A framework for studying the factors that influence the BIM adoption process

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Abstract

Building Information Modeling/Management (BIM) is an emerging technological and procedural innovation within the Architectural, Engineering, Construction and Operation (AECO) industry. Adoption of BIM has increased significantly over the last few years and BIM adoption is an active research area that aims to construct a better understanding of the spread of BIM and factors that may explain the speed of BIM adoption and its diffusion. Unfortunately, in this literature, the factors that influence the adoption process are unclear: those who influence the decision to adopt (Decision Factors or DFs) are confused with those that influence the success of the implementation (Implementation Factors or IFs). IFs are very rarely studied, although they could make it possible to produce recommendations to help firms to implement BIM. This paper aims to identify the elements that can influence the BIM adoption process. The main findings of this paper is a classification model of innovation adoption influencing factors, a critical view of methods used to study BIM adoption factors, and an overview of factors that can influence the adoption of BIM, including DFs and IFs.

Keywords: BIM adoption, framework, influencing factors, barrier, driver.

1. Introduction

Building Information Modeling/Management (BIM) is an emerging technological and procedural innovation within the Architectural, Engineering, Construction and Operation (AECO) industry. Adoption of BIM has increased significantly over the last few years and is now an active research area. It aims to construct a better understanding of the spread of BIM and factors that may explain the speed of BIM adoption and its diffusion. Our understanding of the BIM adoption process has recently evolved, through the *Diffusion of innovation theory*. It is described in a five-stages process that opens up new (as yet untapped) perspectives for the study of BIM Adoption Influencing Factors (BIM-AIFs). It reveals that some of BIM-AIFs are not taken into account in the BIM adoption literature.

In a **first section**, the model of the adoption process is briefly introduced. It brings out the difference between two types of BIM-AIFs: those who intervene before and after the decision of adoption. The value of this distinction and reasons of its absence in BIM-specific literature are explored.

In a **second section**, literature on innovation is investigated, taking into account the distinction made in the first section. Factors that may be involved in innovation adoption are identified and classified to facilitate the study of specific innovation (as BIM). As a methodology, we started from the generic literature to avoid omissions that may appear in the BIM-specific literature.

In a **third section**, BIM-specific literature that explore BIM-AIFs is investigated to identify methodology strengths and unexplored opportunities for the study of BIM-AIFs.

As main findings, this paper proposes a framework that can be exploited for the study of BIM-AIFs. This framework takes into account non-BIM-specific literature, recent distinctions made in the BIM adoption area and a critical analysis of the methods used today to study BIM-AIFs.

2. The BIM adoption process and what impacts it

In this section, the model of the adoption process is briefly introduced. Possibilities that emerge from this model and reasons why they have not yet been studied are explored.

2.1 The BIM adoption process

As BIM is an innovation, its spread follows the generic models of the diffusion, adoption and implementation of innovations. BIM adoption is here described in a **five-stage process** (Hochscheid & Halin, 2019a) (fig. 1), as in the Diffusion of Innovation Theory (Rogers, 2003). This process begins when possible adopters become aware of the existence of BIM (fig. 1, stage 1), evaluate the possibility of using it (stage 2), and take a decision: to adopt or to reject it (stage 3). If **decision of adoption** is made, adopters undertake a set of activities to deploy BIM processes, tools and methods (stage 4), and need time to anchor these new uses and practices in their habits (stage 5).

Key moments **milestone** this process: **Decision of Adoption (DoA)** is the moment when stakeholders make a commitment to start implementing BIM, **Effective Implementation (EI)** is when stakeholders have tested and used BIM on a part of their production, **Confirmation of Adoption (CoA)** refers to the moment when stakeholders have anchored BIM in their practice, reached a certain level of mastery of it and have indicated their willingness to continue.

This process can however stop at different moments (**Adoption failures**), including during implementation (Klein & Sorra, 1996). Factors affect the continuation, speed, and cessation of the whole adoption process, here called "**BIM adoption influencing factors**" (BIM-AIFs) are considered differently depending on whether they occur before or after the DoA.

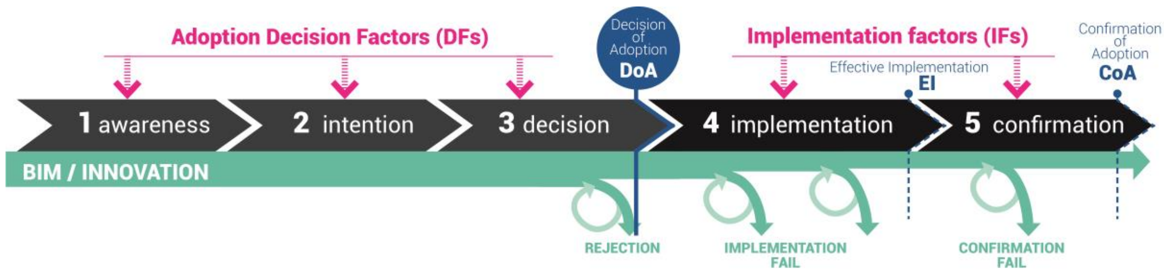


Figure 1: Model of the BIM adoption process, adapted from (Hochscheid & Halin, 2019a)

2.2 BIM-AIFs: before and after DoA

The DoA (fig. 1) appears to be a turning point in the adoption process. Potential adopters move from a period in which they will need elements to position themselves to make a decision (before DoA) to a period in which they need to achieve an objective they have set for themselves: acquire some mastery of BIM (after DoA). Factors that intervene in the adoption process **before the DoA** (Decision Factors / DFs) therefore influence the **decision-making period** whereas factors that intervene **after the DoA** (Implementation Factors / IFs) will influence **the success of implementation** and the anchoring of new practices. Both DFs and IFs intervene during the adoption process (and are therefore BIM-AIFs), but they do not concern the same phenomena, and must be differentiated. However, it seems that the difference between DFs and IFs is not explicitly made in BIM adoption literature. The study of the factors that influence the adoption of BIM has rarely been completed with a clear differentiation between the stages of the adoption process, except for very recent work (A. L. Ahmed & Kassem, 2018). Thus, the study of factors that influence BIM adoption have often been confined to the study of DFs. Some hypotheses are put forward here to explain this.

First, it should be noted that Rogers' five-stages model (Rogers, 2003) concerns the *innovation-decision process*. This model focuses on the *decision* to adopt: even the confirmation stage refers to confirmation of *decision*. Although this is a seminal work, many research have criticized the Diffusion of Innovation theory, in particular on the vagueness left in the definition of the term "adoption" (Bayer

& Melone, 1989). The concept of *adoption* has several and contradicting definitions (A. L. Ahmed & Kassem, 2018; Hochscheid & Halin, 2019a). It is often considered that adoption is synonymous with a decision to adopt (Mohammad, Abdullah, Ismail, & Takim, 2017), but recent work considers that adoption is a process that includes implementation (A. Ahmed, Kawalek, & Kassem, 2017). Recently, a study has aggregated BIM-AIFs by positioning them on the adoption process. The authors indicated, by addressing only the first three phases of the process, that they focused on DFs (A. L. Ahmed & Kassem, 2018). It is a step towards understanding the adoption process and the demarcation between DFs and IFs.

Theories of technology adoption were exploited very early on to study BIM-AIFs. These theories describe and explain how individuals choose a technology. After being investigated in a few research, BIM-AIFs extracted from these theories were aggregated in literature reviews and synthesis on the factors that influence the adoption of BIM (A. Ahmed & al 2017; Ahuja, Sawhney, Jain, Arif, & Rakshit, 2018). These syntheses have led to a consensus on the BIM-AIFs that do not include IFs.

It is also possible the difficulty that companies have in implementing BIM has been underestimated. It would seem that we considered that making the decision to adopt would necessarily lead to successful implementation, hence the fact that DFs have been more studied than IFs. But the adoption process can stop between the DoA and CoA, hence the interest of studying IFs.

As a conclusion for this section, we note that there is a significant difference between DFs and IFs. However, this difference has only rarely been exploited in the BIM literature where BIM-AIFs have often been summarized to DFs. This omission may be explained in different ways, but probably finds its source in the confusion about the definition of the word *adoption*, which has long been considered synonymous with *decision to adopt*.

3. Classification of BIM Adoption Influencing Factors (BIM-AIFs)

This section is a non-BIM-related literature review that gives an overview of factors that may influence adoption of an innovation. Studies focusing more on the elements that influence the decision of adopters (individuals and organizations) have been treated separately from those that attempt to analyze the success factors of implementing an innovation in an organization. The elements proposed here are a follow-up to previous work (Hochscheid & Halin, 2019a), but they are here supplemented and structured. The identified **factors** have been classified into different **fields** and **categories**, according to the model presented in fig. 2.

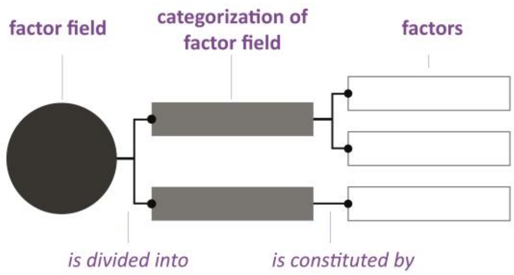
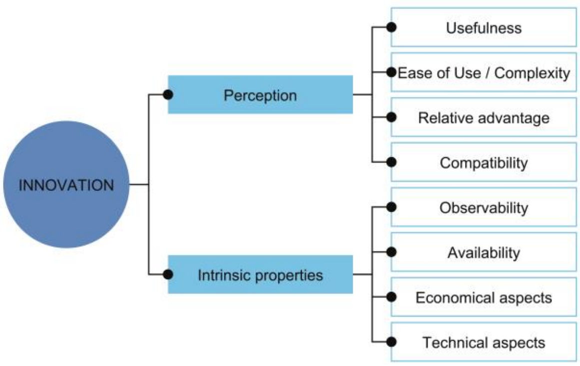


Figure 2: classification model of innovation adoption influencing factors

3.1 Why do people choose to use an innovation?

A consensus is beginning to emerge on the generic factors that influence the decision to adopt a technology. Presented in different ways in the literature on innovation (Waarts, van Everdingen, & van Hillegersberg, 2002), they can be classified in three factor fields: characteristics of the innovation, internal context of the firm and external context of the firm.

Characteristics of the innovation that play an important role in the choice of this innovation has been described in seminal work of Rogers, in the first edition of Diffusion of Innovation, in 1962. Five attributes of innovation are considered: (1) **relative advantage**, *"the degree to which an innovation is perceived as being better than the idea it supersedes"*; (2) **compatibility**, *"the degree to which an innovation is perceived as consistent with the existing values"*; (3) **complexity** *"the degree to which an innovation is perceived as relatively difficult to understand and use"*; (4) **trialability**, *"the degree to which an innovation may be experimented with on a limited basis"*; (5) **observability**, *"the degree to which the results of an innovation are visible to others"*. Around the 90's and 2000's, research in sociological psychology area focused on user adoption and acceptance of technology with several models called *Technology adoption models* (Collan & Tétard, 2011). These theories evoke (among other things) characteristics of the innovation that can be involved in technology selection: (6) **perceived usefulness**, (7) **perceived ease of use**), (8) **technical and** (9) **economical aspects** of the technology. Among the factors mentioned here, some concern the **perception that potential users have of innovation** (1,2,3,6,7), others concern the **intrinsic characteristics of the innovation**, identical for all potential users (4,5,8,9), see fig.3.



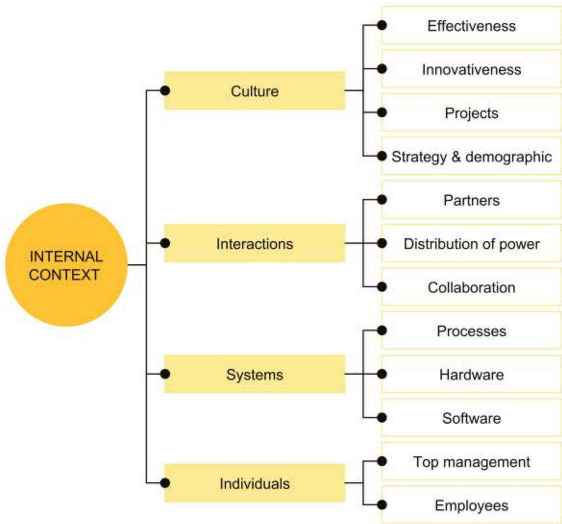


Figure 3 (left): classification of adoption influencing factors for "innovation characteristics" field
Figure 4 (right): classification of adoption influencing factors for "firm's internal context" field

Internal context of the firm refers to all elements that constitute the firm from the point of view of human relations and the material context of work. The constituent elements of a firm presented here are the result of previous literature review synthesis (Hochscheid & Halin, 2019a). The influence of the internal context of organizations for technology selection has been studied in several disciplinary fields and theories. The abovementioned *Adoption Theories* also focused on (1) **individuals** and personal characteristics that can influence their willingness to use a technology. *Population ecology theory* (Hannan & Freeman, 1977) indicates that previous choices made in the firm for (2) **systems** and staff created internal inertia that impacts future technological choices. In extreme cases, these previous choices may totally prevent an individual or a firm from changing technology (Arthur, 1989; Liebowitz & Margolis, 1995). Individuals react differently to innovations, depending on their experience, seniority, career stage, and skills (Mintzberg & Westley, 1992; Sainsaulieu & Segrestin, 1986). Internal political constraints and history of the firm (firm's (3) **culture**), and (4) **interactions** within the firm, participate to this inertia and influences the perceived ease of implementation and decision to adopt. all the above-mentioned elements are summarized in fig. 4.

External context of the firm refers to social, economic, political and competitive environment of the firm. Organizations need to be pushed by external forces to change (Hannan and Freeman (1977), as legal barriers, information channels, legitimacy constraints and collective problems. *Institutional theory* (DiMaggio & Powell, 2000) classifies these forces in three types : (1) **coercive isomorphism** (formal and informal pressures from government and other organizations) , (2) **mimetic processes**

(when organizations model themselves on other organizations), and (3) **normative pressures** (sharing and normalization of conditions and methods of work). They are here referred to as "forces". It is possible to differentiate between those that apply directly from the external context (1 and 3), and another one that the actors apply to themselves (2), see fig.5.

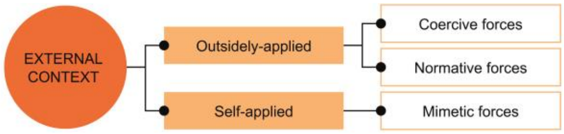


Figure 5: classification of adoption influencing factors for "firm's external context" field

This section presents a classification of generic factors that influence the decision to adopt a technology. In the BIM-specific literature, (A. L. Ahmed & Kassem, 2018) arrive at a very similar classification on the basis of an extensive state of the art of literature specific to the BIM. These factors have therefore, on the whole, already been addressed in the BIM literature.

3.2 What influences the success of innovation implementation in a firm?

Much work in the field of management has focused on how an organization can implement change Hannan and Freeman (1984) identified factors that may affect mortality of firms due to change. According to them, *characteristics of a company* (i.e., size, age-specialized, or generalist), *external environment* (i.e., stable, uncertain), and the *implementation method for change* (i.e., type, speed) are involved. Pettigrew (2012), developed the "receptive" and "non-receptive" concept for change context in a firm, and pointed out that "*environmental pressure, a supportive organizational culture, the quality and coherence of policy, key people leading change, the change agenda and its locale, the quality of managerial clinical relations, simplicity and clarity of change goals, and co-operative inter-organizational relationships*" are eight signs that seem to be associated with a faster pace of change. These work are in line with the conclusions of a previous qualitative study of the BIM implementation (Hochscheid & Halin, 2018) that identified IFs : implementation time management, change agents chosen, previous habits, availability of BIM-educated professionals, type of projects made by the firm, training process, the firm's culture, project teams, and external partners. In this section, a non-BIM-specific literature is therefore explored to identify and classify possible IFs.

On the basis of the elements presented above, it is here proposed to examine the following fields : **characteristics of the innovation**, **internal context of the firm**, **external context of the firm**, and **characteristics of change**. Pettigrew (1987) also evokes the role of chance and surprise in this process. Let us keep this in mind to remind ourselves that change within a firm is a very complex process that certainly cannot be predicted or fully modeled.

Characteristics of the innovation that influence decision to adopt described in the previous section (fig. 3) may also influence implementation and confirmation. The **subjective part of these characteristics** (if the innovation is perceived useless or too complex for example) will influence individual's motivation for implementation and can cause high resistance to change during implementation (Kotter & Schlesinger, 1989). **Intrinsic properties** of innovation can influence individual's perception of it (Klein & Sorra, 1996) and can be directly involved during implementation, for example when individuals are confronted with interoperability problems (technical aspects), lack of help and tutorials (observability, availability), or an insufficient return on investment (economical aspects) (Hochscheid & Halin, 2018).

Internal context of the firm's impact on successful change (and therefore during the implementation) has been highlighted in several research (Franklin, 1976; Johnson, 1992; Kim, 1998; Pettigrew, 1987, 2012). Mintzberg & Westley (1992) identified different levels of change in an organization: culture, structure, systems, people, vision, positions programs and facilities. The firm's **culture** can, for example, integrate a general openness to innovation and an active and permanent desire to improve effectiveness, which facilitates implementation. Demographic characteristics of the firm (number of employees, projects size, number of hierarchical levels), **interactions** within the firm (between top-management and employees) or relations with partners can boost or lower implementation easiness (Laforet, 2013). As indicated in previous section, the nature and functioning of previous **systems** and characteristics of **individuals** (i.e. tolerance to change) also play a role in the ease of implementation. All the levels of the company presented above (fig.4) are therefore involved in the decision to adopt as well as in the implementation process.

External context of the firm can impact change implementation at different levels (Franklin, 1976; Pettigrew, 1987). Conditions of demands, sharing and exploration of innovation with partners and clients (**normative forces, coercive forces**) can encourage or discourage people for implementation (Pettigrew, 2012). The availability of implementation protocols (**normative forces**) or possibility for firms to identify good practices through other firms that have already taken the plunge (**mimetic forces**) impacts ease of implementation. These three factors have been put in place to explain decision to adopt BIM (fig 5), but can be translated into IFs as well.

Change characteristics refers to the way in which change is implemented in the company. Change management in the company is essential to the success of the implementation. Main components of change that play a role in the success of implementation are here extracted of change management literature, and classified in three main categories, according to (Hochscheid & Halin, 2019b) (fig. 6).

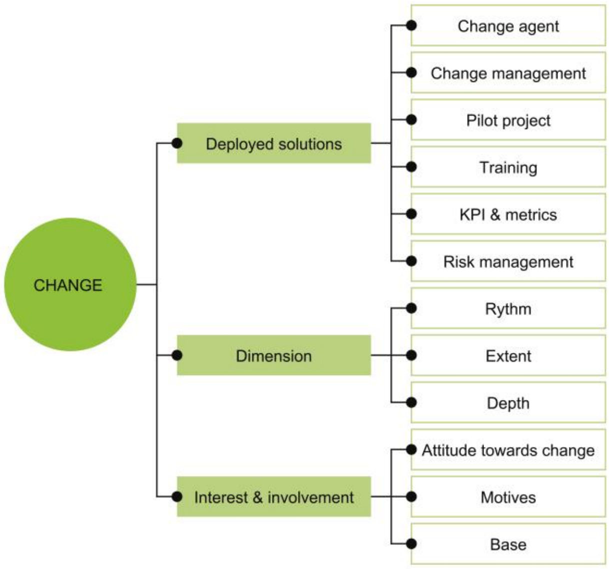


Figure 6: classification of adoption influencing factors for "change characteristics" field

(1) Dimension of change represents the breadth of change in three axes, based on Giroux's (1991) topology of change : (a) the time and duration of change (**rhythm**) (Kotter & Cohen, 2002), (b) the **extent** of change within the company (Pettigrew, 1987), (c) the distance between previous practices and new practices, which refers to the amount of change to be made (**depth**). **(2) Interest and involvement** of individuals (top management and employees) in change matches three aspects: (a) **attitude of individuals towards change** and climate in the firm that can lead to resistance or openness to change (Franklin, 1976; Johnson, 1992; Klein & Sorra, 1996)), (b) **motives** and commitment that led to implementation effectiveness (Greenwood & Hinings, 1988; Klein & Sorra, 1996), (c) **base**, which refers internal dynamics related to the change (top-down or bottom-up). **(3) The practical solutions that can be deployed** within the firm to manage implementation of an innovation were the subject of further study in (Hochscheid & Halin, 2019b). These are here summarized in six categories : (a) **change management**, refers to the way change is organized (needs assessment, transition planning, evolution of the firm's strategy, staff and team management), (b) characteristics of the **change agent** (Franklin, 1976), which is the person or group that leads implementation in the firm and who can from inside and outside of the firm (both are needed (Johnson, 1992), (c) the first project on which tests are made (**pilot project**), (d) the **training** progress, topics, and assessment of internal standards, (e) **Metrics** (key performance indicators and maturity metrics), and (f) **risk management** for the firm towards implementation.

3.3 Synthesis

In this section, factors that intervene throughout the adoption process (DFs and IFs) have been identified and classified, on the basis of literature area not related to a specific innovation. The respective literatures associated with these two types of factors are different and bring out factors that are expressed differently. It appears that the main areas involved in the adoption process are: the **internal context** of the firm, the **external context** of the firm, the **innovation characteristics**, and the **change characteristics**. Change characteristics only concern the implementation and confirmation phases of the adoption process (IFs), whereas the three other factor fields concern both DFs and IFs. The classification model of factors proposed here is very similar to the taxonomy proposed by (A. L. Ahmed & Kassem, 2018), which covers the first three phases of the adoption process (and therefore only the DFs). However, in this paper, an additional level of classification is proposed and the entire adoption process is covered. This overview includes a wide variety of factors involved in innovation adoption process and is intended to be used for the study of innovation adoption process.

4. BIM Adoption influencing factors

The previous section provides an overview and structuration of the factors involved during a generic innovation adoption process. In this section, the way this topic is handled in BIM-specific literature is explored; with an emphasis on the methodologies used rather than the results obtained.

4.1 A critical view of the methods used for the study of BIM-AIFs

Several theories and fields that make it possible to study the adoption of an innovation have been presented previously. BIM studies on adoption influencing factors are generally mono-oriented: it

focus on one theory or one field but does not offer an overview. *Technology adoption theories* are for instance investigated in (Lee, Yu, & Jeong, 2015; Son, Lee, & Kim, 2015), *institutional theory* are covered in (Cao Dongping, Li Heng, & Wang Guangbin, 2014). However, some recent studies undertake a classification of factors and propose an overview to get a research framework, notably technological, environmental, and organizational fields of influencing factors (A. Ahmed et al., 2017; Ahuja et al., 2018). *Change characteristics* don't seem to appear in a structured way in BIM-specific literature, even if some change-related factors are mentioned (Aibinu & Venkatesh, 2014).

BIM-AIF are seldom positioned on the adoption process. However, it has been shown that the significance of the impact of a factor depends on the stage of the adoption process concerned (A. L. Ahmed & Kassem, 2018). This impact also depends on the diffusion process (Waarts et al., 2002). For instance, the adopters who decided to adopt BIM 5 years ago were not driven by the same reasons (factors) as those that are doing it today. But taking into account all these parameters (factor field, adoption stage, positioning in relation to the diffusion process) makes the study very complex.

Methodologies used in BIM-specific literature to study these factors are varied. Most studies carry out a *literature review* to identify factors that influence the adoption of an innovation, and include at least one theory or field mentioned above. To identify the factors that influence the adoption of BIM specifically, some studies use *qualitative methods* (i.e. interviews, action research (Bin Zakaria, Mohamed Ali, Tarmizi Haron, Marshall-Ponting, & Abd Hamid, 2013)), but most of them exploit *quantitative methods*. Studies that combine qualitative and quantitative approaches are rare (Aibinu & Venkatesh, 2014; Cao Dongping et al., 2014). The number of respondents for the *questionnaire surveys* (quantitative) is generally relatively small (137 for (Cao Dongping et al., 2014), 125 in (Acquah, Eyiah, & Oteng, 2018), 184 in (Ahuja et al., 2018), 102 (Arunkumar, Suveetha, & Ramesh, 2018). Quantitative research generally provide in-depth statistical analysis to study relations (correlations) that can exist between the different factors (correlation matrix, Pearson's chi-squared test, Cronbach coefficient, Spearman's rho coefficient, or the Kendall's Tau coefficient).

The vocabulary used for describing BIM-AIFs is wide and varies from one paper to another: they can be referred to as factors, determinants, drivers, or barriers. It is sometimes considered that *factors* can take two forms: *drivers* (if they positively influence adoption) or *barriers* (when they hinder adoption) (Ahuja et al., 2018). Some research focus exclusively on barriers (Hosseini, Pärn, Edwards, Papadonikolaki, & Oraee, 2018; Olawumi, Chan, Wong, & Chan, 2018) or drivers. There is research that differentiates between the two and addresses both (Abubakar, Ibrahim, Kado, & Bala, 2014; Arunkumar et al., 2018). The wording given to the factors makes it possible to know whether the impact studied is *a priori* rather negative (i.e." absent harmonization between standards") positive (i.e. "efficient interoperability"), or neutral (i.e. "interoperability"). However, this can have a strong impact in a questionnaire survey because respondents can be influenced by the question's wording.

4.2 Synthesis

Studying BIM-AIFs is difficult because it depends on many different elements such as the stage of the adoption process and the dissemination process. Many studies carry out literature review to find factors that may influence adoption, but provide only a partial view of these factors. This underlines the need of a framework for the study of BIM-AIFs. The explored approaches (qualitative, quantitative) are varied but rarely combined in a single study, while a variety of methods might produce interesting new results. Also, if we note that a lot of literature review work has already been done on DFs, it seems that IFs are very little conceptualized. Lastly, the way the factor is worded is important and can convey the kind of impact the factor may have. We therefore propose to extend the classification model (fig. 2) to include the *factor's expression* and its *properties* (fig. 7) (positive formulation: *driver*, neutral formulation: *determinant*, negative formulation : *barrier*).

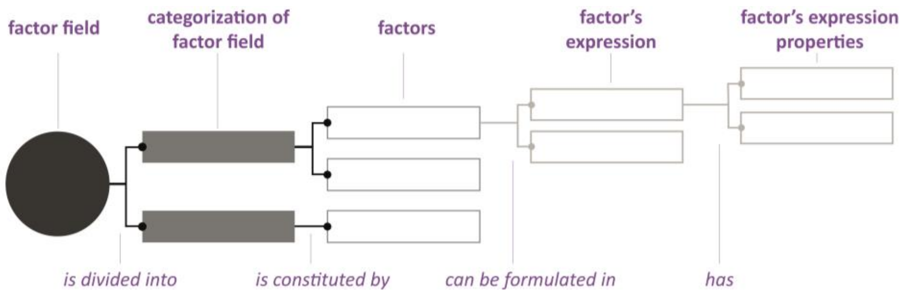


Figure 7: classification model of innovation adoption influencing factors (extended)

5. Conclusion

Adoption is here presented in a five-stages process from which we can deduce two main parts: the **decision part** and the **implementation part**. These two parts do not refer to the same phenomenon among adopters and the factors that influence them must therefore be differentiated. BIM adoption influencing factors (BIM-AIFs) may address users' decision to start using BIM (**Decision Factors**, **DFs**), or the success of the implementation (**Implementation Factors, IFs**). This distinction is fundamental because DFs cannot by themselves explain the speed of diffusion, while BIM-specific literature, though, seems to focus exclusively on DFs. *Adoption* has, indeed, often been considered synonymous with *decision-making*. This paper provides an overview of DFs and IFs, by investigating non-BIM-specific literature. The latter have been classified in **four fields of influence**: **internal context** of the firm, **external context of the firm**, **characteristics of the innovation** and **characteristics of change**. There is overlap between the two types of factors within these fields, but depending on whether they are DFs or IFs, they do not seem to operate in the same way. Research on BIM-AIFs mainly provide partial view of these factors, by confining oneself to the study of a single field, or only to the decision part of the adoption process. This underlines the need of a framework for the study of BIM-AIFs. Also, the distinction between factors that act negatively (barriers) or positively (drivers) is sometimes not made although it can play a predominant role, especially in questionnaire surveys. This research therefore proposes a complete framework for the study of BIM-AIFs. The authors have already used this framework to create a questionnaire, in which both DFs and IFs are addressed, and distinction between barriers and drivers is made.

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