated, including whether relative to input or conditional constraints. For BIM, this not only includes technology orientated perspectives, in terms of model content\(^47\), relative scales\(^48\) or technological capacity\(^49\). But it can also relate to external factors that may be:

- immediate and direct, such as certain knowledge states (be it skills/expertise, professional standards of user/author, project team, client/owners); or
- indirect, whether arising from commercial considerations and implications (purpose of work, contractual scope, resources costs, insurance) or those that are part of wider social contexts (culture, economic, legal or political pressures).

It may also relate to the mismatch of presumptive expectations where the possible is not illustrative of the probable\(^50\). But nor does it disregard those points in time when such difference or presumptive expectations may no longer exist, including that may arise due to or as a result of adaptation or purposeful decision making.

Subtly, these examples highlight the potential scope to consider the entropic characteristics of a system as another way to delineate bounding factors. That is, the potential extent to which something

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\(^47\)For example, models that comprise multiple components or objects, dimensions, detail/development levels and relations of and between object forms, or having multiple purposes, be it discipline or perspective based etc.

\(^48\) This includes capability to model a built form masses as part of concept designs, as well as a screw as part of a door hinge (although practically this is unlikely).

\(^49\) Several commentators have highlighted the practical limitations of BIM, including in noting the use of federated models (rather than single models) and problems with large file sizes.

\(^50\) This includes whether highlighting the relevance or importance of data: rather than graphic representations as a determinative factor for BIM, such as for FM or operations applications (Teicholz, 2013) (pp. 6-7); or relative to the type of stakeholder. For the latter, some perceptions suggest parties with short term interest in a building may not see the benefit in investing in data (including that may be relevant for longer term considerations) (i.e. developers). This may be further exacerbated when comparing these to other parties who have longer term objectives (i.e. building operator/owner).
is not or the potential measure of factors for certain “information”\textsuperscript{51}. This includes for those circumstances that lead to disproportionate weighting, whether as something to be recognised or that may be deemed problematic or undesired\textsuperscript{52}.

\textit{Transition v translations (including a word on standards)}

Relevantly, describing transitions of states from informational perspectives may offer alternative views on the types of “exchanges”\textsuperscript{53} that can occur from using BIM (as a technology)\textsuperscript{54}. To an extent, this highlights the intermediary role of standards (in the broadest sense, as another type of data structure) that attributes towards facilitating translation\textsuperscript{55} processes. This includes whether it be for and by people\textsuperscript{56}, as well as between people and/or technologies. But it may equally be reflective of a codification example, as changing representations and that may occur at different levels (Burgin, 2010) (p. 206) (i.e. micro, meso, macro and mega). It is a circumstance that is readily recognised for BIM. This includes for city scales or smart cities, whether:

- connoted as “a hierarchy of categorisation and representation...to be addressed in any proposition for BIM”; and

\textsuperscript{51} One example includes non-BIM data that may otherwise still comprise certain BIM-like characteristics (i.e. a PDF (digital format) hand drawing of a 3D door (object representation) with an arrow (object label) specifying the door is fire rated (an attribute)).

\textsuperscript{52} An example of this includes the digital/data divide that may attribute to the promotion or exacerbating inequality or information asymmetry (OECD, 2015) (pp. 18, 21). Whether entropic characteristics of systems could be described in economic terms may be of interest, including relative to the lack of information or information asymmetry, see (Stiglitz, 2017).

\textsuperscript{53} A strict interpretation of GTI possibly renders the term “exchange” as describing or encompassing two different types of transitions. This is despite the type of systems being the same.

\textsuperscript{54} For example, BIM can be translated into 2D formats/forms (and vice versa) and exchanged between other IT systems. How these translations are achieved (and how effective this is) can vary depending on the systems.

\textsuperscript{55} Relevantly, a translation may not necessarily evoke information but may attribute to informational transitions. By way of simplistic example, “le chien” only equates to “the dog” by virtue of translating French to English.

\textsuperscript{56} For example, Turk (2016) identifies three type of standards that are important in terms of BIM, including standards for the definition of concepts, syntax and application interfaces (APIs).
• dependent “on which data sets cities share in common”, are city specific, attribute to city identities, relations characterisation within buildings and at city scales.

(Al Sayed, Bew, Penn, Palmer, & Broyd, 2015)

A challenge about standards is acknowledging the likely lack of universal application for any and every informational circumstance, possibly prefaced upon the changing systems contexts that can occur. However, Turk (2016) further notes IT developments have involved bottom up standardisation, which may possibly point to more systemic issues about technology and society. One such example includes the intended objectives towards “open standards” (or Open BIM). Whilst these approaches are purposeful and arguably practical, they may still infer the need for additional translations (including that may be data, cognitive). Whilst this arguably reflects another step, it is also predicated upon the downstream systems being able to take receipt of such data.

57 Another aspect of this concerns the relevance of standards which can be just as much about development as it is about uptake and implementation. This includes questioning if a standard is not used (or degrees thereof), is it justifiably “standard”?

58 This may include socio-technological orientated questions around role, scope and evolution of institutions, leadership, knowledge etc. But it also may relate to some technological evolutions that have resulted in differences and that are inevitably accepted or deemed cost prohibitive to change (for example driving on left/right hand side of the road, power point plugs/adaptors).

59 Whilst a key objective of the Open BIM movement includes overcoming the interoperability limitations of proprietary systems (as a monopolistic behaviour), this is perceived to be relatively narrow in intent. Also refer to the commentary by Turk (2016) who advocates for schema not only to open but to also be machine readable, use standard data/schema representation language and be compatible with a standard schema. The OECD (2015) (p. 39) also highlight other factors for non-discriminatory access to data (i.e. preferably online, machine readable/structured and linkable, recognise intellectual property rights and ensuring optimal pricing). However, it may also raise other procurement related questions. This includes whether these type of requirements:

• are or should be determinative factors in the purchase of ICT programs or licencing;
• this is considered or traded-off by potential consumers/buyers; or
• that are otherwise non-negotiable (as part of standard purchase or licencing software/service arrangements), or possibly constitute unfair contracts.

That is, for consumers/potential buyers having some knowledge or understanding of the interoperability capability or capacity (including if this could be measured or rated).

60 Whether this is desired or a necessary function of wider problem may be relevant. However, future developments may be predicated upon automating, removing or overcoming such middle steps. One example includes blockchain which ultimately aims to by-pass (or simplify?) the complexity of global financial frameworks and systems that have amassed over time and operate at international and global scales.
Informational transactions?

However, ascertaining the value (or depreciation) derived from or due to informational transitions offers another perspective. This includes considering these dynamics as a type of transaction (in which an informational transition from potential to actual has been carried out or performed). However, it may overcome part of the challenge associated with data having “no intrinsic value” (being subject to context and use) (OECD, 2015) (p. 39), but may be otherwise determined via informational perspectives. Evolutionary economic perspectives are likely to offer a comparable view (as noted by Miettinen and Paavola (2014)). This includes, in reference to “knowledge”, considering the role of carriers performing operations, including through the use of “rules” and via a trajectory, for:

- transformations for production and consumption processes in time and space; and/or
- transactions as processes of boundary crossing between agents and agencies;

(Dopfer & Potts, 2008) (pp. 11-12).

Such value propositions arguably turn depending on for and by whom the value is attributed, including the scale at which this is determined. It is different again in ensuring such value is actually acquired, let alone holding those responsible or accountable for this. Inevitably, this may bring into play the question of measurement.
Dimensions of measuring value: informational perspectives on BIM data

Measuring data transactions (relative to the built environment), despite potential differences in reference terminology, is arguably far from new. This includes those examples at larger scales, despite still possibly being piecemeal or having bounded scope, be it jurisdictional\(^{61}\) or relative to data types\(^{62}\).

However, the measures in respect of information are also likely to differ. For example, a technology based measure may be about industry adoption (number of organisations/individuals purchasing, licencing or using a type of software/tool). Data based approaches may relate to:

- the rate, quality at which data can be translated or transferred through systems (i.e. usability);
- rate, degree and breadth of adaptation relative to outcomes (i.e. achieving objectives, innovation\(^{63}\));
- degrees of interference, noise (as an entropic consideration); or
- rate of production effort to reuse by and adaptation of systems.

This may also related to analytical “information” monetisation examples offered by Laney (2018) (ch 4) on data more generally and from organisational perspectives.

However, it raises another question about whether informational orientated approaches can form part of developments on data\(^{64}\) more generally. This includes towards justifying and establishing

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\(^{61}\) See for example the research into the costs associated with interoperability problems between construction and FM in US industry, relative to “industry’s continued paper-based business practices, a lack of standardisation, and inconsistent technology adoption among stakeholders” (Gallaher, O’Connor, Dettbarn, & Gilday, 2004) (p. v). Relevantly, the authors (p. ES-1) define interoperability “as the ability to manage and communicate electronic product and project data between collaborating firms’ and within individual companies’ design, construction, maintenance, and business process system”.

\(^{62}\) For example, Smart (2017) (p. iii) reports on the economic value of spatial data (which includes BIM) for NSW, Australia, but specifically excludes the economic “knock on” effects of such data.

\(^{63}\) Notably “innovation” has been described relative to an “informational approach”, including in terms of new products, ideas or firms arising “endogenously” and “exerting an adaptive effect on other elements of the economy” (Potts & Mandeville, 2007). The authors further suggest that the informational model is: “non-linear; information from many sources, collaboration, services; emphasis on intangibles, flows of knowledge; and not well understood by policy makers”.

\(^{64}\) See for example (BITRE, 2017; OECD, 2015; Productivity Commission, 2017).
approaches or frameworks for broader scaled use of built environment related data generally or in reference to BIM derived data, including from public procurement perspectives (Kuiper & Duffield, 2018a). Paramount to this is the likely relevance of data as a transferrable or tradable commodity or unitary item, rather than “information”.

Whilst information itself (or the absence thereof in some situations) may have discernible value (including that can be relative to the system), value may be attributed to the way in which information is realised, possibly akin to productivity. Drawing from Burgin’s (2010) (p. 117) analogous comparison to energy, this may envisage developing support for or ensure information transitions (as a flow of transactions, not “information flow”) can be minimised or optimised (be it relative to effort, resources or some other bounding standards or parameters). But it may also leverage from the notion that information may go towards alleviating and reducing friction in the function of systems (Hofkirchner, 2013) (p. 19). This includes whether:

- as an intended measure or expectation for efficiency, life-supportiveness and good life (Hofkirchner, 2013) (p. 226, Figure 6.43); or
- by and for beneficiaries, be it society and/or individual elements, and despite the potential relative differences that may arise (Stiglitz, 2017).

To the extent that social value considerations and social impact measures for public procurement contexts (Halloran, 2017) (pp. 46-47) (rather than pure economic determinations) are feasible or not (and despite evaluation challenges noted by Halloran), may offer further views.

As one example is the BIM based patent citation network analysis and synopsis by Park, Kim, Lee, and Lee (2018). The authors offer a contributory view of the relative to technological advancements and “knowledge flow”, albeit that are jurisdiction, time based. But such examples may also be discerned relative to a cities productivity, relative to rate of idea flow (Pentland, 2014) (p. 183). Whether such analyses can extend beyond registered patents is likely to be relevant. For example, this may include identifying all “new” or distinguishable “products” (be it apps, plug-ins for example) or discrete
services and industry offerings, including those that are created to “fill” or overcome the gaps and limitations of BIM (as technology). Scoping actual and potential secondary markets arising out of BIM may offer further insights.

Transaction cost economics...but of data...of information, and information economics?
If premised upon transaction cost economics (TCE), all of the above may yet see the call for “a comparative institutional strategy for evaluating alternative modes of organization whereby transactions are assigned to governance structures according to a transaction cost economizing criterion” (Williamson, 1984). This includes consideration of those “opportunity costs of which investments is much lower in the best alternative uses or by alternative users” (Williamson, 1985) (p. 55).

However, in supposing TCE may be relevant, certain interpretative adaptations and leveraging that may be required for application to informational contexts. To the extent this may then converge with other information orientated measures and developments may also be of interest. These are discussed further below.

Adapting Transaction Cost Economics?
Relevantly for information value analysis, there is some departure from Williamson (1985), including the unitary emphasis of “transaction” being premised upon the transition from states of potential to information (rather than being contracting orientated, and further stepping away from legal centralism). It also sits outside of those tantalising examples that link TCE and “information processing” albeit limited upon certain types of organisation and qualifications for the “prudentially reasonable sensemaker” (Winch, 2015). This includes perceived silence on the role of technology and

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65 This may include examples Potts and Mandeville (2007) describe as “servisization”, a process transforming traditional manufacturing ability, into that of “a provider of services...through the adoption of new ICT to create new patterns of consumption”. The authors further highlight this as part of “the meso-economic convergence of social and physical technologies” creating economic opportunities in services.
despite the overlay of actor-network theory based examples alluding to such (see discussion by Linderoth (2010)).

Such approaches further highlight the relativity between the intended objectives or goals, the systems (as modes of organisation) and interactions these relate to and that attribute to achieving intended outcomes. To the extent that the respective “rules of the game” (Stiglitz, 2017) or order or types of rules (Dopfer & Potts, 2008) (p. 94) facilitate or exacerbate these circumstances may be telling. This includes whether such rules, including as relevant to governance or to steer, that extend beyond what may be arguably higher order rules guiding societies, through to those every day, informal “rules”.

But leveraging Transaction Cost Economics

However, other inferences from the work by Williamson (1985) are conceivably invaluable towards recognising other potential informational considerations. To this extent, it may contribute to determining the scope and cost implications, whether arising from or due to:

- forward, lateral or backward integration of data;
- the extent or basis to which integration (as well as collaboration) is or should be selective; or
- degrees of interoperability, trust, or any other misalignment between the respective interfaces (as a measure of “friction”).

But such approaches may further overcome perceived limitations of TCE, including as a contributory basis for explaining management and the procurement of complex performance (A. Hartmann, Roehrich, Frederiksen, & Davies, 2014).

By way of example, in terms of procurement, adapted and feasible forms of TCE may be relevant as a bounded, operational basis for analysis. This includes contemplating scenarios of the potential respective costs that may be associated with affecting information transactions (as loosely connoting “production” and discerned as an in-house function or that is outsourced). In taking more expansive interpretations to accord with systems and data, this may be considered from various institutional
perspectives, as well as with social (or public) and private dimensions (as reflecting contrasting positions). One internalised/micro consequence of this, for example, may involve comparisons between multi-systems perspectives of BIM/non-BIM based circumstances and dynamics relative to informational features, that effectively achieve the same or improved products. From organisational and project business case perspectives, this may involve contrasting existing practices and approaches with potential BIM scenarios, in terms of technology, modelling and model based BIM definitions. But it may also include considering the costs that may be associated with any transition to or for BIM.

Converging with other information measures

It is at this point the relevance of Burgin’s (2010) axiological principles become abundantly clear: to measure information. Whilst the types of axiological measures offered by Burgin (2010) possibly reflect a relatively discrete set, it does not forego the potential breadth of unitary elements that could be studied and determined. However, it is another matter again to infer that BIM (or non-BIM) related research already quantifies and measures informational features (including the associated relative dynamics), and despite not being termed as such.

One such example may include “evolutionary information economics” which may benefit from expanded definitions and interpretations of “information”, particularly for determining scalable dynamics. But nor should this detract from those applications where such measures may be relevant but are yet to be determined. This includes institutions such as the common law.

Conclusion

The theoretical approach premised on Burgin’s (2010) GTI and the proposed conceptualisations offers another basis to contextualise BIM in terms of information. In doing so, the working paper provides insights on the following issues that may guide further research into these topics.

1. As an example of theoretical perspectives on information, Burgin’s (2010) GTI:
is likely to provide a basis for BIM related research, including towards defining BIM and distinguishing characteristics and features of BIM (as a phenomenon) within social, technological or cognitive contexts;

could be applied, including for high level interpretations, using the proposed interrelated concepts of EE, NI and ToS to discern informational characteristics and features of systems. Whilst this could relate to BIM research, these concepts may also be applied more generally; and

more detailed or disaggregated ways to describe or understand information may involve profiling the informational nature and behaviour of a system in accordance with each of the twelve ontological principles of GTI.

2. In discerning informational perspectives in respect of BIM:

systems based references and approaches premised by GTI, as well as the literature on BIM, point to consider there are certain contexts, landscapes or realities in which BIM exists, (including that comprise multiple parts and aspects, whether as levels, standpoints, directions, as well as points in time);

that whilst the term “BIM” may be overarching descriptive term, these descriptions are likely to comprise different informational systems, and therefore different information characteristics and features. This includes that may be premised upon immediate and direct interactions;

object/subject distinctions may shift directions of intended objectives, as well as a basis for grounding impacts and implications of BIM (in context);

there appears to be a relevance or relationship of BIM connected to a certain type or of built environment representations (including that may be relative to non-BIM types), including that may be discerned as a type of built environment data;
that if discerned as data, this may be only a contributory element to or relative to information, particularly as enabling certain transitions of state (from potential to actual), which may be discerned as a type of transaction;

• whilst value propositions of BIM have been established (including as data), there may be scope to further re-examine BIM relative to information based approaches, including the types of measures that may be applied; and

• further there may be scope to consider the value of BIM arising from informational transactions. This may include adapting and leveraging TCE and evolutionary economic concepts and approaches and considering other information based measures or concepts (i.e. information economics).

References


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