



Change Triggers in Early Innovation Stages: How Technology Pilots Enable Routine Reflection

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Abstract: Many scholars have denounced innovation in construction as problematic. Existing work processes and routines may resist or even block the adoption of new technologies. Unravelling how new technology interferes with organizational processes could facilitate a more mindful innovation process. This study, therefore, conceptualizes how technology pilots influence early change of existing practices. Five utility localization projects were studied, in which ground-penetrating radar (GPR) technology was introduced. The researchers observed existing practices onsite, demonstrated and moderated the use of GPR, and conducted semistructured reflective interviews. Based on the concept of routine dynamics, selective and axial coding resulted in the identification of two types of mechanisms: (1) change triggers occurred when routines fell short and practitioners started favoring the GPR, and (2) stabilization occurred when routines proceeded as expected and shielded GPR from being considered. Objecting linear innovation adoption, the findings contribute an empirical conceptual model of early-stage innovation adoption dynamics. This model aids decision makers in timely identifying (1) whether routines are receptive to the uptake of new technologies, and (2) how new technologies may advance these routines. Additionally, this study demonstrates the merit of using practice-based studies to conceptualize in rich detail how innovation processes are shaped in situated construction contexts. DOI: [10.1061/\(ASCE\)CO.1943-7862.0002307](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002307). This work is made available under the terms of the Creative Commons Attribution 4.0 International license, <https://creativecommons.org/licenses/by/4.0/>.

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Introduction

Construction innovations may subtly change organizational processes even before organizations formally and consciously decide to adopt them. During this preadoption stage (Rogers 2010), prospective users form an understanding and decide their favorability toward a technology. They shape expectations regarding the technology's future benefits to the organization (Lines and Reddy Vardireddy 2017). The literature has defined possible motivations of users toward the use of technological innovations (e.g., Choi et al. 2017; Davila Delgado et al. 2020; Nnaji et al. 2018, 2020; Pan and Pan 2019; Wang et al. 2020). Most of these factors followed from a questionnaire survey and thus aimed to define generic causal models predicting professionals' usage and behavior. Although innovation scholars argued that technological adoption should be studied in a situated local context of use (Orlikowski 2007), studies that explain how the identified factors emerge and shape dynamics during early innovation stages are scarce. The literature would,

therefore, benefit from closely conceptualized studies of practices that are confronted with construction innovations.

Practice theory provides a conceptual lens to do this by mapping the practical interactions between users' behavior and technological innovations (Feldman and Orlikowski 2011). Within this stream of literature, the concept of routine dynamics specifically focuses on the level of daily activities (Feldman et al. 2019). Routine dynamics help to describe how interacting thoughts and actions of professionals stabilize or reshape existing construction practices during technology adoption (Becker 2004; Feldman et al. 2016). Using this as a conceptual lens, the objective of this study is to develop an empirical conceptual model of early interactions between work processes of prospective users and new technology.

To achieve this, this study focused on a technology that is currently entering the work processes of urban streetworks projects. At those sites, professionals need to assess the existing site conditions and verify the location of buried objects such as cables and pipelines before they start executing construction work. This is currently achieved through cut and cover excavation (ter Huurne et al. 2020; Lai et al. 2018; Racz 2017). Ground-penetrating radar (GPR) technology is gaining popularity in the sector and could advance this existing localization routine (Lai et al. 2018).

To study how the technology influences work processes in organizations that have no experience in using GPR, the researchers introduced it at five construction sites. Based on selective and axial coding of data from observations, demonstration and moderation of the technology, and reflective semistructured interviews, two types of mechanisms were identified: those of change triggers and continued stability. This contributes to the literature an empirical conceptual model of early-stage dynamics during innovation processes and demonstrates the merit of using practice-based studies to conceptualize in rich detail how innovations processes are shaped in situated construction contexts.

The remainder of this paper is structured as follows. First, the interplay between technology adoption studies and routines is

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explained. Second, the research setting and methods that allowed local practices to be studied in rich empirical detail are explicated. Next, the results are presented via analytic storylines and demonstrate mechanisms of routine change and stability. Finally, it is explained how the results smoothen the introduction of technology at postadoption stages, before outlining the limitations of this study and its possibilities for future research avenues.

Theoretical Points of Departure

Innovation adoption is

the process through which an individual (or other decision-making unit) passes from gaining initial knowledge of an innovation, to forming an attitude toward the innovation, to making a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision. (Rogers 2010)

During this process, innovations may change both organizational and operational practices (Sargent et al. 2012), regardless of the timing or relative degree of the newness of the technology (Rogers 2010). This is because the prospective users of technology and the internal organizational and operational processes all may have to adapt to accommodate the new situation (Orlikowski 2000). The literature, therefore, has previously attempted to develop an understanding of the factors that impact an individual's activities and cognitive processes. This helped clarify the individual's intent to use technology and create an understanding of the potential uptake process of technologies in the construction sector.

Classical frameworks presumed that individual adoption of technology progresses linearly (Rankin and Luther 2006). During the postadoption stage (Rogers 2010) of this process, formal and conscious decisions are made to implement the technology in an organization. Technology in use during implementation has been explored by many construction innovation studies. Such studies, for example, explored the impact of an adopted innovation on organizational goals and processes (Gurevich and Sacks 2020), operational processes (Edmondson et al. 2001), and user acceptance (Lee and Yu 2016). Although this was mostly studied at implementation stages, the interactions between technology and prospective users already can occur earlier, during preadoption stages (Rogers 2010).

When professionals develop an early understanding and decide their favorability toward a technology at these stages, insights can be gained about how technology brings benefits to existing organizational and operational practices (Lines and Reddy Vardireddy 2017). Furthermore, postadoption implementation is typically regarded as disruptive (Lines and Reddy Vardireddy 2017). The implementation of new technologies may enforce organizational and operational change (Orlikowski 2000), causing opposing behavior among individuals (Heidenreich and Talke 2020), triggering implementation failures (Klaus and Blanton 2010). To stimulate more mindful innovation in construction, earlier assessments of the dynamics that may change when technologies are used would hence help to better understand in which situations technology can be used effectively, and where it cannot.

To date, popular models like the innovation-decision process model (Rogers 2010), the theory of planned behavior (TPB) (Ajzen 1991), and the technology acceptance model (TAM) (Davis 1986; Venkatesh and Bala 2008) have provided ground for many studies that aimed to assess the motivation of users toward the use of technological innovations in the preadoption phase (e.g., Choi et al. 2017; Davila Delgado et al. 2020; Nnaji et al. 2018, 2020;

Pan and Pan 2019; Wang et al. 2020). These models identified and defined factors of motivation based on, for example, the attributes of perceived usefulness of the technology, the perceived ease of use of the technology, and the behavioral intention to use technology. Most of these factors followed from a questionnaire survey and aimed to define generic causal models predicting professionals' usage and behavior. As much as this is helpful as a first assessment about the merits of the technology, such factors do not depict mechanisms that are needed to describe the potential change processes at a micro-level, when prospective users are confronted with a technology.

Current literature lacks a model that provides a detailed understanding of the interaction between technology and existing practices in the preadoption phase. This is needed to understand the dynamics that might take place when users are first confronted with a technology. Because the organizational context of construction innovations are complex and project-based (Gann and Salter 2000), and therewith significantly different from most manufacturing innovations (Sarah 1998), this study posits that construction innovations should be studied in a situated and local context of use instead (Orlikowski 2007). Yet, studies that explain how factors of motivation emerge and shape dynamics during early innovation stages in such contexts are scarce.

To address this knowledge gap, this study proposes to use closely contextualized studies of innovation in the situated and local contexts of practices. The literature advocates that this can help to better understand the detailed, local dynamics that are at play when innovations confront the work practices of professionals (Orlikowski 2000). Practice theory provides a conceptual lens to do this by focusing on the empirics of practice to elicit real-life dynamics constituted through the ongoing, everyday actions in practice (Feldman and Orlikowski 2011).

Within practice theory, the concept of routine dynamics specifically focuses on daily activities (Feldman et al. 2019). Routines are repetitive, recognizable, and interdependent patterns of actions built around a mechanism of stability and change (Becker 2004; Feldman et al. 2016). This dynamic, called the generative mechanism of stability and change, has been used in studies to better understand how organizational change processes take place (e.g., Bygballe et al. 2021; Danner-Schröder and Geiger 2016; Turner and Rindova 2012), and may, in turn, help to describe how interacting thoughts and actions of professionals stabilize or reshape existing construction practices during technology adoption (Becker 2004; Feldman et al. 2016). By using routine dynamics as a conceptual lens, the objective of this study is to develop an empirical conceptual model of early interactions between work processes of prospective users and new technology.

In particular, this study uses the generative mechanism of routines to map the so-called coexisting and recursively related performative and ostensive aspects (Feldman 2000). Performative aspects of routines describe the actual actions (i.e., performances) "by specific people, at specific times, in specific places" (Pentland and Feldman 2005). Ostensive aspects of routines describe the thoughts and patterns that people "use to guide, account for, and refer to the specific performances of the routine" (Pentland and Feldman 2005). As such, the ostensive guides performances, but is also created from the performances. Furthermore, to understand how the performative and ostensive aspects are constituted, the conceptual framework of this study uses the attributes as used in the models of Davis (1986), Ajzen (1991), and Venkatesh and Bala (2008) to explicate professionals' usage and behavior. Specifically, the experiences, expectations, and intent to use technology by professionals are mapped. Fig. 1 presents the mechanisms used as the conceptual framework of the study.

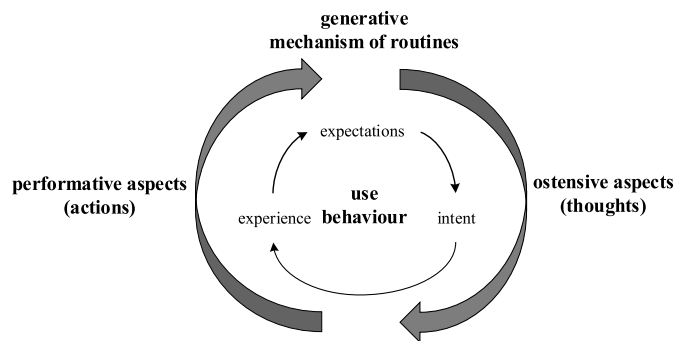


Fig. 1. Conceptual theoretical framework adopted in the study.

Research Method

This study adopted intervention research (Salkind 2010) to qualitatively explore how the introduction of GPR on five construction sites influenced the existing localization routine. The multiple cases were used to develop a broader understanding of this routine and to identify potential similarities and differences between the cases (Yin 2003). Furthermore, this study combined intervention research with grounded theory to streamline the case data toward theoretical interpretations, which were systematically gathered and processed through the research process (Corbin and Strauss 2008).

This study explored the utility localization routines of five urban streetworks projects in the Dutch utility sector. Each case allowed for the exploration of GPR technology and studied different

organizations. Organizations were considered eligible when they had considerable experience with the established utility localization routine but limited to no experience with GPR. This was verified before the pilots during an exploratory interview in which participants were questioned about their experience with the existing routine, their familiarity and experience with GPR technology, and whether they expected GPR to advance the established routine. Participants included workers (performing the surveying activities), supervisors and project managers (guiding the surveying process), and project owners (client of the surveying activity). To further expand the researchers' understanding of the projects, two-dimensional maps of the locations and types of utilities onsite, as well as work plans describing the planned surveying activities were collected. Table 1 summarizes the main characteristics of each case.

For each case, data were collected through three research phases and subsequently analyzed as illustrated in Fig. 2. The selected supervisors, project managers, and project owners were part of the entire sequence of the three phases. The researchers only met the workers at the construction site during the second data-collection phase, but questioned them onsite instead.

Within the first phase, the researchers conducted semistructured interviews of approximately 1 h with the responsible supervisors, project managers, and project owners. The professionals were questioned about how they commonly localize utilities onsite (the performative aspects) without the use of GPR. Additionally, the participants were questioned about their prior experiences with and thoughts of (the ostensive aspects) the existing localization routines. The first phase further expanded the researchers' understanding of the participants starting beliefs and behavior.

Table 1. Description of the cases studied

Case	Organizations involved	Project type	Construction stage	Planned construction activities	Localization goal	Construction area
1	Utility owner and contractor specialized in utility location practice.	New installation	Planning	Installation of new city heating pipelines, including supply and return lines	Verify locations of utilities on existing maps. Determine how new heating lines cross the existing utilities. Determine the free space for the new heating lines.	Inner city
2	Contractor specialized in utility location practice.	New installation	Planning	Installation of three new medium-voltage electricity lines	Verify locations of utilities on existing maps. Determine the free space for the new electricity lines.	City outskirts and port area
3	Utility owner and contractor specialized in utility location practice.	Rehabilitation	Planning	Replacement of old asbestos cement freshwater, medium-voltage electricity, sprinkler, low-pressure, asbestos cement gas, heating, cooling, rainwater sewer, and wastewater sewer lines	Verify locations of utilities on existing maps. Find the asbestos cement lines that had to be replaced. Determine the free space for the new utility lines.	University campus
4	Utility owner and contractor specialized in utility location practice.	Rehabilitation	Planning	Replacement and repositioning of old freshwater line	Verify locations of utilities on existing maps. Find the old water line that had to be removed. Determine the free space for the new water line.	Industrial campus
5	Contractor specialized in utility location practice.	Rehabilitation	Planning	Replacement of old freshwater line	Verify locations of utilities on existing maps. Find the old water line that had to be replaced. Determine the free space for the new electricity lines.	Village area

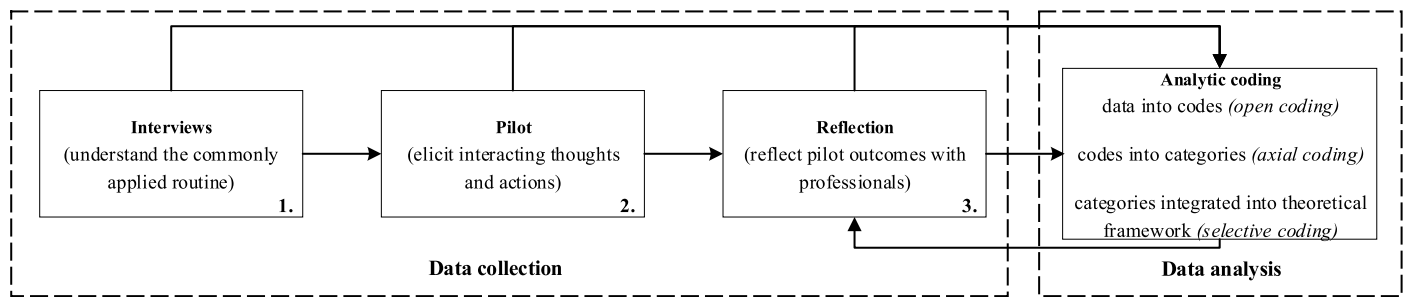


Fig. 2. Main research steps.

Within the second phase, the researchers supported pilots that took, depending on the size of the construction site, 1 or 2 full days. The pilots took place in parallel to existing utility localization routines, which meant that professionals onsite executed their normal routine, but were also confronted with GPR when the researchers executed GPR measurements at the same site. This familiarized professionals with the technology in a minimally intrusive way, and without a deliberate purpose to influence the professionals' ongoing routines. Although the researchers did not initiate action, professionals observed how the technology was used, and consequently gained the chance to assess how this could impact their existing routines. To this end, a moderate participation stance (DeWalt and DeWalt 2011) was adopted because the researcher did not only passively observe the actions in practice, but also assisted professionals in case of a request to use GPR in their routines given their unfamiliarity with GPR and its complex use. To capture data about the actions and thoughts of the professional during the pilot, the first author of this article took notes, pictures, and occasional videos of the site. Additionally, unstructured and spontaneous dialogues with the professionals on the research site helped elicit the reasoning behind the choices that were made by the professionals in practice.

Within the third data collection phase, reflective semistructured interviews of approximately 1–2 h were conducted with the professionals to discuss their pilot experiences, expectations, and use behavior. Namely, it was discussed how the prior thoughts of the existing routine were impacted, how the pilot experiences with GPR were perceived, and how these experiences initiated changing thoughts and beliefs about the role of GPR in the current routines. The interviews, therewith, helped to assess whether the pilot had set routines into change and what might have caused that change.

To analyze the data, the researchers used the analytic coding procedures of Corbin and Strauss (2008). First, open coding was applied to code the interview and field note data line-by-line to categorize the data into codes. Codes were, for example, Experiences with GPR and Findings of Localization Efforts. Second, these codes were linked and grouped into broader categories and subcategories via axial coding to identify the logic behind how and why technology pilots initiated the stabilization or change of a routine. Categories identified were, for example, Disruptions in the Routine and GPR Use Behavior. Finally, the researchers integrated the categories and subcategories into the ostensive-performative cycle via selective coding and expanded the theoretical model of Fig. 1 by including the mechanism that led to stability or change of the existing utility localization routine. The results are presented via an analytic storyline that explains the sequence of the professionals' actions, reactions, and interactions (Saldaña 2013). Within this storyline, the key events within the mechanisms of stability and change are highlighted and described.

Results

The five cases demonstrated the existence of two different types of mechanisms: one of routine changing, and the other of routine stabilizing. Although they were observed in multiple cases, the results show one case as illustrative evidence for this mechanism and subsequently explain in brief how this was observed in other cases.

Mechanism 1: Routine Change

Events observed during the pilots showed how through the confrontation with technology professionals decided to use GPR and alter their routines consequently. This mechanism demonstrated the flexibility in routines to adapt to new technology introduced in the practical context of work, and was, among others observed in Case 3. Case 3 comprised a rehabilitation project at a university campus in which a series of utility services were replaced with new ones because of growing service demand, the deterioration of old utility lines, and the presence of harmful asbestos cement water and gas lines. Further information on the case can be found in Table 1.

During the interview that was held before the pilot, the project manager explained the intent behind the established localization routine:

You want to know what is in the ground. Is the KLIC [i.e., the existing utility maps] correct? With trial trenches [i.e., cut and cover excavation] you see exactly what is there

Trial trenches are a commonly applied utility localization method in the Dutch localization routine to verify the location of the utilities on the utility KLIC maps. The project manager explained their and the organizations' a priori experiences with and expectations for GPR technology:

We have looked at the subsurface with radar in the past, but the question always remained: have you found everything [i.e., all subsurface utilities]? What do you get for your money? There is always a need for a trial trench [i.e., cut and cover excavation]. The radar cannot give you the same level of certainty. The radar is simply not a normal product.

With "certainty" referring to the locational accuracy of the utility lines in the x -, y -, and z -coordinates, and "normal" to GPR not being considered part of the established utility localization routine yet, the project manager expected GPR technology, in the practical context of work, to be inferior compared with the existing routine, disincantizing the intent to use the technology at the construction site.

During the next data collection, a 2-day pilot took place in which the researchers used GPR at the construction site. Four professionals were present: the project manager, the supervisor, and

two workers. At the start, their working activities comprised the established trial trenching routine: the professionals consulted the utility maps, examined which subsurface utilities were to be re-constructed, and then decided where on the site those utilities had to be exposed by manual and mechanic excavation. Subsequently, the x -, y -, and z -location, type, material, and diameter of the localized utilities were noted by the supervisor. Locations of utilities were measured with both tape measures and professional GPS-surveying equipment. Also, pictures of the exposed utilities were taken. During these early stages, no technological intervention took place, and no discernible changes to traditional work practices were observed.

The first key event during the pilot occurred when both the supervisor of the contractor and the project manager debated about uncertainties in the location data of medium-voltage electricity cables. They wanted to expose these cables using trial trenches, but the shortcoming of the map used as a basis for the existing routine triggered a discussion about utility maps and their accuracy. They concluded that in general, KLIC-maps are known to be not completely reliable and did not yet want to start excavation before they reduced the uncertainty they had regarding the chosen trial trench location. They stated:

The KLIC [i.e., utility maps] always has some sort of deviation. I seem to remember that they [i.e., the medium-voltage electricity cables] run differently than drawn on the map.

To reassure that the electricity cables were found, the project manager then approached the researcher and asked the following:

Although I know that the cables and pipes are here somewhere, I am not exactly certain about the location of the medium voltage cables ... Could you look here [with GPR technology] to see whether the trial trench [i.e., cut and cover excavation] is set at the right location, or do we maybe need to dig further? What can you find here?

The observed event demonstrates that the professionals started to assess the merit of the GPR technology in the local practice after they were confronted with a shortcoming of their existing routines. This routine reflection led, in turn, to the intent to use GPR and shaped new use behavior. In this situation, the GPR technology was able to confirm that professionals chose the correct location for their trial trench.

A related second key event was that the use of the GPR led to the detection of unregistered steel pipelines, of which both the supervisor and project manager were not aware. Consequently, the supervisor asked for the use of GPR at every successive location where trial trenches were planned. At that moment, the GPR technology became part of the sequence of actions performed. This disruption or expectation (i.e., the detection of unmapped pipelines) again led to an assessment of the merit of GPR technology for the existing routines. Subsequently, this again led to new behavioral intent and new use behavior. Both the newly created thoughts and observed actions thus indicated routine change because of the pilot.

During Case 3, more examples were observed where new experiences shaped new expectations, leading to a new intent and use behavior. During one successive event, for example, one of the professionals asked the researcher to use GPR and support the routine as follows:

Could you look at this location? We must find pipe protective casings here that cross the road. You should be able to find these with relative ease. They are quite big. Can you tell

whether our trial trench [i.e., cut and cover excavation] is planned at the right location?

Again, this request shows that the previous experiences with the technology seemingly shaped a favorable expectation about the merit of GPR technology. The request to support the utility localization with GPR further demonstrated a change of intention to use the technology.

The previous examples of how the technology pilot impacted the routine have been from the actual activities onsite. Case 3 also showed that the project manager envisioned that the technology had merit in successive cases. When thinking out loud, he told the researcher the following:

Since the radar is here anyway, we could also go to ... [another location] to scan there. We need to know the location of the cables and pipes in front of the ... [name of a building] to update our archive and for when we start our construction activities there.

This example shows that the new experience, induced by the disruptions and shortcomings of the existing routines, also triggered thoughts about new intents to use the technology. The changes in the localization routines thus seem to have transcended the single case studied, suggesting that a routine change might have been initiated. The new experiences further led to changed expectations about GPR, as explained by the project manager during the reflective semistructured interviews after the pilots:

My expectations about the radar have grown. In the past, we never worked like this [i.e., with GPR technology] and typically were not as directly involved during the localization of utilities ... The radar supported us really well. We had to dig more as a result [i.e., of the unexpected finding of the unregistered pipes] but that helped us during our excavation activities.

As a result of unveiled disruptions and shortcomings in the routine, pilots thus may set routine reflection into motion, and therefore, may change routine user experiences, reshape future expectations, and trigger an intent to use the technology in successive activities, leading to early routine change. Pilot experiences and expectations may trigger a mechanism of routine change that is represented as the mechanism in Fig. 3.

Similar routine changes were observed in other cases. In Case 5, for example, the disruption of the existing routine took place when a steel sewage pipe could not be found via the conventional method of a trial trench. The professionals found that the available utility maps were unreliable, and this led them to ask the researcher to scan the area with the GPR, to locate the missing pipe:

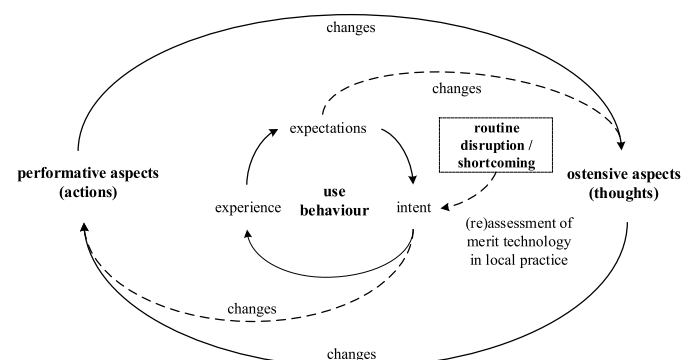


Fig. 3. Routine changing mechanism.

There must still be a pipe here, but we cannot find it yet [i.e., with cut and cover excavation]. We can check to see if it is located under the street if you can scan there?

Here, the shortcoming of using a map to determine a trial trench location led to an assessment of the merit of GPR technology. The technology was assessed to overcome the faced shortcoming and allowed for exploration of the technology in the practical context of work. When the GPR technology proved to be capable of finding the missing pipe in Case 5, it shaped new expectations among the professionals about the merit of the technology. One of the workers approached the researcher and asked:

If you find other deviances with the radar [i.e., in addition to the missing pipe], can you let us know? We still have to dig the test trenches [i.e., cut and cover excavation] on the other side of the street.

For the remainder of the project, GPR technology was used in successive activities to support the conventional utility localization practice by verifying the prior chosen trial trench locations onsite.

Mechanism 2: Routine Stability

The other cases demonstrated that the functionality of existing routines, or put differently, the absence of routine disruptions or shortcomings, did not incentivize professionals to deviate from their existing routines. The routines remained stable despite the availability of new technology on the construction site. This mechanism of routine stabilization demonstrates the inertia in routines to adapt to new technology. Stabilization was, for example, observed in Case 1. Case 1 comprised an installation project in the inner city in which a new heating system was installed to provide a new apartment complex of central heating.

During the interview that was held before the pilot, the project manager revealed the existing thoughts about the technology. The manager explained the lacking experience with the GPR as follows:

Low, very low. We haven't applied radar before, and actually, I only know it by name.

This meant the pilot would be the very first encounter of the project manager, but also the other professionals present, with GPR technology. Additionally, the project manager explained the, and the organization's, a priori expectations for GPR technology:

I expect that the radar will have a difficult time in a crowded area [i.e., many cables and pipes in the subsurface]. In a city environment where the subsurface is very crowded, I think it will be hard to identify cables and pipes on an individual level. Because we need to have precise information about everything that is here [i.e., the cables and pipes], I do not expect the radar to be reliable enough.

To find the information required, the project manager expected the established localization routine to prevail over the alternative pilot GPR technology.

During the next data collection, a 2-day pilot took place in which the researchers used a GPR at the construction site. Four professionals were present: the project manager, the supervisor, and two workers. At the start, their working activities comprised the established trial trenching routine: the professionals consulted the utility maps, examined which subsurface utilities were to be found, and then decided where on the site utilities had to be exposed by manual and mechanic excavation. Subsequently, the

x -, y -, and z -location, type, and for most utilities also the material and diameter were noted by a subcontracted surveyor. When recording the location, pictures of the exposed utilities were taken by the crew. During these early stages, no technological intervention took place, and no discernible changes to traditional work practices were observed.

The first key event during the pilot occurred when an electricity cable could not be found through excavation. The event delayed the ongoing localization activities because utilities had to be found before proceeding to the next planned trial trench location. To reassure that the missing cable would be found, one of the workers then approached the researcher and asked:

You can find cables and pipes with that thing [i.e., GPR technology] right? Can you look where it [i.e., the missing cable] is?

The observed event demonstrates that the professionals started to assess the merit of the GPR technology in their practice after they were confronted with a shortcoming, i.e., not being able to locate a cable using excavation, of their routines. This shortcoming led to the intent to assess and use technology. This first event introduced the professionals to the GPR technology, shaping new use behavior.

The GPR technology, however, did not find the missing electricity cable, despite scanning a broad area in which the cable was situated according to the utility maps. In the local context, the subsurface was very congested with many cables and pipes. The missing electricity cable had a relatively small diameter and was difficult to find amid this stack of utilities. This meant the local context did not lend itself well for GPR usage, resulting in the cable not being found. This demonstration of the GPR led to new experiences among the professionals. However, the assessment of the merit of the GPR technology was perceived as seemingly unfavorable: the use of GPR by the expert did not lead to a better evaluation of the whereabouts of the electricity cable compared with the existing routine. For the further utility locating activities during this case, the professionals did not request usage of the GPR.

When reflecting on the merit of the technology after the pilot, the project manager explained that the GPR confirmed the prior expectations:

Not as a replacement [i.e., for cut and cover excavation] in an area with many cables and pipes. The reason is that the radar cannot find cables and pipes on an individual level. You need to know whether you have found everything [i.e., all cables and pipes].

Future adoption of GPR and change of the ongoing activities accordingly was not considered yet a viable alternative to (partially) replace the established localization routine.

Once again, through unveiled disruptions and shortcomings of the existing routine, pilots set routine reflection in motion and thus may create new user experiences. However, the initial success of the technology to overcome the specific—locally identified—disruption or shortcoming of the existing routine determines in which way the initial experience reshapes expectations and triggers an intent to use the technology. The observed unfavorable experience with the piloted technology did not incentivize a behavioral intent to use the technology elsewhere. The routine remained stable. Fig. 4 summarizes this mechanism in which pilot experiences and expectations trigger a mechanism of continued routine stability.

Similar routine stability was observed in Cases 2 and 4. In Case 2, none of the professionals approached the researcher to use GPR. Showing no signs of routine disruptions, shortcomings, or routine

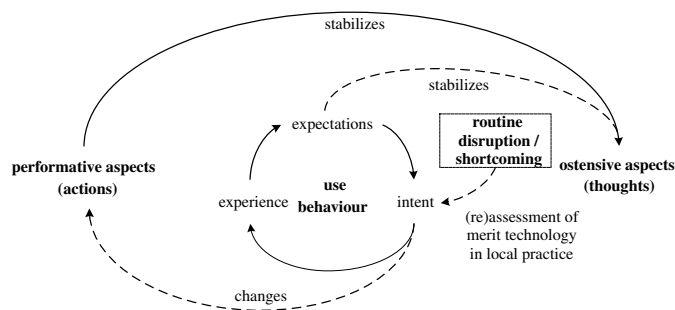


Fig. 4. Routine stabilizing mechanism.

reflection, the existing utility localization routine proceeded without the use of GPR. The absence of the former thus led to continued routine stability despite the availability of new technology on the construction site.

Furthermore, in Case 4, the existing routine was disrupted when a public lighting cable could not be found via the conventional cut and cover excavation. The utility maps proved to be unreliable in providing the correct coordinates for the public lighting cable. To find the missing cable, one worker approached the researcher and asked:

The public lighting cable should be here, between the street-lamps. Can you look with the radar? I guess the cable does not follow the straight path as shown on the KLIC [i.e., utility maps].

In search of a solution to overcome the faced disruption, the professionals started to assess the merit of GPR technology and asked the researcher to scan the location. This allowed for the instantaneous exploration of the technology onsite. However, use of the GPR did not lead to a better evaluation of the whereabouts of the missing cable compared with the existing routines. Like Case 1, the use of GPR in Case 4 led to a new experience among the locating professionals, but arguably also to an unfavorable assessment of the merit of the GPR technology for the existing routines. For the further activities during the remainder of the pilot, the professionals did not approach the researcher again to use GPR, engaging continued routine stability.

Discussion

This study used the lens of routine dynamics to develop an empirical conceptual model of early interactions between work processes of prospective users and new technology. This resulted in the following three contributions.

First, this study contributes to the construction innovation literature an explicated and empirically grounded conceptual model of routine change and stabilization mechanisms during technology pilots. Specifically, this model demonstrates that change triggers are crucial in initiating either routine change or routine stability. This aids decision makers in timely identifying (1) whether routines are receptive to the uptake of new technologies, and (2) how new technologies may advance these routines. The study therewith objects to the presumed linearity of innovation adoption theories (Rankin and Luther 2006) and provides a first empirically rich understanding of the routine dynamics in early innovation stages to the construction innovation literature.

The mechanism of routine change depicts how the emergence of change triggers incentivizes professionals to assess the merit of the technology instantly. Change triggers, either in the form of routine

disruptions (events where existing routines lead to new results) or routine shortcomings (events where routines lead to deviating results), happen when existing routines fall short. As a solution to the failing routine (Feldman et al. 2016; Feldman and Pentland 2003; Mitropoulos and Tatum 1999), professionals enact an alternative seeking behavior (Levitt and March 1988). Findings demonstrated that the subsequent exploration of new technology creates new experiences, reshapes future expectations, and in turn, may trigger an intent to use the technology in successive activities. This indicates an early routine change. The identification of this mechanism thus suggests that routines susceptible to change triggers are also receptive to the adoption of new technologies.

The other mechanism depicted how either the absence of change triggers, or implementation failures, led to continued routine stability. Findings demonstrated that stabilization of routines occurred if the routines proceeded as expected. Despite having ready-to-use alternatives to the routine (i.e., the introduction of new technology) offering opportunities for new routine directions as demonstrated both in this study and in recent routine literature (Kiwani and Lazaric 2019), this study and prior literature suggest that established experiences seemingly steer the decision making toward the existing routine (Betsch et al. 2001). This demonstrates an inertia to change that shields professionals from new actions and hampers the uptake of new technology (Pentland et al. 2012).

Furthermore, even in case of change triggers, the initial success of the new technology as an alternative to the prevailing routine determines in which way the initial experience reshapes expectations and triggers an intent to use the technology. Findings indicated that unfavorable experiences of exploring the new technology hampered the further accumulation of experience with that routine, even when the new routine was considered superior (Levitt and March 1988). This confirms that the likelihood that a new technology-enabled routine is used will decrease when it is associated with failure in advancing the existing routine (Rogers 2010). Such early unfavorable experiences may thus significantly hamper later innovation adoption stages.

This study adds to the context of innovation adoption processes by unveiling that change triggers in early stages, such as the types of disruptions and shortcomings identified in this study, may initiate routine reflection and a subsequent exploration and uptake of new technologies in construction practices. This suggests that construction innovations should focus on those situations where the existing practices are susceptible to falling short. These situations are most likely to exhibit a dynamic in which new technologies could replace routines. Notwithstanding, even within this dynamic, contractual arrangements or specific project delivery methods (PDM) may significantly impact whether practices and their routines are truly receptive to the uptake of new technologies (Adriaanse et al. 2010).

Second, this study demonstrated the merit of the routine dynamics lens in practice-based innovation studies at preadoption stages. In the previous literature, routine dynamics were already used to better understand how organizational change processes take place (Bygballe et al. 2021; Danner-Schröder and Geiger 2016; Turner and Rindova 2012) but not specifically as a lens to study the micro-dynamics in innovation processes. The detailed and empirically rich descriptions gathered through the routine dynamics lens complement the individual behavioral change models of Davis (1986), Ajzen (1991), and Venkatesh and Bala (2008) that focus on an individual level but do not allow for a detailed analysis of performed practices and behavior. Instead, this study demonstrated that focusing on actions helps in disentangling complex organizational phenomena like technology adoption in routines (Feldman et al. 2019). However, although the use of technology is not necessarily unique,

the use of technology in practice-based studies is always situated (Orlikowski 2007). Scholars should thus proceed with caution in generalizing results from practice-based studies if these results are not demonstrated across a variety of local and situated contexts of use.

Additionally, because adoption and use of technology, especially in the construction practice (Gann and Salter 2000), is highly context-dependent, this study stressed the importance of the early engagement with technological innovations in a practical context of work to better understand the value and use of technology in its situated action in practice (Feldman et al. 2016; Orlikowski 2000). By using routine dynamics, this study is a first example of how an empirically rich local context of innovation can be studied to better understand how professionals' interacting thoughts and actions impacted the generative mechanism of performative and ostensive aspects and, in turn, technology use behavior.

Third, this study also has practical contributions. By identifying those conditions in which the technology is seemingly favorable for the prospective end-user, organizations might be able to describe what value the technology brings to existing operational processes. The advantage of a pilot—one that is supported by technology experts—is that it brings an instantaneous opportunity for prospective end-users to freely explore technology as part of their ongoing routines. Because postadoption technology implementation is considered to be rather disruptive, enforcing organizational change (Lines and Reddy Vardireddy 2017), provoking opposing behavior (Heidenreich and Talke 2020), and potentially triggering implementation failures (Klaus and Blanton 2010), this study postulated that the possibility to change routines in early adoption stages could stimulate an alignment among technology, its users, and the practical context of work. This grounded understanding might eventually streamline adoption processes in practical contexts of construction toward more mindful and less disruptive implementations of new technologies.

Finally, this study offers recommendations and opportunities for further research. First, the chosen research approach provided limited insights into the thought processes of the individuals. For future research, the researchers recommend that scholars adopt an autoethnographic research approach, in which they use their personal experiences from the field to describe, analyze, and understand complex and often multilayered cultural phenomena (Ellis et al. 2011). Rich descriptions of these experiences may help to further amass the thoughts processes of individuals during technological pilots, and therewith, understand its impact on routines better.

Second, it was not observed whether a sustained change of routines took place. Instead, this study claimed whether and when the pilots initiated a mechanic of routine change or stabilization. Successive studies could observe the prospective users for a longer time frame to explore whether the routine change or stabilization was sustaining.

Third, the presence of the researchers as moderator of the pilot technology—which was indispensable given the lack of experience of practitioners with the technology—likely influenced how the professionals shaped their behavior. This is also known as the Hawthorne effect (Oswald et al. 2014). The researchers' presence itself might have already triggered the attention of technology-savvy professionals, leading to an inquiry of the technology's use in their routines. So, despite the attempt of the researchers to not voice their opinion and steer conversations about the value of the technology, it could not be avoided that practitioners were influenced by the researchers' presence. The researchers recommend that future studies consider this impact on professionals carefully.

Fourth, although the pilots evidently correlated to the identified mechanisms of stability and change, this does not prove causality even though this seems very likely. Future studies are, therefore, recommended to consider baseline cases as a benchmark against which the outcomes of the pilots can be assessed.

Conclusions

This study conceptualized how technology pilots influence early change of existing practices. In specific, it was explored whether and how GPR technology influenced the generative mechanisms of stability and change of utility localization routines of five urban streetworks projects in the Dutch utility sector. Through a combination of interviews, observations, and intervention research, the findings demonstrated that new technology like GPR can initiate both mechanisms of routine change and routine stability. When prevailing routines fell short, this enabled professionals to reflect on the routine and assess the merit of the technology as an alternative solution. The subsequent exploration of the technology created new user experiences, reshaped future expectations, and triggered the use of technology in successive activities. This indicates the start of a potential routine change. Conversely, this study demonstrated that when routines proceeded as expected, the routine shielded professionals from the uptake of GPR.

The contributions of this study are as follows. First, it contributes to the construction innovation literature an empirical conceptual model of routine change and stabilization mechanisms of when innovations entered a construction practice in preadoption stages. Second, it demonstrates the merit of the theoretical lens of routine dynamics to conduct studies of situated local practices during innovation pilots at construction sites. This enhances the understanding of the implications of technology adoption and contributes to the existing literature an empirically rich study in the practical context of work. Third, to construction practice, the routine concept brings a meaningful way to better understand whether existing routines are susceptible to change, and therewith, receptive to new technologies. This grounded understanding might eventually streamline adoption processes in practical construction contexts.

Finally, this study offers opportunities and suggestions for further research. Scholars are (1) recommended to adopt an approach such as autoethnography to further expand insights into the thought processes of individuals partaking in technology pilots, (2) suggested to extend observations beyond the level of pilots toward other innovation adoption stages, (3) urged to carefully consider the impact of the presence of the researcher on routine dynamic change in technology pilots, and (4) advised to consider baseline cases against which the outcomes of pilots can be assessed.

Data Availability Statement

Some or all data that support the findings of this study are available from the corresponding author upon reasonable request. These include the notes, pictures and ground-penetrating radar data from the field experiments, and the interview data. Some of or all data used during the study are proprietary or confidential, and may only be provided in anonymized form.

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