A critical inquiry into the hyperreality of digitalisation in construction[1]

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The built environment is literally and metaphorically concrete but its creation from conception through design and construction involves many levels of abstraction. This spectrum of activities between concrete and abstract is complex and unexplored in construction but it will be shown that a deep understanding of this is required to make successful buildings in a modern age of digitalisation. Abstraction is the simplification of an entity with a degree of generalisation of purpose and causality but also used to promote the idealisation of the entity. When abstractions are believed to be real then there are conditions of hyperreality. This paper unpacks the nature of abstraction in the creation of the built environment through three vignettes of practice; considering: drawings, project planning and building modelling. Abstraction has been key to making buildings but is growing in significance because of BIM. The themes of loss of meaning, loss of control and loss of perspective are used to show that digitalisation involves creating a dangerous illusion of the connection between data and reality thus creating a problematic hyperreality. This can be avoided by stronger thinking, more openness about abstractions and less exaggeration of their performance.

Keywords: modelling, representations, practice, learning

INTRODUCTION

The development of digital approaches to design and construction is changing the way the industry operates and even what can be produced. These approaches are being promoted with only a limited amount of critical analysis as most studies investigate how the approach can be further developed. As an example, Kunz and Fischer (2020), (a world leading team publishing in a world leading journal) promote Virtual Design and Construction as if this is merely a matter of adoption and show the simplicity of it in a diagram (see Figure 1). In this, there is a danger that these changes are being adopted without due regard to the deeper consequences for construction; indeed, this promotion of digitalisation is explicitly suggesting that construction should change the way it is conceived and expedited (e.g in the UK, HM Gov, 2015). However, there are a growing number of more critical studies which start from the realities of the use of digital approaches. Much of this literature that explores actual practice shows a much messier and less efficient practice thus challenging the idea of simple adoption. They show, for example, the need for working against procedures in practices (Harty 2005), the need for trialling to trust digital solutions (Whyte, 2013), the fragmentation of digital and construction tasks (Cidik et al., 2017), the hidden skills of work-arounds (Merschbrock and Figueres-Munoz, 2015), the problem of working against Utopian presentations (Miettinen and Paavola 2014; Gade et al 2019), the naïve framing and multiple

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fallacies that are part of digital hype that only consider possibilities (Fox, 2014) as well as the creation of the digital divide (Dainty et al, 2017). There is something about the nature of digitalisations that creates these problems whilst enabling the less-real positive perspectives to be promoted. The critical studies referred to above use concepts of practice based theory (Cidik et al., 2017), activity theory (Gade et al 2019) and socio-materiality (Whyte, 2013). This paper considers the way digitisation changes the way we conceive and act in construction by exploring how digitalisation is moving the industry away from lived experience to abstract experience. The paper recognises that abstraction has been part of construction for a long time; however, digitalisation makes this move more significantly thus decoupling even further the abstract world and the physical world causing some of the problems identified in the above literature

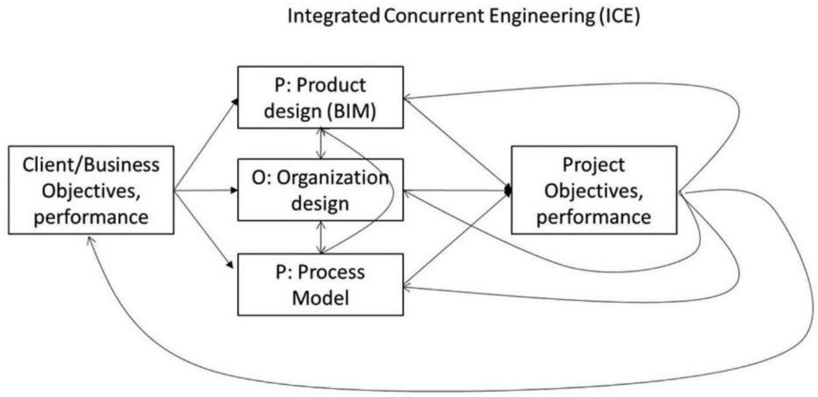

Figure 1. VDC framework includes explicit target and measured client/business objectives, Product design as a Building Information Model (BIM), Organisation design and Process models of the tasks to do design, construction, commissioning and operations. Informed by the client and project performance objectives, the project team specifies, builds, cheques and incremental revises the P, O, and P models, based on measured and target values of project objectives. These iterative Plan, Do, Check tasks take place in the multi-disciplinary Integrated Concurrent Engineering (ICE) collaboration process.

Figure 1. Example of Promotion of Digital Transformation and of Abstract Conceptualisation (from Kuntz and Fischer, 2020)

Abstraction is involved in the way we think and controls our outlook and engagement with the world both physically and socially (Giunchiglia and Walsh, 1992). This is a philosophical concept (Rosen 2018, Back 2014) as well as a useful practical explanation of how we as humans undertake work. The separation of thinking and action is also a fundamental basis of how computing and AI works (Saitta and Zucker, 2013); thus, is an appropriate subject for the analysis of digitalisation. Many consider that these abstractions work within mental models which we use to observe and then act effectively (or ineffectively with poor mental models) in new situations (Kelly, 1955; Simon and Baranfeld,1969). This argument is the basis of the belief that computers emulate these mental models leading to the proposition that human thinking can be automated (Johnson-Laird 2010). It is this assumption that is unstated in most digitalisation studies. Others consider that thinking and action are more complex involving the whole bodily experience and social interaction; suggesting that computers cannot deliver a substitute human skill (Dreyfus 1992; Anderson, 2003). This paper aligns with these human-centred positions and explores the way abstract skills are used in design and construction and the way that digitalisation will work with and against these.

There is a degree of irony that the philosophical opposite of abstract is concrete. This metaphor of concrete references the construction industry (cf Brochner, 2009) where it means drawing together of conglomerates to form a hardened mass. However, the distinction between abstract and concrete is important both in knowledge terms but also in social terms

(Rosen 2018). Concrete embodies the idea of practicality and being relevant to action whereas abstract suggests a distancing from practice (Back 2014). This distinction is not absolute being dependant on context and subject. Socially the cognitive ability to engage in abstraction is regarded as part of the development of a child (Piaget 1929) and so abstraction is taken as a superior activity. In this child development, thinking abstractly provides the ability to transfer knowledge from one context to another; being able to use the abstraction allows learning from a specific situation to be used in a different situation which has similarities.

Abstraction is normally seen as the simplification of an entity in order to reduce the complexity to make it comprehensible (Rosen 2018, Back 2014). This simplification can be done by identifying common qualities so that they can be handled together thus involves generalisation of purpose and an assumption as regards causality. These common qualities are named and are handled as the generalised name. The simplification can also be done by leaving out some qualities and focusing on a much smaller set. The identification of which qualities to retain makes the assumption that the whole can be understood by those qualities that are retained. Giunchiglia and Walsh (1992) define abstraction (for their purpose of automation of reasoning) as 'the process of mapping a representation of a problem, called … the "ground" representation, onto a new representation, called the "abstract" representation'. In this way, abstractions are involved in theories which connect abstract entities into a larger abstract system where the connection are formed by causality (Back 2014). Finally, the idea of a model takes the abstraction system as a workable representation of the grounded problem situation where the reduced set of abstract entities and their causal connection are assumed to be adequate (Saitta and Zucker, 2013).

The transforming construction agenda involves the promotion of innovations, all involving the use of abstractions and abstract systems, to increase productivity and quality whilst reducing cost (e.g in the UK, (HM Gov, 2013)). In this agenda, digitalisation, computer modelling and new abstract business processes are being developed to support a concrete activity. The connection between these more abstract tools and the concrete reality is assumed to be able to be overcome but this assumption would benefit from more critical enquiry. This paper undertakes this through an investigation into the how practical meaning is created through abstract artefacts and how these are used socially. It is a critical essay that utilises a variety of literature and vignettes of construction practice to explore this complex digital transformation in order to disrupt the current discourse and provoke a response and discussion from researchers and practitioners. Vignettes are narratives from a particular viewpoint to emphasise the connectedness of different aspects of the world. They have been used to stimulate reaction so as to explore and challenge previous conceptions (Jenkins et al 2010). The bias in this is acknowledged with the paper's purpose to critique digitalisation in construction against a normal position where hype and uncritical studies are accepted. The paper takes a critical realist stance, acknowledging the existence of the concrete but exploring how the abstract is part of the social construction of the meaning of experience but also sees the opportunity for change (Mingers 2000). This does align with the arguments of socio-materiality (Leonardi 2012) where, in particular, Styre (2019) argues that how we think about construction is limited without acknowledging the material. The paper uses socio-material approaches, in particular Latour (1999), which conceive of an entanglement between the material and conceptual worlds, although with a critical realist perspective where the separation is much more distinct, as explained by Walker and Davies (2014). There are three sections; firstly, theories of abstraction are presented that explore language, visual representation and systems of abstraction in order to demonstrate the challenges of abstraction and surface the idea of hyperreality (Baudrillard, 1994) where the abstract is taken as real; secondly, three construction vignettes (design drawing, time programming and BIM modelling) are analysed to show the difficulties of using abstractions in practice. Three themes emerge from this; the loss of meaning, the loss of control, and the loss of perspective as processes are hidden. These themes are fundamental to being able to understand the problems of future digital practices. In the third section these themes are used in a critical discussion of digital developments in construction where due to a circularity of argument, the loss of the concrete can be absolute; however, the possibilities of overcoming this are discussed to develop a useful engagement with greater abstraction.

THEORIES OF ABSTRACTION TO HYPERREALITY

This presentation of theories considers how abstraction is used in thinking and action. This is initiated through studies of language and action which brings out the difficulties of generalisation and the ease of communicating in abstractions as if the concrete was represented. Visual abstractions are then explored as it is the ability to design that demonstrates the success of the human ability to connect abstraction to the concrete and use geometry for action. However, what is seen in a visual abstraction may be an illusion of reality and this can be difficult to identify and challenge. The final theories consider that abstractions are not just used in isolation but are set within systems of abstraction involving organisations, processes and institutionalisation. In this there is an abstract framework that connects individual abstractions in a consistent way and enables further abstractions to be created and new uses to be postulated. This leads to the danger of living in hyperreality where abstractions (including language, visual representations and systems) are considered real.

Language in thought and action

Language is a key component of abstraction both because it names things and because it communicates these socially. As Hayakawa (1990) states about the simplification from abstraction 'this process of abstracting, of leaving characteristics out, is an indispensable convenience'. It involves finding a general term to refer to a number of examples of specifics. Many have looked at the symbolic nature of language and distinguished between signifier and the signified of objects (e.g. Pierce 1931-36). Thus, words are abstract but they are not the thing they refer to. It is this symbolic nature that gives meaning to abstraction in art where gross simplifications represent meaning in the learned eyes of the viewer. Pierce (1931-36) distinguished 3 types of signs: icons which have a physical resemblance to the signified; an index which shows evidence of what's being represented; and symbols which have no resemblance between the signifier and the signified. For symbols such as numbers the meaning needs to be culturally learned.

Hayakawa (1990) cites Korzybski (1933) in presenting a Hierarchy of Abstraction. Korzybski (1933) derived a theoretical view of the use of human knowledge through his general semantics involving a consciousness of abstracting to provide a powerful tool of analytical thinking and action. The hierarchy involves creating a set of levels from a specific 'concrete' example upwards to increasing degrees of abstraction (see example in figure 2). In order to make abstract thought into action then we need to come down the hierarchy to operationalise the abstract concept. As Hayakawa (1990) muses this is seldom done explicitly and often arguments are confined to levels of abstraction where they are merely principles and there are great jumps in assumptions of meaning; as is exemplified in Kunz and Fischer (2020) which does not relate to physical construction. Language is driven by such abstraction which also allows us to obfuscate or pretend that abstract thinking defines reality. This discussion at high levels of abstraction makes reality seem simple and accommodating to the abstract analysis. This might be theories or strategies or policies or models such that the gap to the concrete is neglected or assumed simple to overcome.

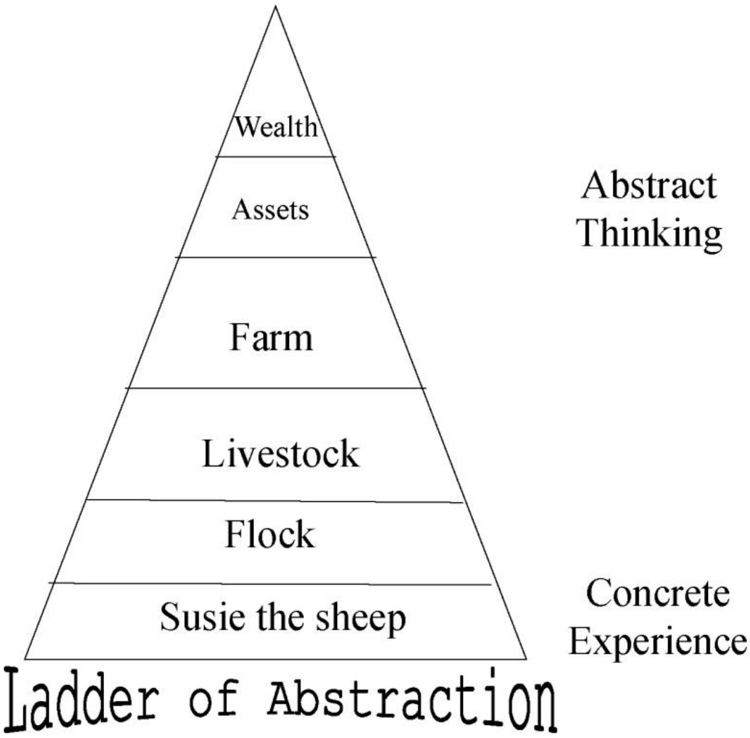

Figure 2 Ladder of Abstraction for language and thought (derived from Hayakawa 1990)

This problem is particularly evident in computer programming where the 'symbol grounding problem' (Harnad, 1990) shows the limits of the overtly abstract nature of information systems and how they struggle to connect to reality. As Floridi (2014) states computers are just syntactic machines thus 'The snag is semantics. How do data acquire their meaning?'. This problem of the gap between abstract symbols and meaning is often overlooked in computing but there are examples of successful abstraction such as drawing.

Visual abstraction and illusion

Visual representations and drawing are often seen as a language. In that sense they have elements and structure equivalent to words and sentences and narratives thus communicating and helping people work together collectively. Visual representation may be symbolic such as in diagrams (for example Figure 1 or 2) or iconic such as in design drawings (for example Figure 3). Drawings, as compositions of a whole, have been extremely successful in design (Lidwell et al, 2010). This use of drawings and abstractions is centuries old and it is impossible to dissect the interactions between design creation and design representation. That is, what is thought about is more than the representation; however, the representation holds together the idea of what is being designed (Lidwell et al, 2010).

Drawings are extremely successful examples of meaning being extracted from abstract representations. Bafna (2008) makes the distinction between notational and imaginative function of drawings. The first is the technical drawing where “pre-specified elements are matched to their pre-specified referents" (Bafna, 2008) which is useful for communications. Latour (1986) proposes that drawings offer immutability and mobility to give them meaning socially which is an extra step from just being a mental extension for their creator. This immutability determines that the meaning can transfer to different situations and different times. Thus, Latour (1986) postulates two functions of 'paperwork' firstly (quoting Heidegger) that drawing 'thinking is hand-work' giving affordance (see, for example, Dotov et al (2012)) to the minds-eye and secondly as social, the communications and control of design. The purpose of drawings, then, is not just communication but also imagination. The imaginative drawing has low syntactic density and high semantic density which is used to provide greater meaning in the observer; this is the position of an object of art (Gombrich, 1960). Latour's (1986) analysis of drawing, sees the use of sketches as incomplete, but staging points in design, that involve the abstract essence (form, space, rhythm etc.) that the designer has in their imagination. Bafna (2008) and Latour's (1986) ideas on sketches are consistent when explaining their imaginative character as having lots of meaning (semantic density) for the designer but a different meaning in an observer as the syntax is personal to the designer. The designer is in complete control of the creation and interpretation for themselves but, later, is seeking a shared social meaning. This is achieved through a syntax which is learnt socially, for example in conventional technical drawings, so that the drawing as a communication can be understood by others. Latour (1986) indicates that this control of design results from descriptive geometry which allows three dimensions to be represented in two dimensions and visual abstraction allows the control of universals "by working on papers alone, on fragile inscriptions that are immensely less than the things from which they are extracted" (Latour 1986). Geometry is successful not only because it is an abstraction of space but also because it can be expressed by the abstraction of mathematics (Eves 1990). This connection and usefulness made geometry fascinating for people in earlier times such that it was considered sacred (Schneider 1995). Geometry is an abstraction that is useful for thinking about space but crucially it can be related to real space and corresponds to grounded practice.

Like abstraction in language, visual representations have the potential for obfuscation and this is often referred to as illusion when this is the intention. An illusion is a visual representation that shows something that looks real but is impossible (Gombrich, 1960). There is much psychological (and physiological) discussion about why such visual representations are so confusing and can be seen as real (Gombrich, 1960, Gonzalez-Franco and Lanier 2017)). In particular, the idea of perspective and 3D imagery in 2D is an everyday illusion but can be very useful. However, symbolic and diagrammatic representations which allude to connections with real meaning (such as Kunz and Fischer (2020), figure 1), can be an illusion which it is difficult to ground. The significance of an illusion is often in its purpose so that, for example for mapping, Massey, (2009) shows how geometry and visualisation has the power to control space and those that have these tools have this power to control land and building. Thus, although visual abstraction can be agreed socially and so be useful; it is important to understand the illusion to reveal what is its purpose, what it prioritises and what is left out of its representation, in order to trust its affect.

Systems of Abstraction

A number of authors have seen abstraction as the key feature of working in the modern world. This takes abstraction, not just as a single aspect of thinking, but as the basis of the environment of the modern world (Saitta and Zukker, 2013). Thus, abstractions now exist within systems of abstraction that include the organisations, the processes and the roles that people are identified with and these operate within governance and regulatory systems. Individual abstractions are placed within a system which is itself an abstraction but at a higher level that provides rules for the lower levels. This idea of levels is a key part of systems thinking which seeks to represent the complexity of the real world (Checkland 1981) in a hierarchical structure. Leonardi (2012), taking a socio-materiality perspective, analysed these different levels in the design of safety in cars, which is now done substantively through computer models rather than through testing. Socio-materiality argues for the interdependence of technological developments and organisational arrangements (Leonardi 2012) and suggests that technology can have agency through the organisational system (Styre 2020). Leonardi (2012) showed the change in organisations, activities and thinking which caused disruption and identified differences of meaning at different levels of the system. Thus, the system of abstract, described here, relates to the socio-material environment but emphasises the reduction/ simplification because of the abstract thinking but also the overarching power of the abstractly conceived system. It is within the system of abstraction that the reduction is regarded as better and thus suitable for describing the world and using it to promote action. Turkle (2009) shows the limit of this when considering trust in using abstract complex models in organisational systems of abstraction and argues how this changes the way organisations (and ultimately society) work between management, and experienced professionals.

Floridi (2014) explains some of the technical limiting factors of IT systems as “the frame problem” where 'the real difficulty is to cope …. with the unpredictable world'. Thus, the problem of modelling systems is that they cannot handle uncertain and ambiguous situations. In this, Floridi (2014) explains that 'the most successful AI systems are those lucky enough to have their environments shaped around their limits'. Thus, the world is selected (or changed) to make the model or digital system viable and the system of abstraction supports this selection and promotes its viability. Baudrillard (1994) used similar ideas but refers to specific power interests when he deconstructs simulation and simulacra as abstract systems and introduces the idea of hyperreality. Simulation being the abstract representation of a system to perform as the system. Whereas simulacra is the substitution of reality by a simulated system. These choices of simplification and system are not neutral but made with purpose to prioritise some features over others and this choice is always made by power interests. Baudrillard(1994) states:

> “Today abstraction is no longer that of the map, the double, the mirror, or the concept. Simulation is no longer that of a territory, a referential being, or a substance. It is the generation by models of a real without origin or reality: a hyperreal.”

Baudrillard’s work was concerned with culture and has generated many critiques because of its overstatement (e.g. King 1998) but it does provide a useful metaphor for the problem of thinking and acting in systems of abstraction. Baudrillard’s ideas have been used by Grandy and Mills (2004) to analyse strategy in organisations with similar ideas to those in this paper. They show that with strategy where a single acceptable discourse and way of working has been created, then "reality [has] been replaced by hyperreality”, Thus, in digitalisation of construction, hyperreality is formed by the hierarchical system of technology, organisations and processes such that positive analyses, modelling and simulation are normalised; such that digitalised construction is taken to be better and perfect representations of reality.

EXAMPLES OF ABSTRACTION

These theories provide tools to analyse how abstractions are used in construction. The three vignettes analysed here (design drawings, construction programmes and BIM models) show an increase in the degree of abstraction changing the way they relate to tasks and so provides an insight into the problems of use of abstractions in construction practice.

Design Drawings

Visual abstraction is at its most useful in design drawings as was described in the last section. The building drawing shown in figure 3 is a conventional example that could have been produced by hand or by various forms of computer aided drafting. It is a plan which is a horizontal section through the imagined building, thus, it is a projection of important features onto a 2D plane. It follows the rules of technical drawing based on descriptive geometry (Bafna, 2008). This output then has a number of characteristic abstractions. Firstly, the main abstraction is geometric and this is iconic in that it is a scaled representation of the space created by walls. These walls are themselves iconic but their representation is less complete than the geometry; for example, the internal composition has been idealised and does not show internal surfaces such as plaster. Items such as stairs are partly a representation of reality but follow an agreed syntax for such technical drawings. Many other features are extremely abstract or have been omitted.

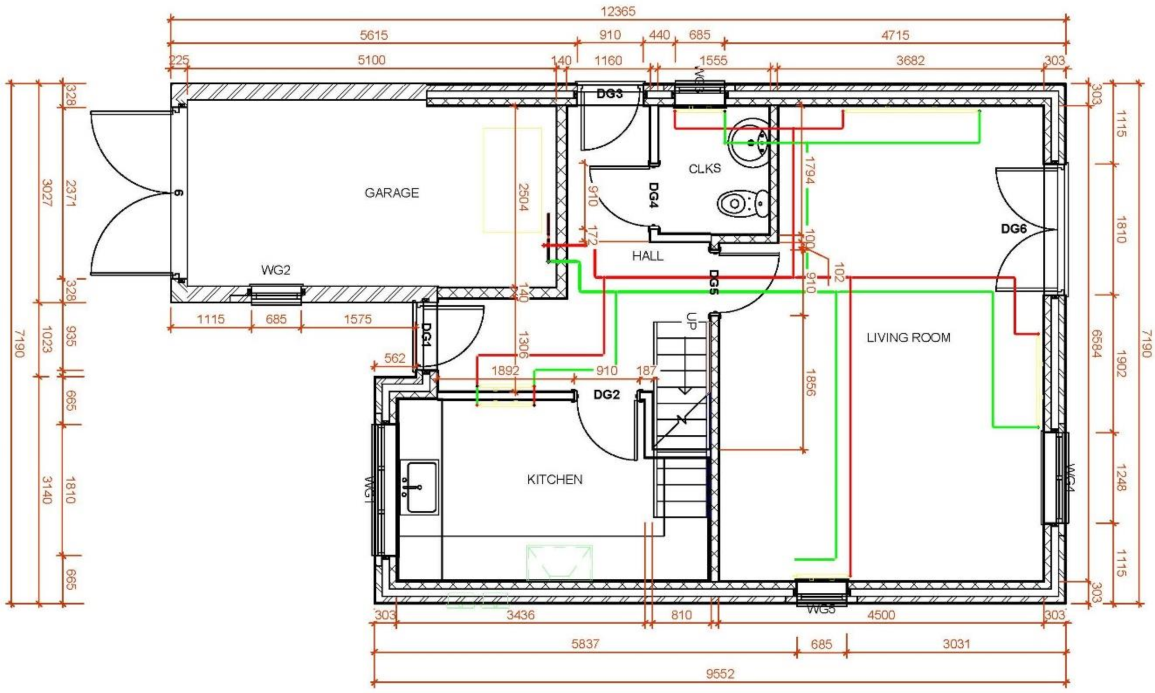

Figure 3. Conventional Construction drawing

An understanding of what is missing in a drawing, such as Fig 3, is key to working with drawings. The imaginative qualities of design that appreciate the building as a living entity are not represented. Attempts are made to represent some of this in isometric and artistic representations but these are illusions which in fact reduce the technical accuracy. Even technical aspects such as materials and constructional junctions, production aspects and how they are used, are missing. The simplification of the design, such as Figure 3, are necessary to avoid complexity and make the representation understandable. This missing technical information is commonly dealt with by having a suite of drawings each showing different aspects, some at different scales, plus a textual specification. This fragmentation of representations gives rise to the problem of coordination and the need for integration. BS1192 (2007) sets a standard for this information and coordination by fixing naming and coordination requirements (i.e. sets a syntax) but does not recognise what is missed from the abstraction or the different requirements of abstractions used by different roles.

The role of drawings tends to focus on the finished product; however, the process of production of the drawing is also pre-figured into the finished product. Drawings are particularly good at testing 2D geometry when done to scale. Thus, the affordance that drawing provides for thinking about buildings is critical to being able to conceive complex buildings. In this activity, the tools of production, (initially pencils, rulers, squares and compasses) are important as they enable particular forms of representation but make others more difficult. Similar to the imaginative qualities, the content of drawings is an expression of the imagination during the conception of the building and how they are to be built. Drawings then are part of an intermediate production which is used for testing of the imagination to be related to practice. Further, why a feature is in a particular place is also hidden in the final drawing even if this drawing is more replete and correct.

These multiple layers of abstraction, hides the simplifications resulting from the production of the drawing and this is understood differently by the different project participants. That is, the designer architects/engineers, as they draw, knows much more than other viewers. It is left to convention and the skills of the viewer in re-composition of the thinking. Indeed, Booker (1979) states even with multi-plane orthographic views

> "the interpretation of drawings, in which one object is represented by a number of pictures, is a difficult matter sometimes even for those with considerable experience".

Thus even experienced, clients, architects, engineers and quantity surveyors see different meaning in the technical drawing related to the needs of their role based on what they have learnt in their practice. However, non-experienced viewers have a much more confused interpretation which may be different from the designer's intent. Thus in the abstraction, drawing information can be assumed to be complete, ubiquitous and universal; but in reality are actually something that is open to interpretation because of what is missing.

Construction Programmes

A construction programme involve greater abstraction than drawings. As is shown in Figure 4, the programme is still an iconic abstraction in that it directly relates to what is being represented but it is a metaphorical relationship. Thus, time is proportional to the length of a bar and activities are identified as discrete activities. However, it is an illusion that the variables have the same qualities as geometry; that is with an inherent logic that checks consistency. For example, it is an illusion that the activities in Figure 4 are discrete which, of course, is not possible in practice.

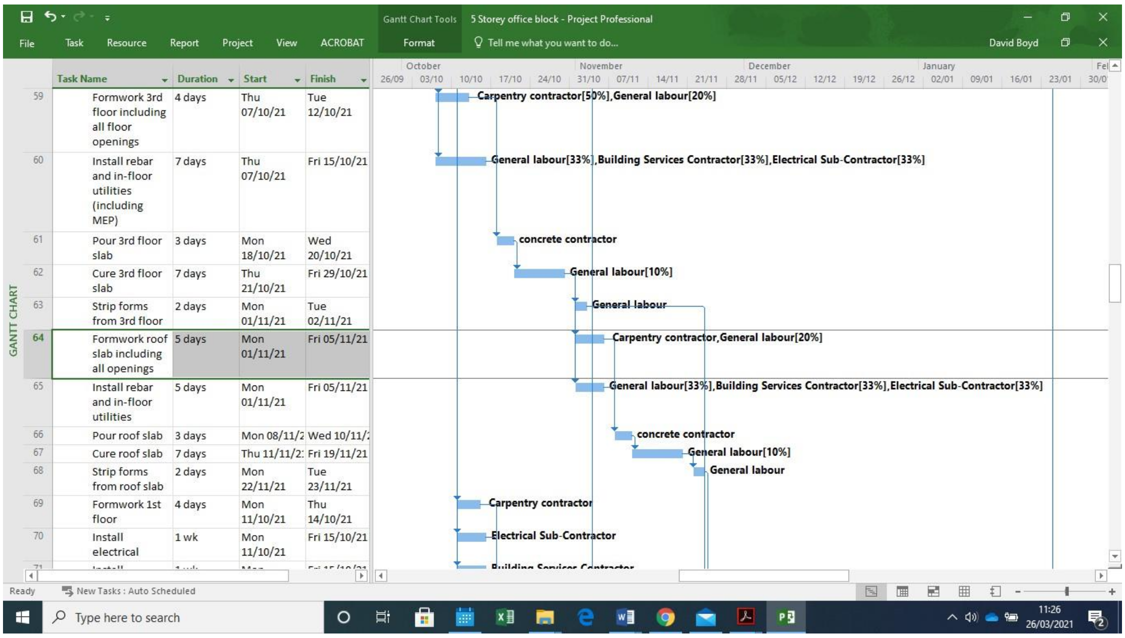

Figure 4 A conventional Gantt chart for construction programming

In a more complex way, the idea of linear time is also a problematic abstraction. In the past, concepts of time included circular and phenomenological time which is not experienced linearly; for example, because of critical moments to get things done (Boyd and Madzima, 2017). Chan (2012) sees a sense of time being structured socially to experience productive and non-productive periods, and referencing Henri Bergson, rejects 'the causality of time'. This challenges the degree to which rational planning can be achieved in practice such that it is 'the way time and temporalities are conceptualised and mobilised in organisations' that determines success not the accuracy of the abstract rational planning (Chan, 2012).

As construction programmes use greater abstraction, this involves a choice of variables relating to the needs of the producer. Thus the tool of time planning can be seen as an exercise in power (following Baudrillard, (1994)) rather than in just assisting construction. The programme is a critical aspect of contract, certainly to manage sub-contracting, being used to both direct action and to show compliance. Planning is a top-down activity which is seldom challenged on its assumptions/simplifications about resources required to deliver the construction programme. The programme is also a tool for determining productivity, a further abstraction which has become symbolic of the failure of the construction industry (McKinsey 2017). In this productivity abstraction, it becomes possible to compare the construction industry with the financial industry as if they were similar activities but this abstraction is an illusion.

A further abstraction is that the programme is used for payment. However, this aspect is less well formed for this purpose and so the way money, time and activity are related is not clear. This induces behaviour to secure more money earlier, (such as front loading, see Ross and Williams (2013)); and such meaning is hidden in the programme. Similarly, the meaning of practical completion of a project can be questioned sometimes to prevent having to pay money.

In another use of this abstraction, the project programme can be used for delay analysis (Braimah, 2013) and this adds another dimension to already complex thinking. In this scenario, the consequences of an event, or the failure to perform an activity, can be determined in order to prove liability or for demanding payment. This is speculative and is based on presenting an argued case utilising constructed data and logic. As this involves great complexity, then it becomes a specialist tool for presentation to courts and arbitrators even though based on multiple simplifications.

Such issues of loss of meaning and suspicion of control in the programme, mean that the programme becomes a confrontation of purpose. The players in this game tend to be aware of the limits of the abstraction and have learnt to manage it and the consequences; however weaker parties often lose if the stronger party needs to, for example, reduce budget or enhance cash flow.

BIM and Models

Building Information Modelling (BIM) involves significantly greater levels of abstraction than drawings or construction programmes. What BIM is, is often disputed between a process and software but it is the geometric modelling, involving parametric objects, that makes it possible (Kensek, 2014); an example screen shot is shown in Figure 5. The multiple layers of abstraction are seldom articulated. Behind the model is a database that contains the reference information for all software operations. Thus, the visual outputs, building object tables and automated building-object-interaction are all stored in this database. At the most abstract level are binary code. This is structured into the database where the structuring gives some prefigured and fixed meaning to the code. This structuring has purpose for the BIM task but also for the efficient operation of the software that uses it. There are generic data structures for buildings, most notably IFCs, however this is not efficient for software and most software manufacturers have a proprietary native data structure. Software manufacturers can have modules that take their native structure and output data in formats for others to use. These translations can never be perfect, thus, further abstracting and losing data and meaning. The operation of the software on the data is a further abstraction. The creation of geometric representations in a digital information world works because of the rule based nature of geometry. BIM objects are further abstractions being both physical objects and data objects and there is no distinction in code between geometric data and parametric data. This abstraction hides the fact that non geometric data does not operate with the same rule base exactitude as geometric data.

Figure 5. An Output Representation from a BIM model

In BIM, unlike with conventional drawings, the data and representation of the data are separated. The representation is produced through the visualisation software and, although this is fundamentally based on geometry, this manipulation is partly an illusion (Figure 5 shows an example visualisation output). In that sense, the visualisation needs to look correct for people to believe that the data is correct and this becomes critical in complex buildings and interconnections between objects. BIM technicians use a number of ways of making the visualisation look correct in order to overcome the software limitations. This hides the assumption/simplification that if the visualisation looks right then the data is right.

The use of the non-geometric data is more complicated as it is not possible to apply a similar clash detection logic. Without such a check then the data looks right but may be wrong. This is a danger of multiple abstraction; it embeds error by looking correct but without the ability to check. In addition, many non-geometric manipulations are based on models that are abstractions and so the outputs need to be carefully studied for value. This is well known in the performance gap with energy models (Gram-Hanssen et al, 2018)) but occurs with other models in their problem of connecting abstraction to reality.

ANALYSING GREATER ABSTRACTION

Abstraction has great benefits as it allows us to see wider aspects and see changes in time both are obscured when we focus on specific aspects and get bound up in the detail. In addition, it allows us to see similarities across events and objects that mean we can deal with them collectively and learn across them. Indeed, this ability to abstract and represent this has made building, particularly building at scale, possible. However, as the examples have shown we need to take care with the work of abstraction and its representation; thus the need for critical analysis. To assist this, three analytical themes are presented which were derived from the literature review and the analysis of examples: loss of meaning, loss of control and loss of perspective. These develop from purely technical aspects of abstraction to the organisational aspects of the abstractions in use. Thus, the loss of perspective is not just due to the technical complexity but also because of the promotional rhetoric and the organisational changes to accommodate the technical; this loss of perspective makes it difficult to see illusion from reality. As will be shown, this leads to the potential for hyperreality when the danger of believing that the abstraction is real.

Loss of meaning

One of the key activities of abstraction is simplification; thus, abstractions are always reductions of reality hence there is a loss of meaning. All the examples of abstractions that were described showed this loss of meaning particularly in the relationship with grounded reality. As the opportunity for abstraction increases, the loss of meaning becomes more critical. The danger is that abstraction becomes the thing or activity such that the connection back to the grounded specifics is unimportant as warned about with language by Hayakawa (1990) and philosophically by Floridi (2014). This aligns to the fallacy of reification or misplaced concreteness as presented by Whitehead, (1925) in his analysis of the application of science. In the BIM literature, there is seldom a discussion of what is left out from abstract models and what assumption have been made about the connection between the abstract variables and reality. It is argued here that BIM is only discussed in its abstract form which means that developments are only presented as abstractions as if they were real without acknowledging their problematic connection to reality (e.g. BS EN ISO 19650: 2018 and Kunz and Fischer, 2020).

Loss of Control

The loss of meaning also removes control by users both because of the way that the simplifying process choses variables and the way the abstraction operates for the user. That abstractions are chosen, rather than being natural, means that they always represent a perspective and this gives control by this perspective over others. Thus, what simplifications and omissions are chosen to make the abstraction work supports a particular position and loss of control by other positions. This was the case in the construction programme where it is the main contractor who uses this programme to control subcontractors although this might be contrary to their needs. However, BIM and other simulation software, controls this to another level. For example, the roots of Revit favour building design and the input of data is through the geometrical design programme; conversely the roots of Tekla are structural design and so benefit engineers.

This also affects the way the abstraction operates such that the user can only do what the software allows them to do. For BIM software to work, there needs to be standardisation and a fixing of design approaches and even design solutions. This is embedded in software and this can only be adapted by a user to the level allowed by the software; thus, represents a loss of control. The software forces people to use it in the structured and controlling way dictated by the system which benefits some and not others. This is referred to as 'ordering in disguise' by Cidik at al, (2017).

The operation is also controlled by the degree of separation between data and representation. So, for example, hand drawings do not suffer from the same loss of control because their data and representation are combined. This allows hand drawing to be manipulated for the operators' benefit so that they have control over the interpretation for their particular context. The construction programme separates data and representation more because of the selection of the abstract variables and the data requirements to operate it. BIM however separates data and representation completely and further places this behind hidden proprietary processes. This data - representation gap makes the system more complex for users and, means it is impossible for users to understand the system operation; thus giving no facility for user control.

Loss of Perspective

Given the loss of meaning of abstractions and the loss of control, it is extremely difficult for designers and constructors to understand the world that they work in; thus, many practitioners merely use systems and lose the perspective to be critical of them, as evidenced by the separation of digital and design tasks (Cidik et al, 2017) and the use of workarounds (Miettinen and Paavola 2014). The loss of perspective occurs in three ways: digital systems are complex, operating at multiple levels; there is an idealisation of their operation, and lastly it is only possible to validated them by their use.

Firstly, it is difficult to state how BIM actually works because of the complexity and orders of abstraction plus the secret nature of proprietary systems. Users, then, have limited understanding and cannot argue against the system processes; thus, lose a sense of perspective. An explanation of system operation is only very vague (e.g. Kensek, 2014) focusing on what BIM does and not on how it does it. The explanation of how BIM model work is often obscured; for example, Autodesk (2007) explains the connections between digital geometric objects involving a description of the connections and algorithms for these data objects and how they operate to change with changing input parameters. Any details of the ‘geometric engine’ and how it allows real time development of the model are not explained. Thus the various operating levels from data to user interface are left opaque and outside the general knowledge of users. This is all significant before errors and inconsistencies which are in all software are considered which further limit the understanding of the whole system.

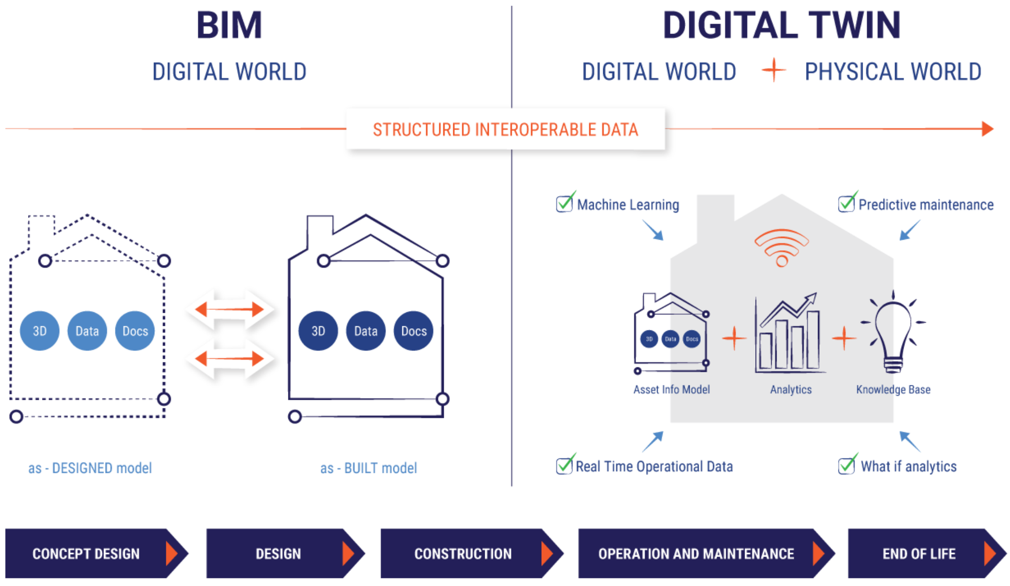

Figure 6, A diagrammatic representation of digital twin in construction (from Daskalova, 2018)

Secondly, the examples that are promoted always show idealised situation where the abstract system works and this forms an illusion and so loses a critical perspective. In these situations, the system works because its frame is heavily bounded. Indeed, much work in engineered systems is to control the environment rather than undertake the task. Floridi (2014) refers to this as “enveloping” which overcomes the frame problem by fixing the boundary within which the ICT system has to operate. This boundary fixing is an abstraction and simplifies what the system can really do. The result is that users are left trying to make the abstract systems work in non-ideal circumstances; coping with inadequacies whilst promoting the success of the system (see e.g. Merschbrock, and Figueres-Munoz, 2015; Dossick and Neff, 2011). There is evidence (e.g. Cidik et al, 2017) that the difficulties of the technical aspects of the model actually fragment the delivery of real construction practice between technical model meetings and design meetings, rather than integrating the delivery process as is promoted. This dislocation is disconcerting and the loss of perspective makes real practice appear ‘messy’ (Dossick and Neff, 2011; Miettinen and Paavola, 2014).

Thirdly, the proof of the viability of BIM can only be determined through its use because of this complexity and hidden operation creates a self-referential system. It is possible to put data in and get outputs which meet the needs of designers; however why this works is not known and thus forms another illusion. The illusion assumes that the system which works in one context will work in another. Such use of abstract systems is known as 'blackboxing' (Glanville 2015). Latour (1999 p. 304) comments on this

> "the way scientific and technical work is made invisible by its own success. When a machine runs efficiently, when a matter of fact is settled, one need focus only on its inputs and outputs and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the more opaque and obscure they become.”

The opaqueness and lack of understanding creates the loss of perspectives thus meaning that users are detached from the system and cannot engage with it fully. This forces the operation of the abstraction system to become the task in itself and this is merely learnt as a task skill.

WORKING THROUGH HYPERREALITY

This paper has surfaced the need to understand concrete action more explicitly when engaging in abstract thinking. It supports Styre's (2017) call for a deeper engagement with materiality in the built environment by distinguishing physical materiality from abstract materiality which would include digitalisation. If organisationally, we value the abstract too highly then this simplified and idealised world can seem better than reality and at that point we start living in hyperreality. This section will firstly explain the current drive to hyperreality with new digital technologies but then explore how this can be avoided.

Road to Hyperrreality

The drive to hyperreality in new digital systems occurs not just technologically and but also through promotional rhetoric from advocates and suppliers, and these together create new organisational norms and beliefs in the digital systems. This involves a circular argument where unreal idealisations are promoted at policy and industry level such that these induce organisational change; then when the technical systems do not deliver the idealised improvements then the organisation, as it has now invested in change, either: avoids this as being unimportant and shows selected outputs (Fox, 2014), accepts the limitations to be worked around (Merschbrock, and Figueres-Munoz, 2015) or blames itself for the inadequacy requiring more capability (Mahamadu et al., 2019).

The promotional rhetoric operates at many levels. BIM modelling is promoted (erroneously) from the assumption that we are getting to very nearly perfect data for a building (e.g. Laing O'Rourke, 2016). Certainly digital 3D modelling involves the creation of an extremely large amount of geometric data, but the assumption that more data means that the model is better is wrong; it is still a simplification of reality. Further, these systems are often promoted through their visualisation capabilities and these visualisations are sometimes presented as a check on the model's meaning. This aspect of visualisation in BIM is particularly problematic. On first impression the visualisation is a pragmatic representation of the real world. However, this is an illusion; the visualisation is an abstract representation of abstract data and the apparent reality is constructed psychologically (Gonzalez-Franco and Lanier, 2017). Problematically, this is marketed as seeing the building built before it has been built (See e.g. Kunz and Fischer, 2020). This belief that we are not losing meaning by using BIM, and, indeed, it is often sold as delivering greater meaning, is seldom challenged. Further, such expressions as a 'single source of the truth' are often used to promote to the participants, that this is not an abstraction but nearly reality (e.g. Jellings, 2017). Although 'single source of the truth' is a computer data management term where data is held only once, it is used as an illusion that the data provides a truth. Thus, the promotion of the idealisation of abstract systems makes them appear better than reality.

The promotional rhetoric and the technologies exist within organisational systems which use, validate and develop the abstract systems. For example, the promotion of BIM by the UK Government set a context and a drive for the implementation of BIM (HM Gov, 2013). This included a BIM mandate and the creation of a BIM promotion organisation within the cabinet office. Thus, many organisations invested in the development of BIM capability; for example: the NBS (National Building Specification), the CIAT (Chartered Institute of Architectural Technologists) and BRE (Building Research Establishment) all became BIM driven organisations. Early adopters of the digital technology saw economic advantages at least from the promotion of their capabilities but also from the ease of reproduction of the abstract representations. This meant that jobs became available that required BIM skills and consultancies offered expertise to those undertaking the transformation. At the same time, Universities and colleges developed courses and started to teach BIM software skills to students, mostly led by the free educational licenses from major software suppliers. This organisational environment that evolved has a vested interest in the apparent success of BIM; thus, became part of the rhetoric of promotion. Universities became eager to get research money to show the success of the abstract systems and promote their BIM courses. Those within the system are recruited to support the system and those with any doubts find it difficult to voice criticism. As a result, there was little real engagement with the problems of abstract systems. It is this promotional rhetoric and its inculcation into the organisational system that constitute the move towards hyperreality. This enables the conditions where the abstractions are considered real but with ensuing dangers of the potential failure of systems because of the illusion that systems can operate as their idealisation.

Overcoming Hyperreality

The use of abstractions has been a key activity of humans which has delivered great benefits and this must be continued. The road to hyperreality is not inevitable but if it is to be avoided then a number of inappropriate conceptions and actions need to be avoided. This will be explored using the three themes and the example of digital twins. Digital Twins are being promoted as a transformational way of running buildings (Harris 2019). In this, a model and data are continually compared to each other; one a prediction and the other an apparent reality generated from sensor data, see figure 6 (Daskalova 2018). The worthwhile purpose of the digital twin is to improve the operation of buildings with a desire to automate or improve human decisions (Khajavi,et al., 2019).

Overcoming the loss of meaning then users (and promoters) need to understand the simplifications in the models, digital formulations and output representations such as visualisations. Given the other themes which detract from this understanding then this needs to be undertaken proactively by addressing the question “what is missing?”. So for the digital twin this would involve seeing the loss of meaning as twofold involving simplifications in both the dynamic model itself and the sensor data used for comparison. The model can only have very particular scope in relation to the variables that are chosen within the system of simulation that is chosen. Hence the large difference between the requirements of a BIM model based on geometry and a digital twin model based on performance as stated by Khajavi,et al., (2019). The other side of the digital twin are the data describing reality and this is also a simplification. Sensors generally measure at point locations of what has been chosen to be measured. This might be acceptable in a single dimension finite element structural analysis of a homogeneous material, but in a digital twin with multiple performance criteria such point and limited measurements are inadequate in a building-operation model. Such an analytical skill, evaluating the loss of meaning in models, needs to be developed through education such that it is a key capability. Such an analysis, establishing real meaning, does in fact enhance the usefulness of the model, even if it seems to be being negative, as it is making the connection to reality.

Overcoming the loss of control requires acknowledging this problem at higher level by managers and system developers. It follows on from the loss of meaning as it acknowledges different meaning by different stakeholders in the awareness that the simplification in the model promote a particular position. There needs to be an openness and presentation of what is left out from abstract models and what assumption have been made about the connection between the abstract variables and reality. So for the digital twin the choice of model variables and the sensor point of measurement is critically important and as such is wrapped up in the purpose of the digital twin. In particular, with buildings, the difficulty of addressing human activity and human-building interaction (Hong et al, 2018) leads to buildings being viewed as inadequate machines. Model operators' need to understand that the model is socially selected such that some parties lose control giving, for example, an exaggerated focus on technical operation and outputs. This responsibility of the model operator must be extended to make them more than machine operators such that they can interact with the system purpose. In this they need to demand an understanding of the data - representation gap removing some of the complexity and giving a facility for user interaction which is the key to good abstractions.

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Overcoming the loss of perspective requires acknowledging the complexity of the technical task and avoiding the promotional rhetoric. The use of idealised representation, such as Figure 6, (Daskalova, 2018) for digital twins, must be challenged to understand what can actually be done and what cannot be achieved. It is what cannot be achieved which has to be included in explanation to avoid presenting an illusion of opportunity which cannot be realised. Again for the digital twin, it needs to be acknowledged that BIM does not allow a dynamic digital model to be constructed for the building as there are major difference in modelling requirements (Khajavi,et al.,2019). This helps those working in the field as the difficulty of their task is acknowledged and the reality of benefits better understood. Exaggerated language must also be challenged for example the statement that the Digital Twin is an exact digital replica (e.g. pbctoday, 2019). This idealisation is unsupportable because of the nature of abstraction and also dangerous. This promotion confuses lay audiences and gives too much credibility to the IT outputs.

These approaches to overcoming hyperreality require a concerted effort by researchers to not engage in idealisation and promotion. It is important to challenge the abstraction illusion to reveal what is its purpose, what it prioritises and what is left out of its representation, in order to trust what it produces. This cannot involve every user understanding everything but it must involve a requirement for those at every level to present a more critical understanding of the system of operation and to surface the problematic nature of the conceptualisations and the difficulties of action. From this, models and abstractions can be seen as opportunities for learning about the world. Abstractions can then be used in a process way to surface opportunities and problems and to provide explicit social benefits.

CONCLUSIONS

Abstraction is at the heart of the way humans think and comprehend the wider world in extended time. This has allowed us to create tools to assist with design. The advent of systems of greater abstraction like BIM and the digital built environment place a whole new burden of understanding on participants because of loss of meaning, loss of control and loss of perspective from hidden processes. These allow the illusion of a successful operation of BIM with support from exaggerated promotion and organisational vested interests. This drives the danger that people believe that the abstract systems are real and so engage in hyperreality. There is a danger of getting locked into abstract digital systems and of supporting the illusion of their perfection through research and so being compromised so that it is difficult to overcome. To avoid this, the limits of abstraction need to be better understood and used to strategize the use of emerging digital technologies. There is nothing inherently wrong with abstraction, indeed it is a major skill of human thinking that allows us to deal with variety and the future. In this, we must address questions of simplification, power of choice and difficulties of understanding that are inherent in such systems. Abstractions need to be seen as tools of thinking not a substitute for reality.

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