CHALLENGES FOR CONSTRUCTION IT ADOPTION ON PROJECT LEVEL

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Construction IT - as ubiquitous computing, location based services, GPS, 3D GIS, 4D design - challenges the work practices in inner city infrastructure projects in terms of improving information exchange between client and contractor and communication with stakeholders in the project environment. Although Construction IT (CIT) can offer benefits to support these communication streams, most project teams in (Dutch) inner city reconstruction projects do not make use of the available technologies. This paper discusses the challenged practice in inner city reconstruction projects in two mid-sized municipalities and a large Dutch contractor. With an ethnographic research approach, this paper used perspectives of individual change, work practices and CIT-features to document and structures the coping processes of clients, contractors, and technology suppliers. A first analysis on the use of 4D-modelling, 3D-design and 3D-GPS systems provides insights in the mismatches between individual ways of reasoning, existing work practices and CIT features. These mismatches helped to identify challenges that change agents should consider when developing or introducing new technologies.

Keywords: construction IT, industry recipe, innovation, socio-technical landscape.

INTRODUCTION

The recent growing population density in Dutch urban areas pressurises the scarcity of public space. With the increasing number of people using space in city centres, construction managers are urged to minimise the impact that their activities have on the environment. They need to make efficient use of the construction site, while simultaneously minimise nuisance and prevent schedule overruns. The tasks of the construction manager get more complicated on inner city projects that involve renovation of underground infrastructure and reconfiguration of public space at street level. Another complicating factor is the densely populated underground that often contains complex patterns of different types of cables and piping. Together with this physical complexity, the amount of different stakeholders that these projects involve turn inner city projects into a challenging project management task.

CIT can support inner city reconstruction projects by providing a structured platform for information exchange between client and contractor and stakeholders in the project environment. For example, CIT-tools enable parties to exchange, better align or optimise different designs, schedules and construction work flows. Albeit these features, most project teams that work on inner city reconstruction projects have not adopted the new technologies.

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Construction management literature states that CIT influences the working practices of people and organisations. It suggests that these practices must be aligned with CIT to overcome difficulties while adopting new technologies (e.g. Adriaanse, 2007 and Egbu et al. 1998). Although this research generally describes how construction industry's characteristics influence the adoption of CIT, it does not provide insight into the problems that appear at construction project level. A more pragmatic, bottom-up approach that we use in this research identifies what really troubles inner city reconstruction professionals in their daily work practice when they confront new CIT.

This paper describes a first analysis of how CIT challenges practice on three Dutch inner city reconstruction cases. We explored this from different angles by studying relations between individual reasoning, working practices and features of CIT. The next section introduces the perspectives of socio-technical landscapes (Kemp and Rip, 1995), individual change (Weinberg, 1997), and industry recipes (Spender, 1989) that helped to study coping processes of clients, contractors, and technology suppliers. The subsequent section discusses mismatches between individual reasoning, work practices and features of 4D-modelling, 3D-design and 3D-GPS excavation activities. It provides insights in how more structured and formal use of information can improve the adoption of CIT-features. It also elaborates on how hybrid use of technologies should be limited to enable professionals to fully benefit from new CIT. This paper concludes with a discussion, conclusion and an outlook to our consecutive research activities.

**DESCRIBING INDIVIDUAL CHANGE AND WORK PRACTICES USING THREE DIFFERENT PERSPECTIVES**

New technologies such as CIT enter the construction arena continuously. Some take time to get adopted, some will never be. Innovation adoption is a change process which takes place at individual, team, and organisational level (Cameron and Green 2004: 8). In this section, we use the perspective of socio-technical landscapes to introduce and relate industry recipes, a psychodynamic model of change and CIT-features. This framework helps to identify mismatches between individual ways of reasoning, existing work practices and CIT innovations in inner city reconstruction projects.

**Technology adoption in socio-technical landscapes**

The perspective that considers the features of a technology in a broad context is the socio-technical landscape. A socio-technical landscape describes how technologies are part of a social environment that consists of different norms, habits and standards. As part of this landscape, Rip (1995) and Kemp et al. (1994) use the term technological regime to describe "complex of engineering practices, [...] skills and procedures, ways of handling relevant artefacts and persons [...] all of them embedded in institutions and infrastructures." The social environment of which technologies are part has its own dynamics and shapes opportunities for novel configuration of technologies in their environment (Rip and Kemp 1995).

**Individual reasoning within the innovation adoption process**

During an innovation adoption process, change recipients confront incentives to change their ways of thinking and acting. The psychodynamic process model of Weinberg (1997) describes the different stages and key events that individuals experience during a change process (figure 1).
In the model, a change recipient with established work practice meets a foreign element. For inner city construction industry, such an element can be CIT. Once that happens, the recipient will first try to reject it to maintain the existing situation. When she realises that rejection is not possible, she tries to implement the foreign element without changing anything to her existing work practice. This often results into unintended change. To achieve better integration, an individual keeps rejecting the foreign element, until a transformation idea will help her to change the old work practice and to integrate the element. As a next step, the recipient tries to integrate the element with the existing work practice to create a new status quo. During the process, the various iterations illustrate how all kinds of external influences have disturbing effects on the deliberation process of the change recipient.

![Figure 6 - critical points in the change process (Weinberg, 1997).](image)

Next to individual reasoning about features of CIT, also the concept of work practices can be used to better understand the adoption of CIT. Next paragraph therefore describes the industry recipe that helps to describe and understand work practices of practitioners in inner city reconstruction industry.

**Using industry recipes to identify and describe work practices**

Technologies mostly originate outside organisational boundaries. According to Spender (1989:182), existing work practices must synthesise all the relevant technologies into a coherent rationality that matches the ways of thinking and acting that are relevant to that industry's context of activity. The individual perspective forms a basis to understand the change process, but does not offer the explanatory power to describe how project groups in inner city reconstruction industry form such coherent rationalities. One reason for this is that established working practices are co-creations that emerge through collaboration of different individuals.

To understand how insiders of an industry organise their daily work practice, Spender (1989) introduces the industry recipe: a loose, ambiguous, and open concept to describe ways of thinking and acting in an industry. Spender discusses Schutz (1967, 1970a, 1970b, 1972): "a recipe is a shared pattern of beliefs that the individual can choose to apply to his experience in order to make sense of it, so this response can be rational." Insiders accept and understand the body of knowledge that an industry recipe describes. The knowledge and assumptions that underlie industry recipes help practitioners while creating strategies and making decisions (Spender 1989). These
recipes of shared meaning change with time. As it changes, industry participants go
through a period of openness, data gathering, and exposure to the environment. What
follows is a period of closure during which industry participants reconstruct data,
make this into information and conclude this in a new industry recipe (Spender, 1989,
p63). "As time proceeds, the recipe becomes more coherent and more of a closed
universe of discourse," adopters will increasingly reject what not makes sense in the
reconstructed recipe (Spender, 1989: 87-88).

Industry recipes offer standards of how insiders think and act, yet they also form a
barrier to change. Tidd (1997: 34-35) states that routines and ingrained ways of
thinking can be barriers that prevent people to think differently. Although it helps to
prioritise information, the way of selectively filtering information limits creation of
alternatives and future options and often leads to overdue commitment to the current
strategy (Webb, 2008).

CIT-features

Software developers create CIT with a multitude of basic features that are applicable
to practically all software. As Repetti, Souter and Musy (2005) argue, basic features
should be, at least, an understandable interface and data management functionalities.

Further, specific CIT offers specialised features. For example, features can be
visualising or simulating construction or design information. When using CIT in
practice, individual reasoning and work practices should be in line with the features of
a tool to make full use of its benefits. The conceptual framework in figure 2 combines
the perspectives of CIT-features, individual thoughts and work practices. To achieve
successful adoption of CIT, practitioners should align these three perspectives to
optimise CIT adoption.

![Figure 7- research framework that illustrates necessary alignment between individuals, work practices and CIT-features.](image)

**RESEARCH METHOD**

We used an ethnographic approach to study relations between the reasoning of
individuals, work practices and CIT-features without intervening with daily practices
of the participants on the projects. This supports the claim Spender (1989: 75) makes
about studying work practice. He states that, in order to understand industry recipes,
researchers must transform from outsider to insider into the rationality of the
population they study. From this context, the researcher can make sense from the
language, culture and perception of reality through the eyes of the insider. As an
important field study practice within ethnographic research, participant observation is a good way to collect data when the researcher wants to explore and gain understanding about a culture that he is not part of (Jorgensen 1989: 14).

Ethnographic research took place at two Dutch inner city reconstruction projects and at one large Dutch contractor. Here, we observed construction sites and multi-stakeholder meetings. We had formal and informal conversations with technology developers, project team members and construction workers. Furthermore, we obtained project documentation such as drawings and construction schedules. We collected and structured the data in an ethnographic dairy that described what work practices and implementation problems of CIT. To analyse this data, we created a log-book. In the dairy and documents we obtained, identified and labelled key-sentences and filtered these to extract more meaningful information. This resulted into a series of narratives that describe mismatches between individual reasoning, work practices and CIT-features.

RESULTS FROM FIELD RESEARCH

In this section we elaborate on three cases. We first provide brief project descriptions and elaborate on these in terms of individual reasoning, work practices and CIT-features. We conclude each case with an analysis.

Case 1: 4D support for construction schedule coordination on project in inner city of Hengelo

The first inner city reconstruction project is located in Hengelo, a city in the eastern part of the Netherlands with 80,000 inhabitants. A part of the six month project involves replacement of cables and piping and reconstruction of a main traffic intersection. The project has three contractors. The main contractor renovates sewer pipes and the interior on street level. The second contractor reconstructs all other cables and piping, while a third installs a new traffic signalling system at the intersection.

Individual reasoning

We individually met the project manager of the municipality and the daily supervisor of the contractor to discuss the value of a 4D-model that simulates the construction activities. They valued it positively and argued that this could be helpful to better align the onsite construction activities that different parties simultaneously execute. A third practitioner that gave his opinion about 4D was the daily project supervisor of the municipality. He did not perceive 3D-drawings as value adding and argued that the absence of depth-information about the underground assets would not make it possible to make sense from 3D and 4D-models. He stated that collecting and modelling dept-information would only add value on more complex projects.

To implement 4D, one also needs 3D-designs of the existing and new situation. As stated below, the current work practice only uses 2D models.

Existing work practice

During the multi-stakeholder meetings and work practice we observed that there was no structured or formal way to coordinate and align the construction schedules of the different contractors. Although the contractor and municipality organised multi-stakeholder meetings to discuss and align schedules, no formal integration of the schedules took place. For example, there was no 'main schedule' that incorporated all schedules. On the project, the main contractor's daily supervisor created a Gantt-chart with MS Project software. Next to that, the utility and traffic signalling contractors did
not create a formal schedule at all. They used key-dates and experience based estimations of construction activity durations to plan activities. During the meetings, different parties 'aligned' the different schedules only through intuitive and experience based discussions.

Another characteristic about the work practice was the use of digital 2D-CAD drawings. The contractors favoured working with these 2D artefacts. During the multi-stakeholder meetings, they only exchanged and discussed annotated printouts. Apart from the main and utility contractor, the traffic signalling contractor did not have a digital design at all. Instead, they exchanged hardcopy sketch drawings.

4D features
A 4D-model integrates the digital schedules and designs of the different construction stakeholders involved in a project. This combination between a static design and time-based construction schedule results in a simulation of construction activities. It helps parties to create and improve alternative construction plans. When creating such, a 4D-modeller links designed objects - such as sewer pipes, asphalt pavement, street lanterns - to the specific parts of the schedule that represent the related construction activities.

A 4D-model consists of a digitised schedule that represents the construction activities. To link this with construction objects, the modeller should at least integrate this with two digitised 3D-models; one describing the physical as-is situation, the other the designed future.

Table 1 compares the differences between the currently available information and input that is needed to support implementation of 4D.

Table 1: required versus available input for the 4D-model on the Hengelo project

<table>
<thead>
<tr>
<th>Required</th>
<th>Used by Main contractor</th>
<th>Used by utility contractor</th>
<th>Used by traffic signalling party</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representation of as-is situation</td>
<td>Digital 3D model</td>
<td>Digital 2D CAD</td>
<td></td>
</tr>
<tr>
<td>Design of future situation</td>
<td>Digital 3D model</td>
<td>Digital 2D CAD</td>
<td>Digital 2D CAD</td>
</tr>
<tr>
<td>Construction planning</td>
<td>Digitised construction schedule</td>
<td>MS Project files</td>
<td>None</td>
</tr>
</tbody>
</table>

Analysis
The observations show various mismatches between the perspectives from figure 2. These mismatches prevent practice to adopt and make full use of the features that 4D-modelling offers. First, from the perspective of individual reasoning, three practitioners valued the benefits of 4D-modelling differently: two people valued it as beneficial, while a third did not see direct benefits. This case further shows that, although work practice contains the essential information, the designs and schedules were not available or structured in the right format to use as input for a 4D-model. To create the right, valuable input programmers must make their schedules more explicit. This means that they should digitise and exchange these during stakeholder meetings. Further, 2D-CAD designs should be used to transformed into a 3D-model before it can function as input for a 4D-model.
Case 2: introduction of 3D-GPS system in inner city sewer project Enschede

The second project we observed currently takes place in the centre of Enschede, a city with 150,000 inhabitants located in the eastern part of the Netherlands. The project concerns the construction of a 200 meter bypass sewer that replaces the old sewer pipe which connects the city centre sewer of Enschede to the treatment plant.

Individual reasoning

The contractor of this project owns an excavator with a 3D-GPS technology. The project manager of the contracting company and municipal project supervisor were very positive about the features that this new technology offers. They stated that 3D-GPS helps engine men to perform excavation activities quicker and more accurate as compared with the traditional, manual excavation process.

Existing work practice

The project we observed used two different work practices: a manual land marking and excavation process and one that includes 3D-GPS equipment. In the traditional work practice, land surveyors use lasers and hand-held GPS-stations to exactly identify the locations where excavations must take place. They manually place pickets and cords to mark the intervention area. By introducing the 3D-GPS technology on full scale, traditional, manual land marking becomes redundant.

On the project, the construction workers needed an excavator and crane to perform the installation of a heavy concrete well. In contrast with the crane, only the excavator was equipped with 3D-GPS. This meant that traditional land marking was still needed to help the crane operator to determine the correct position of the concrete well. As a consequence, the 3D-GPS features of the excavator could not be used and was left idle.

3D-GPS features

When using 3D-GPS, the cabin of an excavator is equipped with a computer screen that virtually models the position and movements of the excavator within the existing and designed situation. Using this technology, engine man know directly know where to perform excavations without needing marks that are set up with pickets and cords. When the construction fleet uses this technology, land marking becomes redundant.

Analysis

This case illustrates that, albeit the positive individual reasoning about CIT, a mismatch between work practice and CIT-features can hamper successful CIT adoption. In this specific situation onsite equipment did not all use 3D-GPS systems. This meant that there still was a need for traditional land marking. It prevented the contractor to benefit from its 3D-GPS system. Only if the both the crane and excavator used 3D-GPS, new work practices could make traditional surveying redundant. This hybrid situation where old and new technologies and work practices co-existed thus had a negative impact on the use of CIT. In other words, 3D-GPS can only substitute traditional land marking when the full construction fleet involves 3D-GPS in their work practice.

Case 3: co-existence of 2D and 3D-design activities at a Dutch contractor

During the research, we repetitively visited a large Dutch contractor who is currently implementing 3D-designing in its organisation. We discussed the implementation of 3D-modelling at organisational level and discussed the existing work practice with a designer, project manager and technology supplier.
**Individual reasoning**
The designers at the contractor currently use the design features of the 3D-software to aggregate existing 2D-drawings into a 3D-model. They use this additional to their standard 2D-design software to work on specific parts of the design. For example, designers use the viewpoints within a 3D-model to design more sophisticated elements, such as slopes. These elements are easier to make in a 3D-design environment.

**Existing work practice**
The work practice that illustrates how the different designers co-operate can be described as follows. First, a 2D-designer makes the drawings that represent different viewpoints. Next, a 3D-designer aggregates these viewpoints into a 3D-model. Using this model, the 3D-designer works on specific design aspects. Consequently, when the 3D-designer identifies design errors, he communicates this with the 2D-designer. The 2D-designer then separately changes 2D-model so that it matches the 3D-model. At the final design stage, another designer uses a different tool to create a 3D visualisation.

**3D features**
When the design process is executed in the way that technology suppliers propose to use it, 3D-design activities will form the basis for the design process. Using this approach, designers can create a 3D-model and derive other meaningful information. For example, one can derive 2D-images from different 3D-viewpoints, and use the 3D model as basis for a high-end visualisations. Further, the construction project team can directly derive design information that provides input for cost calculation and scheduling activities.

![Diagram](image)

**Figure 8: Design activities that use 3D-models as point of departure (above) versus separate 2D, 3D-design and visualisation activities as in practical example (below)**

**Analysis**
This example indicates that the individual reasoning for using 3D is not fully in line with the features of 3D-modelling. As a consequence, the work practices that are based upon the individual reasoning also do not match the CIT’s features. In the work practice that currently exists, 2D and 3D-design processes co-exist and are executed in an independent, fragmented way. Further, current work practices leave 3D-modelling features that provide input for cost calculation and scheduling unused.
Figure 3 illustrates how the process as proposed by technology suppliers relates to the design and visualisation process as it actually is in the current work practice. The hybrid situation where 2D and 3D are used in a fragmented way, limits practitioners to make full use of the features that 3D-modelling offers.

DISCUSSION

This research adds more detail to the claim that organisational environment greatly influences the potential to adopt CIT (e.g. Adriaanse 2007, Egbu et al. 1998, Rip and Kemp, 1995). The first case shows that lack for formalisation and structuring of information hampers alignment of CIT-features, individual reasoning and work practices on in inner city reconstruction projects. Further, case two and three support that the a hybrid environment that consists of old and new technologies and work practices also limits the use of new CIT-features. We suggest that initiatives are needed to reform inner city construction industry so that construction activities can be streamlined better.

CONCLUSION

Construction IT (CIT) challenges work practices and individual ways of reasoning of practitioners. Some CIT will be adopted fairly quick, while others will never be adopted in practice. This paper applies three different perspectives to understand the dynamics of change at inner city reconstruction projects. Ethnographic research was conducted understand how insiders in practice think and what troubles them when using new CIT. Applied to three cases, the psychodynamic process model, industry recipes and socio-technical landscapes effectively helped to identify mismatches between existing individual ways of thinking, work practices and CIT-features.

The results of the field study indicate that a mismatch between individual ways of thinking, work practices and CIT-features hampers the adoption of CIT. On the Hengelo project, the perspective of individual reasoning led to the insight that practitioners do not equally agree on the potential benefits of 4D-models. We further concluded that work practices on the project were not sufficient to deliver 4D-model input in the right format. To create meaningful simulations, 4D features, individual reasoning and work processes should therefore be better aligned.

On the Enschede project, the project manager and supervisor were positive about features and benefits of 3D-GPS excavators. Although their knowledge was sufficient to deal with the features of the technology, the excavator using 3D-GPS was left idle because the complementary equipment did not use this new technology. In this hybrid situation where old and new technology co-existed, CIT-features and individual ways of thinking were well aligned, but work practice did not support full use of the new technology.

The case of 3D adoption by the contractor showed that a fragmented design approach where 2D and 3D-design were executed separately. In this case, there was no match between the features that 3D-modeling offers and the way that individuals perceive how to use 3D. It also affected work practice that is currently organised in such a way that it supports the dominant 2D-thinking styles. It does not offer room to make full use of the features that 3D-design packages have.

From practical standpoint, we conclude that introducing CIT requires better alignment between practitioner's ways of thinking, working and the features of CIT. Practitioners currently mainly rely on traditional, experience and feeling based work practices.
where tacit knowledge is not formalised, nor communicated in a structured way. To change this process, practice should become aware of the fact that a more structured way of exchanging information helps streamlining inner city projects better. Secondly, as hybrid situations that combine old and new work practices have negative consequences on the benefits of CIT, the length of these situations must be minimised.

CONSECUTIVE RESEARCH EFFORTS

To look for more profound evidence, future research will explore the relations between individual reasoning, CIT-features and work practices more extensively. We plan to integrate recent literature and gather more empirical data by executing more field observations and conducting ethnographic interviews.

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