BIM mediation and users' behavior

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Abstract

Purpose – With building information modeling's increasing influence, it becomes important to analyze building information model (BIM)'s impact on users' behavior. Therefore, the purpose of this paper is to explore BIM's influence on users' behavior, using the innovative philosophy of technical mediation. This philosophy implies that perceptions and actions are always, to some degree, constituted and transformed by technologies. The question in this study is how the perceptions and actions of users are mediated by BIM.
Design/methodology/approach – A framework developed by Dorrestijn to assess the impacts of technology is used to explore the different types of impact that BIM has on the perceptions and actions of its users. Through a literature review, this framework is used to categorize the mediating effects of BIM. Following this, expert interviews, a workshop and user interviews explore these effects in practice.
Findings – Based on Dorrestijn's framework, it is concluded that guidance and persuasion are important mediating effects of BIM. BIM also impacts the human decision-process through coercive pressures to implement BIM and to embody BIM through acquiring skills.
Originality/value – With the increasing influence of BIM, analyzing its impact on users' behavior becomes increasingly relevant. This is the first study to use the technical mediation approach to analyze this impact. In this approach, humans and technologies are seen as interacting with and co-shaping each other.
Keywords ICT, Learning, Supplier, Construction projects
Paper type Research paper

1. Introduction

A building information model (BIM) is a digital "intelligent" object-oriented model of a construction project and the related construction processes that include both graphical and non-graphical data (Eastman *et al.*, 2011; Trebbe *et al.*, 2015). A BIM contains all the relevant information about a project and relevant organizations can access this information as required. BIM offers the potential to decrease project cost, increase productivity and reduce project delivery time. It is expected that different parties involved in a construction project will work more accurately and efficiently compared to traditional processes (Azhar, 2011).

A BIM can support and optimize communication and collaboration processes through the transmission and provision of information to all the involved participants across the various specializations within a construction project (Aranda-Mena *et al.*, 2009). Ideally, organizations working together can use BIM to develop well-coordinated project schedules, and optimize the flow of resources to, from and within the construction site (Irizarry *et al.*, 2013). According to Azhar (2011), BIM even represents a new paradigm that "encourages integration of the roles of all stakeholders on a project" (242).

To achieve better integration through using BIM, Latiffi *et al.* (2015) provide an overview of changing roles and responsibilities of project partners. The role of architects in projects using BIM is to develop conceptual and detail designs and based on that detailed information regarding building components used. Based on BIM, engineers are able to develop more accurate designs. Contractors can perform constructability analyses and improve project scheduling and planning by using BIM. Quantity surveyors can extract quantities and produce cost estimations from the BIM model. Facility managers can use the information of a BIM model for maintenance purposes.

With this growing influence of BIM, analyzing the impact of BIM on users' behaviors becomes increasingly important. Most studies on the impact of BIM suggest a one-way

influence in terms of BIM impacting on design costs (Lee *et al.*, 2012), labor productivity (Poirier *et al.*, 2015), project quality, cost and schedules (Zuppa *et al.*, 2009) and design and construction processes (Rowlinson *et al.*, 2010).

The objective of this study is to explore the influence of BIM on users' behavior by using the innovative philosophy of technical mediation. This philosophy implies that while our perceptions and actions are always, to varying degrees, constituted and transformed by technologies (Ihde, 1990; Verbeek, 2005) that these technologies only acquire their function and meaning in the context of specific use practices. In such practices, humans and technologies interact with and co-shape each other: that is, it is a two-way process.

The central idea of technical mediation is that technologies mediate and shape the relationship between humans and the world they experience (Ihde, 1990; Verbeek, 2006, 2011). The question guiding this study is how the perceptions and actions of users are mediated by BIM. Where and how does BIM interact with its users, and what is the effect? In answering this question, an appropriate framework developed by Dorrestijn (2012a, c, 2017) is used to explore the different types of impact that BIM has on the perceptions and actions of its users. This framework translates the technical mediation approach to practice and provides an overview of types of impact and dimensions of human-technology interaction.

Below, this framework is first elaborated. Following this, by using this overview of the types of impact and dimensions of human-technology interaction, the mediating effects of BIM are categorized, initially through a literature review, and then refined using expert interviews, a workshop and interviews with BIM users to explore these effects in practice. The final sections close this study with a discussion on the findings and conclusions.

2. Technical mediation effects
The concept of technical mediation is a notion found within the philosophy of technology (Verbeek, 2005, 2015c). Technical mediation directs attention to the concrete relationships between humans and technology, and of humans, through technology, to the world. The central idea of technical mediation is that technologies mediate and shape the relationship between humans and the world they experience. Exploring the various and changing forms of human-technology relationships is seen as an important focus (e.g. Ihde, 2009). Verbeek (2015c) offered the technical mediation approach as a way to deepen the analysis of these human-technology relationships. In philosophical terms, technical mediation adds the idea that humans and technologies interact with, and co-shape, each other. When a technology is used, "it becomes a mediator between its users and their environment" (Verbeek, 2015b, p. 218) (see Figure 1).

This study applies the framework of Dorrestijn (2012a, c, 2017) that is based on the technical mediation approach and distinguishes four categories of mediation effects. Two categories of mediation effects focus on the role that technology plays: first, in our thinking (above-the-head) and, second, how technology impacts human decision making (before-the-eye) (Dorrestijn, 2012c). The other two categories focus on how an individual physically encounters technologies
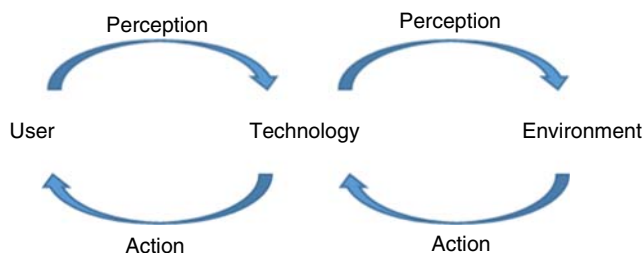

Figure 1.
The concept of technical mediation

(to-the-hand) and what the impact of a technological environment is (behind-the–back) (see Table I). This categorization is intended to be broad but comprehensive. This makes it a useful framework for reviewing the range of impacts that BIM may have.

2.1 Above-the-head

The above-the-head quadrant primarily includes general philosophical theories of technology (Dorrestijn, 2012a). Searching for the essence of technology is typical of many classical philosophical investigations of technology. A good example is Heidegger's famous essay: "the question concerning technology." Such philosophizing about technology is about the impact of technology on society in general: the effects occur "above-the-head." Here, technical mediation is considered on an abstract level. These generalized visions on the relationship between humans and technology often tend to be very positive or very negative. Achterhuis (1998) termed this the "utopia/dystopia syndrome."

Utopian visions of technology consist of an optimistic belief in technological progress. A good example is Le Corbusier's utopian vision of urbanization (Dorrestijn, 2012a). Dystopian technology perspectives refer to the fear of domination by technology and its negative impact on society. Well-known dystopian examples include Ellul (1964) who concluded that technology was becoming "autonomous" at the cost of human autonomy, and Mumford (1970) who stated that humans would become parts of a "megamachine" (Dorrestijn, 2012a). According to Foucault (1977), who also takes a dystopian view, modern technology can play the role of a digital Panopticon. The Panopticon is Jeremy Bentham's prison design that Foucault used to theorize on surveillance (Dorrestijn, 2012a). The prevailing view of the impact of technology on society in contemporary philosophy is somewhat ambivalent. Developing different future scenarios is nowadays seen as an important way to think about the impact of technology.

2.2 Before-the-eye

Technology may also influence the human decision-making process, which forms the focus of the before-the-eye quadrant (Dorrestijn, 2012b). The quadrant is so-named because the eye represents human cognition. Conscious decision making plays an important role in determining actions.

An important type of technology impact in this quadrant is guidance – being steered toward intended use. Technology can guide behavior by giving signs (arrows, texts, light signals) which are inputs to the decision-making process of its users. Besides acting as guides toward appropriate use, technologies can also persuade people to change their behavior (Dorrestijn, 2012b), so-called persuasive technology (Fogg, 2002). An example is the pop-up banners on websites that persuade people to "buy today" or "click here." A third type of technology impact is the expression of people's self-image or lifestyle through design. For example, products such as clothing and cars allow people to shape and express their identity (Miller, 2010).

Above-the-head	*Before-the-eye*
Utopian technology	Guidance
Dystopian technology	Persuasion
Ambivalent technology	Image
Behind-the-back	*To-the-hand*
Side effects	Coercion
Background conditions	Embodied technology
Technical determinism	Subliminal effect
Source: Based on Dorrestijn (2017)	

Table I.
Four categories of mediation effects

2.3 To-the-hand

The most direct influences that technologies have on humans are those that steer physical behavior (Dorrestijn, 2012b). This behavior-guiding effect occurs "to-the-hand," where the hand represents the body.

An important type of influence in this quadrant is coercion. Examples are a fence to control people's access, and a speed bump forcing car drivers to slow down (Latour, 1992). Another type of influence, labeled embodied technologies, concerns abilities such as writing with a pencil, riding a bike or playing a musical instrument (Ihde, 1990). This influence of technology on users occurs during an exercising process in which the technology becomes embodied: people acquire skills and learn routines (Dorrestijn, 2012b). In terms of Heidegger: technologies are ready-to-hand if they are used automatically and without reflection (Dreyfus and Dreyfus, 1996). Technologies become present-at-hand when they break down: users then have to reflect on what went wrong. A subliminal effect occurs when one is attracted or repelled by only half-conscious sensations, for example when supermarkets introduce the smell of fresh bread or coffee to enhance people's experience of hospitality and influence their buying mood.

2.4 Behind-the-back

Behind-the-back effects refer to "the material infrastructure that has an impact on our actions and experiences" (Verbeek, 2015a). Here, technology does not influence humans through decision-making processes or direct bodily contact, but reaches people through the technical environment (Dorrestijn, 2012b).

First, in this quadrant, technologies may have side effects. Even if a technology performs its intended function well, the advantages with respect to this primary function may be undone by disadvantages on another level. A car eases traveling, but too many cars cause traffic jams. Second, the successful functioning of technology depends on background conditions. A technology may require an infrastructure for its maintenance, or skills for operation. Finally, technical determinism reflects that technical developments may create or transform human values and needs. For example, the meaning that people attach to concepts such as privacy and freedom is connected to how the technical environment configures their self-awareness.

3. BIM and technical mediation

The central idea of technological mediation is that technologies mediate and shape the relationship between humans and the world they experience. The mediating effects of BIM, identified through a literature review, are categorized using the above overview of types of impact and dimensions of human-technology interaction. The core concepts used by Dorrestijn (2017) in relation to BIM were used to identify a selection of peer-reviewed articles on different types of impact and dimensions of human-technology interaction. This search for articles was carried out in the Scopus, Web of Science and Google Scholar electronic databases (English language articles only). For above-the-head mediation effects the strings of words used were a combination of BIM and utopia(n), dystopia(n), monitoring, and surveillance. For the before-the-eye mediation effect BIM in combination with guidance, steering, incentive, and image was used. To-the-hand mediation effects were searched for by combining BIM with coercion, power, embodiment, subliminal, and consciousness. The strings of words for the behind-the-back mediation effect was a combination of BIM in combination with side effects, indirect effects, technology, and infrastructure. The various impacts of BIM identified in these articles were then categorized in terms of the different modes of human-technology interaction.

3.1 BIM and above-the-head

In various publications, BIM and its attributes are related to utopian, dystopian and ambivalent visions of technology.

The utopian vision on BIM has been analyzed by Miettinen and Paavola (2014). They characterize future-oriented visions in terms of the advantages that will be achieved, when BIM is fully implemented, as a "BIM utopia" or as the "idealistic goals" of BIM. BIM is promised to eliminate design errors, to improve design quality, to deepen collaboration and communication between partners in the construction process, and to provide new forms of collaboration with clients. BIM is expected to support the optimization of design and execution and possibly of maintenance and operation (Eastman *et al.*, 2011; Sacks *et al.*, 2003). On a note of caution, Fox (2014) comments that BIM descriptions are often overly optimistic about its ability to increase the productivity of the building industry.

A more dystopian vision is discussed by Davies and Harty (2012) who see a potential role for BIM as a tool for surveillance and control. BIM provides opportunities to enact control over users through imposing standardized practices, and through surveillance and monitoring. Nevertheless, based on their study, Davies and Harty conclude, in Foucault's terms, that applying BIM in construction projects will not amount to a regime of total panoptical surveillance.

Several authors adopt an ambivalent vision on the impact of BIM. Dainty *et al.* (2015) are critical of the BIM "hype." They argue that BIM is unlikely to stimulate innovation on a wide scale. Azouz *et al.* (2014), based on the findings of their study, state that the use of BIM platforms over the past ten years had not been on a track that comes even close to the promised BIM utopia. According to Gould (2010), industry-wide open standards and an open collaborative working environment (which define the so-called BIM Level 3) is a utopian concept which, although parts of it are available and have been implemented, will never be realized.

3.2 BIM and before-the-eye

Several studies relate the mediation effects of BIM to different forms of guidance, persuasion and even image (Dorrestijn, 2012c).

The BIM Protocol, by specifying BIM agreements between parties involved in a project, is seen as an important instrument for guiding the efforts required to implement BIM (Mahamadu *et al.*, 2014). A BIM protocol contains BIM-related agreements between the client and the prime contractor. These include definitions for the level of detail and clarity of information required in the project, the standards that are applicable to the project, and definitions of the BIM-related roles.

BIM creates incentives for the prime contractor, designer, subcontractor and suppliers to deliver the BIM data required by other project partners in exchange for the BIM data they themselves require (Eastman *et al.*, 2011; Glick and Guggemos, 2009). These organizations can benefit from aligning processes among themselves and sharing information standards through BIM (Glick and Guggemos, 2009). When organizations reduce costs through BIM, these savings can be shared among the involved organizations according to a predetermined distribution (Chao-Duivis *et al.*, 2010).

Cao *et al.* (2017) give an example of how the image that BIM has is used to create a certain cooperate image. They offer a Chinese case where state-owned designers and general contractors are strongly motivated to implement BIM in their projects in order to create an image that they are deploying innovative technologies. As such, organizations with poor BIM capabilities may need to implement BIM to improve or re-establish their social image as utilizing advanced BIM technology.

3.3 BIM and to-the-hand

Technology in the to-the-hand quadrant is meant to have an impact on the human decision-making process. These mediation effects of BIM can be discussed in terms of coercion, embodied technology and subliminal effect (Dorrestijn, 2012c).

Cao *et al.* (2017) comment that the motivation for designers and general contractors to use BIM is induced by the coercive pressures from regulatory agencies outside a project and by the compelling influence of other project participants (such as clients/owners) strongly advocating BIM use. A major driving force for subcontractors to implement BIM can be the overarching contractor as an external requesting actor. Contractual agreements can compel an organization to use BIM.

Once BIM becomes an embodied technology, users have gained the skills and expertise necessary to work with BIM in an unreflective. BIM becomes "ready-to-hand" when users no longer need to reflect when using it. In this situation, a user embodies BIM. Instruction is required when starting to use BIM, and only through learning do users acquire the necessary skills and know-how (Riemer and Johnston, 2014). Unreadiness-to-hand is the condition where a user is still learning and acquiring the skills necessary to use BIM.

Maradza *et al.* (2014) suggest that BIM unconsciously shapes a firm's internal and external interactive learning processes, amounting to a subliminal effect. Internally, engineers learn from each other through visualizing 3D information and addressing problems that arise during construction. Externally, the firm participates in trials and pilot projects involving other construction firms, government agencies, universities and suppliers to access the knowledge required to solve specific design problems.

3.4 BIM and behind-the-back
In the behind-the-back category, technical mediation affects people through the technical environment. BIM can have these mediation effects in terms of side effects, background conditions and technical determinism.

BIM enhances transparency in the design process. This transparency enables different disciplines to modify their own designs while taking account of possible conflicts. Transparency can, however, appear threatening to certain parties. Arthur *et al.* (2017) argue that this could result in the side effect of suspicious behavior when it comes to sharing data with other stakeholders in a project.

In terms of background conditions (Merschbrock and Munkvold, 2012), effective interoperability among infrastructures within and between organizations is a necessary precondition for industry-wide diffusion of BIM. BIM requires an infrastructure in which to operate. However, several interoperability problems on the technical, syntactic, structural and semantic levels have been observed (Turk, 2016).

Technical determinism relates to the fact that technical developments can create or transform human values and needs. BIM makes the activities of workers more visible and could lead to "anticipatory conformity" and the internalization of norms of what it means to be an efficient worker (Davies and Harty, 2012). As with the prisoners in Bentham's Panopticon, the threat of being watched generates self-discipline and hence conformity.

4. Methodology
Having generated an overview of the types of impact and dimensions of human-technology interaction, the mediating effects of BIM in practice can now be explored through expert interviews, a workshop and interviews with BIM users. The expert interviews and workshop were used to explore the above-the-head and before-the-eye effects. Interviews with users during a BIM implementation in a construction firm and its suppliers were used to explore the to-the-hand and behind-the-back effects.

4.1 Expert interviews and workshop
Developing different future scenarios is a good way to think about the above-the-head impacts of BIM. Therefore, scenarios were developed to describe the impact of BIM on the

construction process in general. Each BIM scenario includes multiple BIM uses that describe a certain way of applying BIM to support the construction process. A BIM use refers to "a unique task or procedure on a project which can benefit from the integration of BIM into that process" (Computer Integrated Construction Research Program, 2010, p. 4). To develop such BIM scenarios, uses of BIM that support and optimize the construction process were identified through a literature review. This list was checked for completeness by conducting interviews with a group of BIM managers and BIM experts, who were selected based on their managerial or coordinating role in ongoing construction projects using BIM at the time of the interviews. Based on these inputs, two BIM scenarios were developed. A workshop with a panel of experts was then conducted to evaluate these BIM scenarios (see Appendix 1). The panel of experts was composed of industry specialists, who have either published in industry magazines and newsletters or presented at industry conferences on the topics of BIM, construction logistics or purchasing management.

BIM also influences the human decision-making process through guidance and persuasion: the before-the-eye impact. To identify the ways in which BIM use guides the contract that organizations enter into with each other, existing BIM protocols and BIM Execution Plans in the Dutch construction industry were reviewed (see Appendix 2). To identify possible incentives that can be applied to encourage BIM use in the construction process, the literature on incentives and rewards used in the construction industry in general was reviewed. The resulting list of incentives was then checked and validated for completeness by three contract managers from the Dutch Road Authority and two purchasing managers from a large Dutch construction firm.

4.2 User interviews

In order to explore the to-the-hand and behind-the-back mediating effects of BIM, user interviews were held during a BIM implementation in a construction firm and its major suppliers. Two selection criteria were used to select these suppliers: having a long-term relation with the construction firm and having some experience with BIM. First, interviewees of long-term partners of this construction firm were selected. Second, these interviewees (project planners and managers, BIM modelers, draftsmen) had some experience with BIM meaning they were still adapting tasks and responsibilities, software, procedures, work processes, and job descriptions, and making agreements on the modeling in BIM.

Of the 12 suppliers, 5 were leading suppliers of prefabricated concrete elements, 5 were, respectively, suppliers of limestone, staircases, wooden prefabricated elements, windows and window frames, and facades, and 2 supplied steel elements. All these firms had some experience with BIM and their BIM users were interviewed. Within the construction firm, four employees were interviewed: three from the BIM department and one from the supply chain management department.

The interviews took place in two rounds. The to-the-hand impact of BIM on the attitudes of BIM users were explored in the first round. The focus of these interviews was on the impact of BIM on the everyday working practices of an organization and on major non-technical barriers when implementing BIM. After this first round of interviews, a second round of in-depth interviews took place, with the same interviewees, focusing on problems and technical barriers that users experience with the ICT (infrastructure), data (structure) and procedures. In this way, the behind-the-back impact and, in particular, the necessary background conditions for BIM use were analyzed.

5. Empirical results

5.1 Above-the-head: BIM uses and scenarios

In total, 13 BIM uses were found in the literature review that could be used to support construction process optimization (see Appendix 3). However, nine of these were perceived as

too advanced to be applied in current practice. The other four, currently applied in practice, were: first, exchanging data with other project partners or project disciplines; second, generating quantities from a 3D model; third, coupling a 3D model to planning (4D modeling) and fourth, supporting lean sessions with the model. The interviewees said that, in their organizations, these were mainly applied in a project for interface management (to detect clashes) and stakeholder management (using visualizations to communicate design intent). Moreover, in practice, there was only limited use of BIM by subcontractors and suppliers in the construction process, and this impeded the prime contractor in using BIM in a project. According to one of the builders, "construction is still not ready for coupling of BIM with GIS [geographic information systems]." Based on the BIM uses identified, two BIM scenarios were developed.

The first scenario involves using BIM for data exchange in which a BIM is used for storing and exchanging data (see Figure 2). In this scenario, the BIM serves as a repository of data that can be retrieved by multiple applications used by project partners and/or project disciplines working in the same project. Information is entered once, is consistent and non-redundant. Through this BIM use, errors in the design (drawings) and any lack of correct essential information are identified and addressed, which result in fewer disturbances in the later execution and logistics processes. One of the builders mentioned that "using BIM in this way led to the discovery of clashes in the design of anchor piles, which if not found, would greatly delay the execution later." The same builder continued: "but because of BIM, we were not only able to correct the clashes, but also optimize the design of the anchor piles and the phasing of their execution." Furthermore, construction partners are able to generate information regarding what and how much material, and for what purposes, should be delivered to the construction site. As such, this scenario can function as a precondition for achieving optimal construction logistics.

The second BIM scenario that became apparent is 4D modeling. In this, the 3D geometries and location of objects in the model are linked to temporal information, such as the timings of their production, delivery or construction. An advantage of model-based scheduling is that it captures the spatial components related to activities, and directly links activities with the design. Through this link, the schedule can remain in sync with the design, and stakeholders are able to easily understand the schedule, evaluate its feasibility and its impact on logistics. When BIM is linked with GIS (see Figure 3), construction partners can generate information regarding where materials should be delivered at the construction site, and which delivery routes and access points provide optimum transportation and handling of materials.

5.2 Before-the-eye: protocols and incentives
BIM protocols guide participating organizations in applying BIM. An information delivery scheme, which is agreed upon by the client and the prime contractor, is the most important
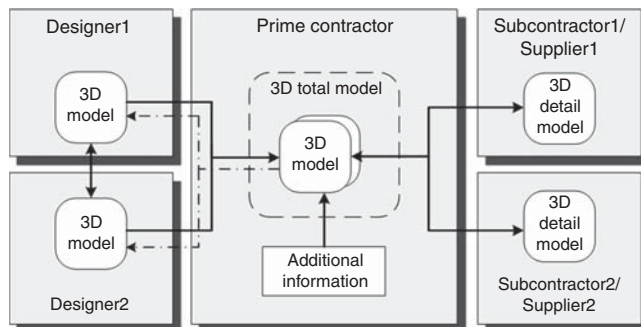

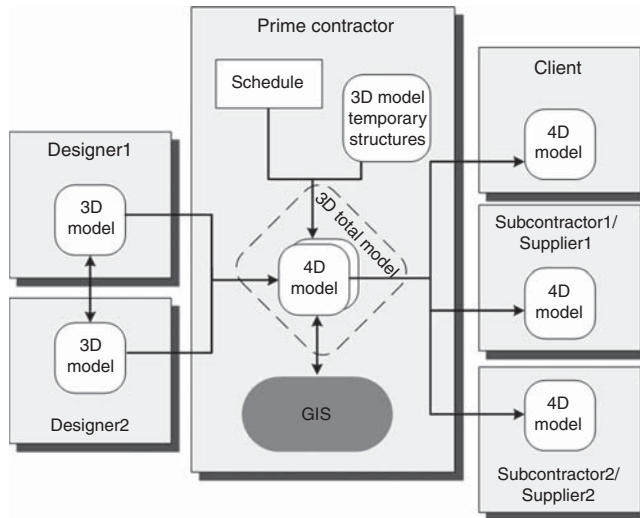**Figure 2.**
Data exchange using BIM

Figure 3.
4D modeling with link to GIS

part of a BIM protocol. An information delivery scheme guides parties as to which information should be delivered to which organization, by whom, in what level of detail, when, and in which data exchange standards and file format. Eight BIM protocols were reviewed, and Table II gives an overview of the agreements included in each of them.

According to all the interviewees, the most important incentive is for an organization to perceive the benefits of using BIM. One contract manager said that "mandating the use of BIM is no use if the [organization] doesn't see the point of using it." In addition, all the interviewees expressed that an integrated contract model is an important precondition for this incentive (see Table III). Integrated contract models allow the prime contractor to start using BIM during the design phase, thereby maximizing the benefits of BIM. Risk sharing and the sharing of savings are viewed as the most important incentives after the perception that BIM has benefits. Selecting organizations based on their BIM competence and readiness is also seen as important since this provides an opportunity for the designers, subcontractors and suppliers to recover their investments in BIM, and to be ahead of the competition. One builder expressed that this incentive "would allow [builders] to earn back

Agreement	Reviewed BIM protocol							
	1	2	3	4	5	6	7	8
Definitions	☑	☑	☑	☑	☑	☑	☑	☑
Roles and responsibilities of participating organizations	☑	☑			☑	☑	☑	
Hierarchy of contract documents	☑							
Intellectual property rights and ownership of the model	☑							
Liabilities for BIM data	☑							
Delivery scheme	☑	☑						
Project details		☑		☑			☑	
BIM organization scheme		☑			☑	☑	☑	☑
Data exchange standards and file formats		☑	☑	☑	☑	☑		☑
BIM goals and BIM uses		☑		☑			☑	
Modeling agreements		☑	☑	☑	☑			
Model management		☑	☑	☑	☑	☑	☑	

Table II.
Overview of agreements included in the eight BIM protocols reviewed

Validated list of incentives	
1	Integrated contract model
2	Integrated supply chain
3	MEAT criteria
4	Require the use of BIM (pay for BIM activities)
5	Select organizations based on their competence and readiness
6	Past performance
7	Adjusting the use of BIM according to the needs of involved organizations
8	Risk sharing
9	Sharing of savings
10	Financial incentive
11	Financial penalty
12	Step-in possibility
13	Payments coupled to deliveries

Table III.
Validated list of BIM
incentives

the investments on BIM, since [they] will have an increased chance of winning the contract, which would motivate others to also invest in BIM."

To motivate organizations to consistently deliver BIM data on time, one of the interviewees stated that the coupling of payments to deliveries was the most effective approach. The interviewee continued: "[this incentive] works well because suppliers are forced to deliver complete BIM data, otherwise they won't get paid." On the other hand, financial incentives and penalties were seen as least effective. Organizations are seldom motivated by financial incentives since they always include a profit margin in their prices. On the other side, financial penalties are perceived as one-sided and misaligned with the spirit of collaboration. In addition, it is very tricky to determine when to award a touted financial incentive and penalty because an argument often arises as to whether the awarding criteria were met. For example, if the designer, subcontractor or supplier is late with deliveries, the prime contractor's construction process will be disturbed; and then who is to blame for late completion? It is seen as better to couple payments to deliveries than to rely on promised financial incentives or financial penalties.

5.3 To-the-hand: coercion and skills development

The most frequently mentioned barrier offered by the interviewed BIM users is that not all supply chain partners are able to participate in the BIM process, leading to additional efforts being required throughout a project that uses BIM (see Table IV). That is, BIM conflicts with the existing work practice environment. Developing new software, updating existing software, making agreements on the modeling within BIM, and the related learning processes all consume a lot of time. For some suppliers these are reasons not to use BIM or to apply BIM only because their client (the construction company) insists: a kind of external coercion. According to a BIM modeler of a mechanical engineering firm, "for us BIM has no added value." A prefab supplier stated "we don't need BIM but the construction firm wants us to use it."

Another frequently mentioned barrier is that embodying sufficient knowledge and experience is a long-term, step-by-step process. Using BIM requires adapting existing software and implementing new software, with new skills and staff training required to use this software. Users learn to use the new software by trial and error and several users revert to the "old" software because they cannot work with the new BIM software, and are not convinced that BIM could facilitate, speed up or professionalize their actions. "The software used has a lot of restrictions […] and to overcome barriers is a continuing process" according to the façade supplier.

	Internal	Prefab	Steel	Other
Not all supply chain partners are able to participate in the BIM process, resulting in additional efforts needed throughout the project to use BIM	☑ ☑ ☑ ☑	☑ ☑ ☑ ☑ ☑	☑ ☑	☑ ☑ ☑ ☑
Gaining enough knowledge and experience is a long-term and step-by-step development	☑ ☑ ☑ ☑ ☑	☑ ☑	☑	☑ ☑ ☑
Too much effort is needed to develop and manage an integral 3D model	☑	☑	☑	☑ ☑
Staff training: organizing and financing education and training	☑	☑	☑	☑ ☑
To further implement BIM, the composition of the workforce has to be changed (mismatch between requested and available competences)	☑ ☑	☑		☑ ☑
Development of new procedures and work processes is complicated and time consuming	☑	☑ ☑		☑
Insufficient support from management for the implementation of BIM			☑	

Table IV.
Non-technical barriers for BIM implementation

Other barriers were mentioned by a few of the suppliers involved. Although efforts are needed to develop and manage an integral 3D model, and to organize and finance staff training, these barriers are not perceived as widespread. The same is true when it comes to the development of new procedures and work processes: "we are playing around with this issue" is said by a prefab supplier, and he is not the only one. This can be complicated and time consuming but is not a prominent barrier. But according to the steel supplier "time is an issue, because there is never enough time." A few interviewees further stated that, for further BIM implementation, the composition of the workforce might need to be changed because of a mismatch between required and available competences. One supplier referred to a lack of management support.

5.4 Behind-the-back: ICT infrastructure and data structure
Behind-the-back problems linked to BIM are related to the ICT infrastructure and to the data structure. The ICT infrastructure covers the software, hardware and network environment. In this regard, the BIM users most frequently commented that data from the building model are not suitable for linking to external systems (see Table V). Another important barrier is that shortcomings of the software systems limit the expansion of BIM applications. Regarding the hardware and network environment, interviewees similarly indicated that

	Internal	Prefab	Steel	Other
Data from the building model are not suitable for linking to external systems	☑ ☑	☑ ☑ ☑	☑	☑ ☑ ☑ ☑
Shortcomings of software systems limit the expansion of BIM applications	☑	☑ ☑ ☑ ☑	☑	☑ ☑
Not enough detail in the building models to use BIM optimally	☑	☑ ☑ ☑	☑ ☑ ☑	☑
Hardware systems are not suitable for (further) implementation of BIM	☑ ☑	☑ ☑	☑ ☑	☑
Standards for the exchange of data are missing or not well defined	☑ ☑	☑	☑	☑ ☑
Accessibility of data for different project partners cannot be properly regulated	☑	☑ ☑		☑

Table V.
Technical barriers for BIM implementation

hardware systems were inappropriate for further BIM implementation and unable to handle the huge amount of data at an acceptable rate.

Users at the subcontractors and suppliers also saw a barrier in there not being sufficient detail in the building models to use BIM in an optimal way, e.g. for detail engineering/design of installation components or for generating quantities. That is, there is no uniform library of objects, and parties adopt different levels of detail in their model objects. Several parties developed separate libraries for each project and for the various software packages that were used. Other firms did have an organization-level object library, but this was not aligned with external organizations because of the diversity of software packages.

Standards for the exchange of data were seen as missing or poorly defined. There is no widely accepted object standard despite object structure decomposition playing an important role in the exchange of BIM data. Over time, many self-developed standards have emerged. Users at the subcontractors and suppliers were having to deal with, and switch between, the different object structures employed by their various clients. Given the lack of widely accepted standards for the exchange of data that are well defined and well implemented in the software, BIM usage is inherently inefficient.

6. Discussion

In exploring the mediating effects of BIM, four categories of human-technology interactions have been analyzed. The first two categories of mediation effects focus on the role technology plays in our thinking (above-the-head) and on how technology impacts human cognition (before-the-eye). The other two categories focus on how an individual physically encounters technologies (to-the-hand) and on the impact of a technological environment (behind-the-back).

Several authors believe that BIM is the solution to several of the challenges faced in the construction industry. Accepting this premise, one of the anticipated above-the-head effects is that "BIM utopia" will follow once all the advantages of a fully implemented BIM are achieved. BIM promises to eliminate design errors, to improve quality of design, to deepen collaboration and communication between partners in the construction process, and to provide new forms of collaboration with clients. Moreover, the BIM scenarios developed together with practice share this optimistic outlook. A contrary, more dystopian, vision is that BIM provides opportunities to assert control over users through the imposition of standardized practices, and through surveillance and monitoring. Several studies have a more ambivalent vision of BIM's impact that BIM will stimulate a more collaborative working environment but realizing the so-called BIM Level 3 is a utopian dream.

When focusing on the before-the-eye effects of BIM, a variety of BIM protocols are used to guide participating organizations in applying BIM. A BIM protocol, by specifying BIM agreements between parties involved in a project, is an important instrument for guiding the efforts required to implement BIM. Adopting BIM also creates incentives for parties to deliver the BIM data required by other project partners by providing, in exchange, the BIM data they require themselves. According to the interviewees, the most important incentive for adopting BIM is for an organization to perceive the benefits of BIM for itself. In addition, an integrated contract model was seen as an important precondition for establishing this incentive.

Within the to-the-hand quadrant, we saw that some parties only apply BIM because their client or the construction company (the client of the subcontractors) requests it: a form of external coercion. Viewing BIM as an embodied technology results in users gaining the skills and expertise necessary to deal with BIM in an unreflective way. Given that users learn to use the new software by trial and error, gaining sufficient knowledge and experience is a long-term, step-by-step embodiment process. As a consequence, only some supply chain partners are able to participate in a project that uses BIM.

When looking at the side effects of BIM, one of the behind-the-back effects, the transparency enabled by BIM, can be threatening for certain parties resulting in suspicious behavior when it comes to sharing data among stakeholders in a project (Arthur *et al.*, 2017). In terms of background conditions, several interoperability problems on the technical, syntactic, structural and semantic levels occur (Turk, 2016). BIM makes the activities of workers more visible and could lead to "anticipatory conformity" and the internalization of norms at to what constitutes an efficient worker: an example of technical determinism. Some studies that discuss the to-the-hand effects of BIM stress that these technologies become an instrument of control.

When evaluating the overall impacts of BIM, one can conclude that the before-the-eye effects through guidance and persuasion are important mediating effects in a BIM context. The to-the-hand mediating effects related to skills development are also important. The relevance and the direction of the behind-the-back and the above-the-head effects are less clear.

7. Conclusions

In this research, the framework of Dorrestijn proved useful in studying the impacts of a technology, in this case of BIM. The four quadrants of interaction modes, and all the associated impact types, could be traced in the BIM literature and most in practice. It was concluded that the before-the-eye effects through guidance and persuasion and to-the-hand mediating effects related to skills development are most important.

Being aware of these different effects might enhance the use of BIM. In the before-the-eye quadrant sharing of savings is viewed as an important incentive for using BIM. Prime contractors, designers, subcontractors and suppliers can be incentivized to use BIM in their project by sharing the savings generated from this use. It is also important to anchor these incentives in a BIM protocol as addendum to the contract. An important to-the-hand mediating effect is skills development. The resistance to use BIM can be overcome by educating users about BIM and making them aware of the potential benefits through skills development.

The outcomes of this study can serve as useful input for future empirical research on specific BIM applications. It could be investigated why organizations choose to use certain BIM applications in their projects and what the perceived benefits (and disadvantages) of these applications are that influence an organization's intention to apply BIM. Future research could also measure the actual savings or benefits when using BIM in a project. Future implementations of BIM could benefit from an assessment that seeks to balance the various mediating effects.

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Appendix 1. Expert interviews and workshop participants

Sector	Interviewed organizations
GWW/Civil structures	1 Client
	2 Prime contractors
	1 Designer
B&U/Commercial and industrial	1 Client
	7 Prime contractors
	1 Subcontractor (MEP)

Table AI.
BIM managers and BIM experts interviewed on BIM uses

Role	Number
Client	1
Prime contractors	6
Designers	3
Knowledge institutes	7

Table AII.
Participants of the scenario workshop

Appendix 2. Overview of reviewed BIM protocols

1	Building Information Council – National BIM Protocol Release 0.9 (2017)
2	Building Information Council – National BIM Execution Plan Release 1.0 (2017)
3	BIM protocol provided by a prime contractor (2015)
4	BIM protocol for design provided by a consulting firm (2015)
5	BIM protocol provided by a prime contractor (2015)
6	BIM execution plan provided by a prime contractor (2014)
7	BIM protocol provided by a prime contractor (2013)
8	BIM execution plan provided by a subcontractor (undated)

Table AIII.
BIM protocols from practice

Appendix 3. BIM uses for the construction process (validated by BIM managers and BIM experts)

1	Data exchange with other project partners/project disciplines
2	Generating quantities from the 3D model
3	Coupling of 3D model to planning (4D modeling)
4	Cost estimation with the 3D model (5D modeling)
5	Labeling and numbering of objects for production, installation and logistics
6	Positioning using laser and machine guidance techniques
7	3D coordination (management of subcontractors and suppliers)
8	Support of lean sessions with the model
9	Monitoring of logistics using RFID tags and/or barcodes
10	3D modeling of temporary structures
11	Coupling BIM with GIS
12	Coupling BIM with traffic simulation models
13	Optimizing logistics for multiple projects within the same region

Table AIV.
BIM uses for the construction process