

# Beyond Knowledge Transfer: Why Building Information Modeling Requires More Than Just Knowledge for Success

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**Abstract:** The German design industry is poised to take the next step in its development when it introduced building information modeling (BIM). The German Bundestag is requiring that public construction projects be completed with BIM. Over forty training providers offer a variety of BIM training courses, yet implementation is slowing. Small and medium-sized businesses (SMBs) are facing the challenge of implementing BIM. This study explores how SMBs' digital skills can be improved to implement BIM effectively. To this end, interviews with experts from nine companies were conducted and evaluated using the grounded theory. The interviewees express the view that investments in employee training can help build skills. All the same, SMBs only commit to BIM and training in response to growing demand. The interviews reveal that SMBs' low level of knowledge is attributable to their lack of practical experience with BIM. SMBs without any prospect of a pilot BIM project do not invest in training. A major finding is that SMBs do not consider BIM training expedient – even when it is free - because they do not anticipate any demand for BIM services in the short or medium term. Public clients must consequently develop BIM expertise. The study shows how knowledge and change management research can be drawn on to establish widespread acceptance of BIM.

**Keywords:** Knowledge transfer, Training, Building Information Modeling (BIM), Empirical study

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## 1. Introduction

The German Federal Ministry for Digital and Transport (BMDV) has observed an increase in costs and delays in major construction projects in Germany. The German design industry is poised to take the next step in its development. Digitalization of the entire construction sector is especially confronting SMBs with a wide range of challenges. The reform commission (by order of the BMDV) has adopted the internationally used, digital process of 'building information modeling (BIM) to reduce costs and delays. "BIM [...] is a digital representation of physical and functional characteristics of a facility; through visualization it eliminates uncertainty at various stages of construction" (Bhatija, Thomas, & Dawood, 2017, p. 65). Studies have found that using BIM in project management shortens the duration and improves the schedule and quality of projects (Kotiranta, 2019, p. 21).

BIM can consequently be instrumental in reducing risks during construction in Germany too in the future. It will also improve tracking of expenditures and minimize delays in construction operations. (Püstow, May, & Peitsch, 2015, p. 87). The BMDV has issued a staged plan to progressively implement BIM. The final stage when the implementation of BIM would be rolled out as a new standard for newly designed structures for Germany's transportation infrastructure was scheduled to start at the end of 2020. The BMDV largely initiated major projects to test BIM. SMBs, on the other hand, largely produce designs for municipal clients. Since such projects have smaller budgets, the pilot projects in the BMDV's staged plan will probably not have any direct impact on SMBs' business activities. It is consequently feared that SMBs will play a negligible role in the development of expertise in the use of BIM in pilot projects. Education and training is intended to foster digital skills in the design and construction industry, while public relations and informational activities will increase the industry's attractiveness

## 2. Literature Review

Wahbeh (2019) identifies technological developments' outpacing of people's ability to keep their knowledge up to date as an obstacle to the adoption of BIM in Switzerland. Tautschnig, Fröch, & Gächter, 2017, p. 18 fear that the trend toward BIM predominantly being used by large companies could cause SMBs to miss out on technological developments or need outside companies to provide their BIM services. Given the wide range of training programs in Austria, Schranz et al., 2021 consider the introduction of certified BIM training courses a solution for more BIM expertise in SMBs. Fechner, Witten, Gillen, & Pfeiffer, 2022 observe that the employees at the German companies surveyed do not seem to have basic knowledge of BIM yet.

Sesselmeier and Blauermel (1998) note that modern human capital theory developed in the early 1960s by Schultz (1961) and others was originally intended to explain the effectiveness of capital investments in industrialized and developing countries before it was also used to explain various real phenomena, such as professional qualifications (Sesselmeier & Blauermel, 1998, p. 65). The useful skills and knowledge people acquire are consequently a form of capital that is largely a product of deliberate investment (Schultz, 1961). This also includes ongoing training. People usually invest in their own professional development after considering the costs and benefits (Becker, 2018, pp. 314–318). Becker demonstrates that employers proceed similarly. They also analyze their investment in ongoing training. They factor in business interests and give employees (human capital) the opportunity for training, assuming that effective training will boost performance and the company's productivity in the long run. The investment in human capital must be smaller than the anticipated long-term benefit (Becker 2018, pp. 314–318).

Academic research has identified numerous obstacles to BIM adoption and BIM team development in the past few years, which are related to the dearth of experts and experience as well as an incapacity to adapt (Milivojević, 2020, p. 18). A few studies combine ideas of knowledge management with BIM, albeit literature on BIM adoption stresses knowledge issues in the industry (Milivojević, 2020, p. 24).

Since SMBs preparing to introduce BIM particularly lack sufficient expertise in BIM, which can be passed on to employees through informational events, working groups or even on-the-job training, they are dependent on third parties to impart knowledge in training courses. Over forty providers offer face-to-face and online BIM training courses in Germany.

### **3. Methodology**

This paper builds upon and expands a master's thesis with research from the field of knowledge management. Since research studies have been unable to fully explain why German design SMBs lack expertise in BIM, this study employs a qualitative research approach to identify the causalities of this phenomenon empirically. Interviews with experts were the method chosen to gather crucial facts, “expert” denoting interviewee with the expertise being researched (Gläser & Laudel, 2010).

Grounded theory, developed by Anselm L. Strauss and Barney G. Glaser in the 1960s, was the basis for data collection and analysis and theory building. Strauss (1994) considers it an analysis of qualitative data geared toward the development of a theory. This methodology is not confined to specific data types, research directions or interests. Grounded theory in which data collection constantly alternates with analysis and theory building following Strauss and Corbin (1996, pp. 43–165) does not permit defining the exact number of interviewees required in advance. This study was intended to be limited to design SMBs (companies) working in transportation infrastructure. Altogether nine interviews were conducted.

Since the questions in the interview guide should not be viewed as concepts with verified theoretical relevance consonant with grounded theory (Strauss & Corbin, 1996, p. 152), they are tentative and the findings have to be scrutinized as the analysis proceeds. Following the first interview and the analysis of the data collected, sections of the original interview guide were revised for the next interviews. The interview guide was reviewed before every subsequent interview and revised whenever necessary. Afterward, the audio recordings of the interviews were transcribed and analyzed based on grounded theory using MAXQDA software.

### **4. Empirical Study Findings**

The cross-case findings of this empirical study of the process of developing skills for BIM expertise in SMBs are the lack of demand for BIM services. The empirical analysis's main findings are an apparent lack of capabilities among clients too, and the resultant lack of demand for training to develop BIM expertise, especially in microbusinesses. Respondents across the cases feel that investing in training their employees (human capital) can contribute to skill development in their companies.

As the findings demonstrate, renewed commitment on BIM and training in microbusinesses will be contingent on a sustainable and positive development of demand and utility expectation. Experiences with BIM are gained in pilot projects. SMBs without any prospect of a pilot project nor a use for BIM that boosts efficiency do not invest in training. Small and medium-sized businesses only took paid training courses after being awarded the contract for a pilot project. This opened prospects of being able to position themselves for growing demand. As the interviews reveal, the low level of BIM knowledge in SMBs is largely attributable to their lack of practical experience with BIM. Wahbeh's (2019) findings, on the other hand, pertain to designers already using BIM.

Our findings clearly demonstrate that capability to acquire pilot projects grows as the number of employees in companies increases and BIM is introduced, whereas microbusinesses neither use BIM nor invest in training. In Germany, on the other hand, certified training providers have been offering BIM training and organizations and associations have been offering free training since 2018. Our findings clearly reveal, however, that BIM training curricula for must be geared specifically toward companies' relevant service profiles.

A major finding is that SMBs do not consider BIM training expedient – even when it is free– because they do not foresee any demand for BIM services in the short and medium term. Companies and clients' lack of capabilities is consequently another important obstacle.

Only additional pilot projects can improve SMBs digital skills for BIM. Opportunities to harness knowledge acquired from training courses and certifications and experiences from initial pilot projects in specific projects with new BIM use cases must follow. Without follow-up BIM projects, companies' BIM capabilities will be reallocated to conventionally design projects. High investments in human capital intended to produce the efficiency increases for the company expected from BIM will not be made. Clients will consequently need to train their own BIM teams strategically. Municipalities, SMBs main clients, ought to ascertain the need to plan projects based on BIM.

BIM capabilities will presumably be developed and expanded by training employees and as demand grows. The interview findings indicate that efficiency will increase as experience from completed projects grows. Such efficiency increases are also attributed to additional process automation. SMBs will probably be unable to afford the research and development required for this. As the findings of the study indicate, commercially available BIM software still holds significant potential. This will require increased efforts from software providers to design the BIM workflow to be user-friendly.

## **5. Discussion from the Perspective of Knowledge and Change Management**

A significant finding from our analysis is that the companies' continued development of BIM expertise is considered expedient in order to future proof themselves. There is no demand for outside knowledge, though, even when it is offered for free. Other research studies contend that BIM will only have a chance of being used widely if companies see an opportunity to benefit from it economically. The return on investment and the communicated benefits of BIM implementation and are impetuses for businesses to adopt BIM (Kotiranta, 2019, p. 22).

Other research studies see the lever for establishing BIM in the dissemination of knowledge. Milivojević (2020), for instance, identifies the following challenges to BIM and knowledge use in a literature review: lack of training in organizations, a lack of understanding of BIM practice, investment in training, problems with knowledge transfer and professionals' failure to adjust to the complex and ever-evolving nature of software tools (Milivojević, 2020, p. 59). The entire focus group in Bhatija et al.'s study (2017), agreed there is a need for a knowledge management adoption strategy is that would help the construction industry in the UK as it moves toward implementing level 2 BIM. Roughly 90 % of respondents see a need for knowledge sharing among clients, consultants, contractors and other project stakeholders. (Bhatija et al., 2017, p. 68)

Milivojević (2020) identifies altogether seventeen critical success factors for the establishment of BIM in companies in her research. Four pertain to knowledge: structured organized training, experiential learning, the opportunity for reflection of learned things and shared experience and learning (Milivojević, 2020, p. 287). She proposes combining formal training with learning by doing (Milivojević, 2020, p. 292). The evidence indicates that social learning enhances team flexibility more than structured organized learning does (Milivojević, 2020, p. 293).

Our findings indicate that the issue is more complex than disseminating knowledge to companies. As with any change, resistance is identifiable whenever BIM is introduced, as different research papers compiled by Milivojević (2020, p. 25) corroborate. The research field of change management can be drawn on here. Change management research has identified latent barriers to change in teams and organizations. Finke and Will (2003) propose an intervention paradigm that activates sustained motivation. Four motivating causes and four ensuing domains of intervention are identifiable. Transparency and communication facilitate "awareness", the motivational component that drives change. Training provides team members the skills they need to manage change. Transformations require management commitment (liability), which the team must accept. The appropriate intervention is leadership. Finally, change also requires individual "commitment" from the team, the relevant intervention being involvement. (Finke & Will, 2003)

Nearly half the BIM introduction success factors identified by Milivojević (2020) in her research relate to change management and the intervention levels identified by Finke and Will (2003). The success factors “communication digital and non-digital information exchange” and “opportunity for reflection” are part of the *communication* level. “Structured organized training”, “experiential learning” and “shared experience, shared learning” are part of *training* intervention. The factors “vision and clarity of requirements” and “establishing top-support, structure and providing skills and resources” are part of the *leadership* level. The factor “openness to new ideas” relates to *involvement*.

Change management primarily analyzes change processes within organizations. One of the main challenges identified in our study was enabling the sustained use of knowledge in practice once it has been acquired. Construction projects using BIM are normally interorganizational because of the different parties involved. Prioritizing knowledge transfer in an organization, e.g., a company, is consequently shortsighted.

Haugbølle (2016) proposes an analytical framework for knowledge in construction with five levels: “1) construction as a system, 2) firms as key players, 3) projects as the focal point, 4) communities of practice in groups and professions, and 5) individuals as bearers of skills.” (Haugbølle, 2016, p. 59) Haugbølle (2016) localizes knowledge in four different interactions between the political-institutional apparatus and business or users, between companies and their customers, between knowledge institutions and all the different business actors, and within each of these units (Haugbølle, 2016, pp. 61–62). More than just knowledge transfer from training providers to companies is needed. Haugbølle (2016) identifies three dimensions of knowledge transfer, networks outside companies, between projects in companies and between all partners in projects.

Knowledge management research has been around for many years but really took off in the 1990s, primarily because of the importance of the resource knowledge in our knowledge society. Knowledge management research is often dominated by a corporate view intent on optimizing the availability of the resource knowledge within organizations (see Davenport, 2011; Mertins, Heisig, & Vorbeck, 2003). One of the few approaches to linking individual, organizational and interorganizational knowledge transfer processes is Nonaka's SECI model. The four modes of knowledge conversion are *socialization (S)*, which involves interaction, knowledge sharing, shared time and joint learning from experience, *externalization (E)* in which tacit knowledge is crystalized, articulated and rendered explicit, *combination (C)*, which involves merging, integrating and systematizing explicit knowledge, and *internalization (I)*, which involves putting explicit knowledge to use and turning it into tacit knowledge (Nonaka & Toyama, 2003, p. 5) This spiral process connects individual and organizational and even interorganizational knowledge.

Transferred to an interorganizational BIM use case, the SECI process could proceed as follows. “Knowledge creation starts with Socialization, which is the process of converting new tacit knowledge through shared experiences in day-to-day social interaction.” (Nonaka & Toyama, 2003, p. 4). Since research has shown that requiring tacit knowledge transfer can be challenging (Chugh, Wibowo, & Grandhi, 2015), companies need to consider their approach to socialization carefully. A public client and several design and construction companies partnered in a joint construction project would collaboratively create new knowledge while developing the shared BIM model. “Such tacit knowledge is articulated into explicit knowledge through the process of Externalization.” (Nonaka & Toyama, 2003, p. 5) By merging client specification with contractors’ design information, such as materials required, agreed costs, three-dimensional drawings and completion dates, collaboration on a shared BIM model of the construction project constitutes externalization. The BIM model produced embodies the explicit knowledge. New explicit knowledge can be combined as project partners, e.g., subcontractors, continuously enrich the model with information. “Explicit knowledge is collected from inside or outside the organization and then combined, edited, or processed to form more complex and systematic explicit knowledge through the Combination process.” (Nonaka & Toyama, 2003, p. 5) Along with the actual BIM model, an explicit base of knowledge on BIM use can be created in joint construction projects and enriched with examples of good practice. Processes, experiences in the project and experiences using the tools for developing the BIM model could be saved in a joint project wiki, for instance. Other project partners can access this base of knowledge and the BIM model later on in a project to effectively reuse the explicit knowledge. “Explicit knowledge created and shared throughout an organization is then converted into tacit knowledge by individuals through the Internalization process.” (Nonaka & Toyama, 2003, p. 5) This process can be repeated on other levels, for instance, by enabling project partners to share the experiences from other projects by collaborating (socialization). Outside knowledge could also be contributed to other projects in exactly the same way through standard training programs by outside trainers, either by socializing in collaborative on-the-job training or by combining and incorporating explicit knowledge in existing bases of knowledge (combination).

This knowledge must be transferred to the entire industry in the medium term and such SECI processes must take place on completely different levels. Our analysis reveals a need among public clients in particular to invest in BIM expertise in order to be able to include BIM in public requests for bids and to enable SMBs in particular to use theoretical knowledge in practice. As the SECI process reveals, all project partners benefit from knowledge transfer since it ideally does not stop at the confines of an organization. A study by the German Bundeswehr found that organizations need to find the right enablers to share and create knowledge (Kreutzmann, Koller, Andresen, & Schulte, 2016).

Change management and knowledge management research has yielded enough points of reference to establish widespread acceptance of BIM. BIM will only experience wide acceptance once political decision-makers understand and put the relationship between change and knowledge management into action. As this study has demonstrated, establishing widespread acceptance will necessitate more than merely “supplying” explicit knowledge in publications or transferring implicit knowledge from training providers to the future users.

## **6. Recommendations**

As Haugbølle (2016) observes, establishing widespread acceptance of BIM will necessitate following a systemic approach. It must include the construction industry ‘s complete system with all the organizations (private and public contractors and companies) that interact in projects. Since individuals developing BIM skills work on projects and in organizations and are more or less in dialogue with each other in different communities, knowledge transfer must be facilitated and initiated on all these levels. Moreover, change management must be transferred to the entire construction industry. Applying Finke and Will’s (2003) approach to the construction industry will bring all four intervention levels into play.

The benefits and practicality of BIM must continue to be communicated openly and widely on the *communication* level. Several good approaches in Germany, such as the Mittelstand-Digital Construction Center funded by the Federal Ministry for Economic Affairs and Climate Action, can be expanded and enhanced. The Mittelstand-Digital Construction Center is a strong partner that helps SMBs in the construction and real estate industry transition to a digital and sustainable future. It teaches digital skills and facilitates the implementation of practicable digital solutions.

Municipalities are advised to study expedient uses of BIM for the design facilities in their purview comparatively with conventional design. To do so, they will have to ascertain their own needs.

Enough programs appear to be available on the *training* intervention level since the companies surveyed would not take advantage of any other training programs – not even free ones – on their own initiative. These authors feel that such programs, free or not, ought to be continued so that SMBs are also quickly able to acquire outside knowledge they are unable to provide themselves whenever demand for BIM services rises. SMBs are advised to study BIM implementation, factoring in their customers’ demands and their own service profile, possibly by taking part in pilot projects.

Training providers ought to gear their curricula increasingly toward municipalities as well and contribute to skill building in municipalities that have identified a need for BIM. Training providers could additionally develop solutions for working groups grounded in practice, which enable SMBs working on their first BIM projects to share experiences. The SMBs surveyed in this study displayed strong interest but also reservations stemming from the potential transfer of expertise to their competitors. Training providers’ job would consequently also entail establishing conditions that ensure collaboration based on trust.

The staged BIM plan and legal standards established the basis for using BIM in Germany on the *leadership* level. The status quo will not change much, though, as long as largely public clients do not (or cannot) implement these standards. The government must set an example and not only establish the conditions for implementing pilot projects in the future but also for completing BIM projects routinely.

We recommend that the German government open online training courses intended for federal employees to municipal governments as well. This would facilitate the training of municipal employees and also make BIM expertise a standard requirement when contracting BIM services.

*Involvement* is usually achieved when the benefits of innovation are recognized. These can be personal and organizational benefits. Performance expectancy is “[...] the extent to which a person believes that using a particular technology will enhance her/his job performance”. (Venkatesh, Morris, & Ackerman, 2000, pp. 36–37) If this way of thinking is maintained at the organizational level and beyond, it will permeate the entire industry (Bhatija et al., 2017, p. 64). Targeted communication and training can communicate benefits but

personal experience in real projects will be most effective. Increasing the number of BIM projects will be the best place to start here.

## 7. Conclusion

Since research studies have been unable to explain fully why German design SMBs lack expertise in BIM, this study employs a qualitative research approach to identify the causalities of this phenomenon empirically. The interviewees express the view that investments in employee training can help build skills. All the same, SMBs only commit to BIM and training in response to growing demand. The interviews reveal that SMBs' low level of knowledge is attributable to their lack of practical experience with BIM. SMBs without any prospect of a pilot BIM project do not invest in training. A major finding is that SMBs do not consider BIM training expedient – even when it is free – because they do not anticipate any demand for BIM services in the short or medium term. Public clients must consequently develop BIM expertise.

This study shows that knowledge management research on the SECI process can be applied to understand the relationships between knowledge transfer mechanisms and different parties in a specific industry. The authors also demonstrate that change management research can be drawn on to establish widespread acceptance of BIM. They propose using Finke and Will's intervention model to plan strategic actions and make specific recommendations for different parties in the German construction industry.

The methodology and procedures of grounded theory constitute potential limitations. The theoretical sampling employed differs fundamentally from statistical sampling (Strauss and Corbin 1996, p. 148). The selection of the initial sample and the achievement of theoretical saturation are crucial to grounded theory. Despite intensive efforts, interviewees could not be recruited from every domain of transportation infrastructure design, including subsoil testing, surveying and landscaping contractors. Since this study's sample is limited to some interviewees' middle management, these companies' interests may be under- or overrepresented.

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