ADVANCED COMMUNICATION TECHNOLOGY AS AN ENABLER FOR IMPROVED CONSTRUCTION PRACTICE

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ABSTRACT

Minimal interaction and ineffective communication between construction project partners are causing major problems in modern construction processes. This interaction and communication is required in an increasing manner but they are neither well-understood nor directly addressed in information technology oriented research and development efforts. Communication and information technologies are too often mixed with each other in an inappropriate way. We should put more attention on getting an improved understanding of communication processes between individuals in construction projects and on harnessing information technology directly for this purpose. The long-term work in VTT Building Technology is addressing novel solutions for improved communication in construction projects with the aid of tools based on computer-based visualisation and lessons from communication processes.

KEY WORDS

Communication, Construction, Virtual Reality, Information Technology, Project Management

INTRODUCTION

The skills and competencies required for successful construction management have considerably changed from the days when general contractors carried out the biggest share of the project by their own resources. Nowadays most construction projects are broken down into a number of subprojects consisting even several levels, and, this set of subprojects is to be completed by a temporary team of companies. In particular the projects of bigger size which typically have the most significant importance, novel architectural solution and the most demanding material technology require the successful management of a temporary network of companies and stakeholders.

In the situation described above the mechanical one-key-player project management approach is not enough. This approach means traditional project management where one individual, that is project manager, is very much the centralisation of power and responsibility. In order to get the optimal level of commitment of all companies and stakeholders involved one should create new project management infrastructure, which clearly improves communication within the team. With the improved communication all companies and individuals involved can easier and faster contribute their knowledge and experience to the construction project. Constructability considerations and site logistics are examples of such fields where clear benefits can be gained. The importance of communication for successful project management is being nowadays acknowledged widely.

New advanced communication can help to form a smoothly operating temporary network of companies with improved trust and responsibility. It seems that advanced communication technology can have a significant role in setting up the new communication infrastructure for construction projects.

VTT Building Technology is together with companies from construction and heavy industry carrying out research and development projects addressing applications of novel communication technologies, such as virtual reality, in construction.

The objectives of this paper are

I) to demonstrate the main shortcomings of current communication practice;
II) to discuss the identified consequences of the deficient communication;
III) to describe the advanced communication technology and methods for applying it; and
IV) to present case studies from live construction projects.

COMMUNICATION PROCESS AND COMMUNICATION TECHNOLOGIES

Communication is a personal, intentional, transactional, symbolic process for the purpose of exchanging ideas, feelings, etc. Communication is not an impersonal conveying process. These widely adopted definitions in communication science are clearly showing that communication is a skill area where one originally puts emphasis on the understanding of messages. This is suggesting that within a properly planned communication process one is always trying to maximise chances for comprehensive understanding of the sent messages. Having this as a starting point the used media, writing or presentation technique and style are chosen. This discussion has presented the communication concept as a wide framework covering all kind of interaction between individuals where we have a message to be sent and received.

Information technology should naturally provide the necessary services for the successful communication purposes. The research and development efforts in the area of construction information technology have put a lot of attention in setting up an infrastructure where the partners of a construction project can access all relevant project data in a timely manner without any delay. Characteristic to this work recently has been the focus on classifying and understanding data and their interdependencies that is expected to result in a standard building data model. The communication concept as presented above provides a supplementary viewpoint to information technology. The core processes of communication are proposing that we should be able to customise each our message according to the needs of the receiver. Examples of experiences and results from recent studies (Turner 1993, Gordon 2000):

1. Poor communication in projects is often caused by *too much rather than too little of communication*.
2. An important factor for successful communication is *the incongruence between the message and reality*. The greater the incongruence between reality and the actual message transmitted by a sender, the greater the chance of a receiver missing the message, or hearing an ambiguous message.
3. An ineffective communication in groups causes "*hidden agendas*" and withdraw into silence and passivity

These are examples of principles that can have a clear impact on the applications of information technology in construction. However communication technology and information technology are often presented as a joint technology without showing their original differences clearly.

Basically communication technologies can be classified into manual techniques, computer enabled solutions and telecommunication enabled solutions. Whatever technology is used an important point is to be able to adjust the message according to the receiver in question. When moving away from face to face contacts to remote communication and its solutions our possibilities can get rather limited in the terms of understanding the preferences of receivers and adjusting messages accordingly.

COMMUNICATION PROBLEMS AS A KEY FOR EXPLAINING MAIN CONSTRUCTION PROBLEMS

The developments and achievements concerning the overall performance of construction has been often compared those of automotive and manufacturing industry. Not so surprisingly the general conclusions have often been rather depressing. The construction performance is far away from optimal performance, its variances and uncertainties relating to the performance are still high. Furthermore the construction industry has not managed to implement integrated solutions and their deliveries as has happened in several other industries. Nevertheless leading characteristics of the advanced modern construction processes are

- Minimal delivery times
- 20 or more organisations form a temporary project team
- Extensive use of subcontracting and special subcontractors
- New procurement forms, e.g. unit product procurement including design, delivery and installation/assembly
- Multiple new values and their combinations, e.g. environmental issues, partnering in projects

In this type of construction the project manager works strongly as an integrator with other key individuals. To be an integrator as a main role means both technical solution integration and team integration. The communication needs are clearly much higher than they used to be and they cannot be solved in a simple manner just providing an access to all possible project data.

The practice at present in progressive projects is to have a project data bank connected to stand-alone IT systems of participants in the process. The amount of data of major projects in such data bank is overwhelming and despite of various indexing the practical communication capabilities are rather limited. Of course, one can easily point out some possible technical solutions to the described situation but this is the state of the art in progressive companies at the moment. The resultant dilemma is that this state of the art information technology solution provides very little help for communication needs, which have gone up in an increasing manner. In practice due to the cumbersome or otherwise too much time consuming communication people tend to minimise all required communication with other participants. Since the various stages and tasks of construction are highly interdependent this minimal interaction is in practice causing severe disturbances widely reflecting other partners and the final product (Lahdenperä, 1995).

The following chapters present results from research having effective communication in construction as a general goal. The adopted approach is to provide self-explaining visualisations of the product (building) and construction processes. This effort is particularly aiming

1. to improve the level of congruence between the message and reality when those involved in construction are communicating about the project and required performance; and
2. to provide a self-explanatory platform for presenting construction projects. This can bring forward issues that could otherwise turn out as “hidden agendas”.

ADVANCED PRODUCT BASED COMMUNICATION

Interactive product model visualisation

A building product model is an information base of a specific building (Björk, 1995). These product models can be used by different computer systems to create, edit, store, retrieve and check data about buildings. A leading principle, and promise, is to store all data relating to a specific building into its building product model. As a result the product model would be a common source for all project participants throughout the building life-cycle to access building data.

A tool developed at VTT Building Technology, ProMoTe, is a product model browser for accessing product model over the Internet. ProMoTe retrieves information from various sources and adds this to the product data model. The use of product data technology (ISO 10303-1 IS 1994) in facility management and construction industry is increasing. The IFC (Industry Foundation Classes) product data model standard (IAI 1997) driven by International Alliance for Interoperability (IAI) is gaining needed momentum. The belief that product models are the foundation for information sharing in the future is becoming generally accepted. Data transfer in the future will be based more on sharing than sending.

The user of ProMoTe can create VR-models from the whole building model or from a part of it. These models can be created by request so that they are always up to date. If the structure of the model supports content hierarchy specifications, it enables the user to specify different kind of hierarchical VR-models for different kind of purposes in the project.

Product model as an interface to the associated information
A Virtual Reality Browser (VRB) can be used as an interface to product data, enabling selection of objects and services (Figure 1). Information about the selected object and the values of attributes can be browsed and the documents linked to a selected object can be studied. The properties of the objects can be changed. By changing the colour of the object one can highlight objects, which are conflicting each other. Additionally various colours can visualise changes in the model by showing different versions of objects.

Figure 1 - Visualized product data model as an interface to product information

4D construction process visualisation
Integration of the geometrical representation of the building together with scheduling data has been a topic for many research and development efforts. Different approaches for this integration are (Figure 2):

- Automated generation of 4D models
- Linking geometrical 3D model with schedule
- "Lego approach" i.e. Developing 4D model from building parts library

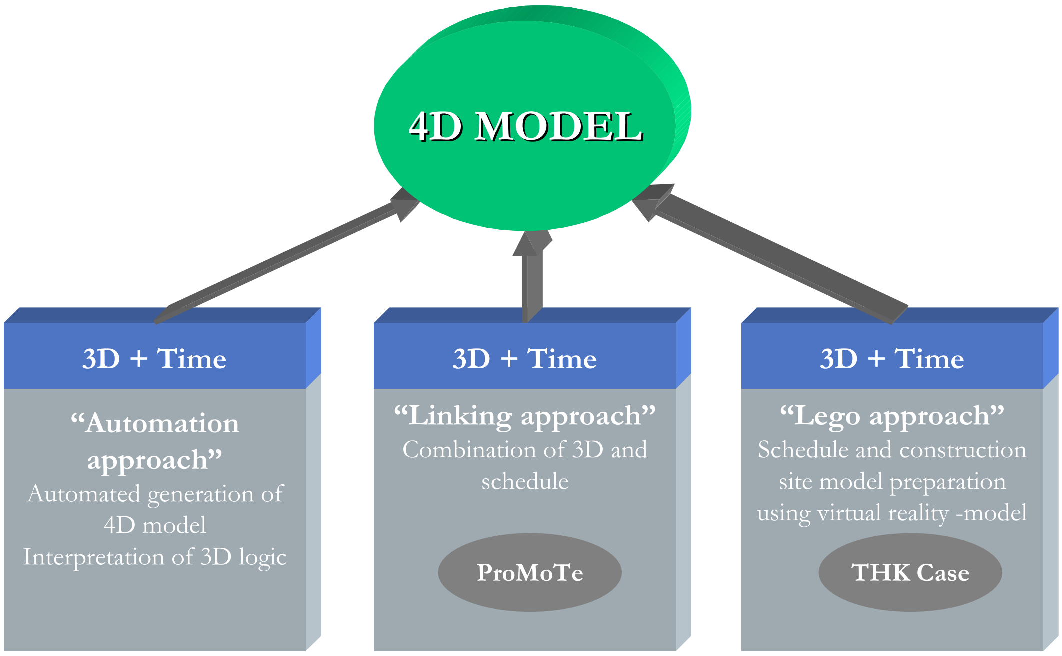

Figure 2 - Different main approaches for the development of 4D applications

Automated generation of 4D models refers to computer applications where a reasoning engine or several engines together with construction operations knowledge are able to interpret 3D geometric data and produce process plan showing how the building can be constructed. Examples of the results from this type of research and development efforts can be found from (Aalami and Fischer, 1998; Froese et al., 1997; Levitt et al., 1988; Zozaya-Gorostiza et al., 1989).

The second approach for the development of 4D models is a "Linking approach", where the schedule data, e.g. start time, finish time, actual start and actual finish, are linked to the appropriate building components. Typically an activity in a schedule covers a piece of work relating to a set of building components. For example, the scope of the activity "Install columns for block A" is self-explaining and in a 4D model this activity needs to be linked to all columns in the block in question. In the following a research and development effort combining 3D product model and schedule data is presented.

Scheduling data is one essential part of the product model data that can be visualised using VR-models. ProMoTe combines a 3D model of a building and scheduling data originating from project scheduling tool (Microsoft Project) into a 4D VRML model (Figure 3). Currently the changes to the schedule are done within the scheduling tool, but the next step is to enable two-way data traffic. This is supposed to result in a system where the required work breakdown structure (WBS) can be created in the 3D VRML model i.e. user can group related building parts to form schedule activities. Furthermore, changes to the schedule can be done either in the 4D VRML model or in the schedule.

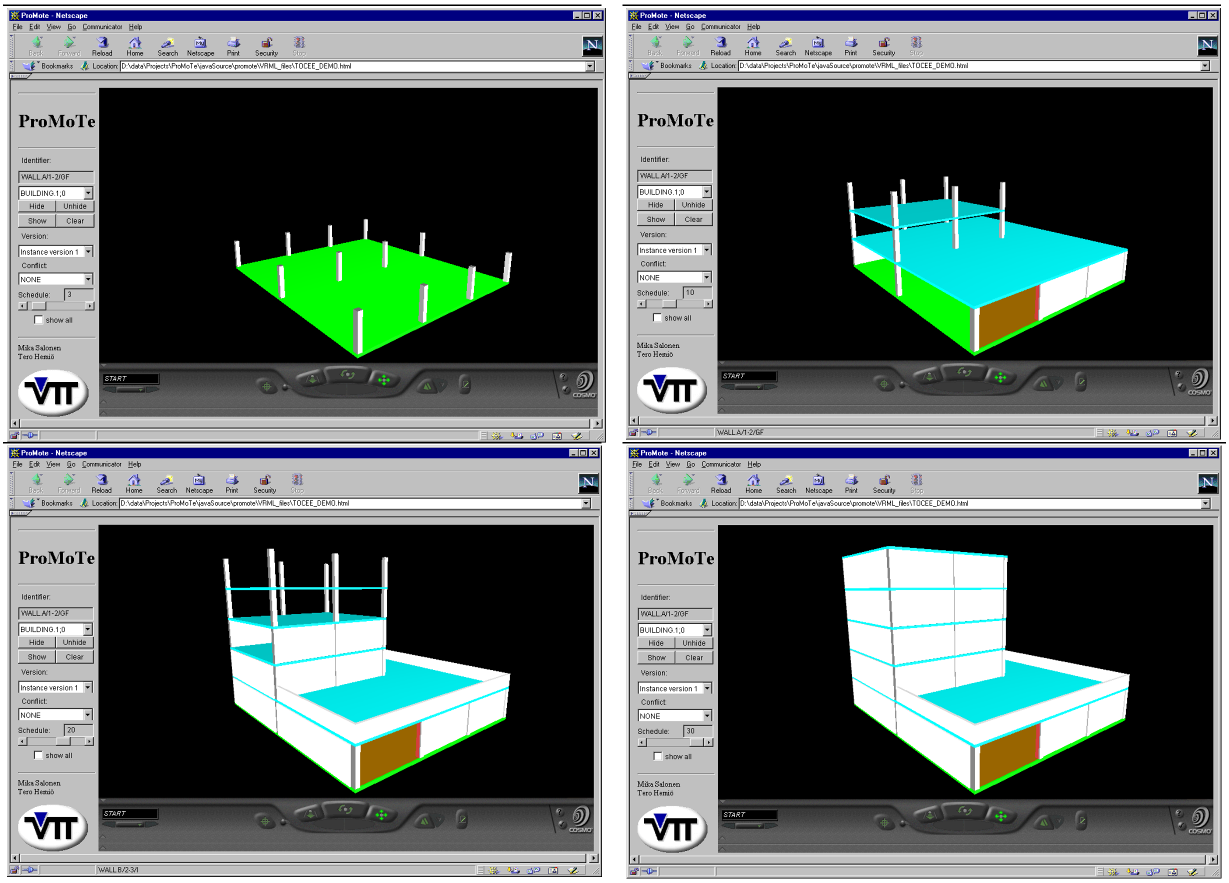

Figure 3 – Construction schedule simulation between 17 working days with ProMoTe.

A third approach for the development of 4D models is a "Lego approach". This approach relies on the interactive study and definition of the building construction model. The user takes advantage of building parts and resource libraries. These libraries are used for setting up a virtual reality model of the planned building process.

The described "Lego approach" has been applied in the THK office building project located close to the downtown of Helsinki. In this case project, a construction process simulation model was developed consisting the construction of superstructure and installation of facade elements (Figure 4). This model was developed in co-operation with Strathclyde University. The model can be viewed using a standard web-browser. The model of the construction process visualises how a building is to be constructed according to the master schedule. In practice the users of this model can interactively simulate day-by-day the construction processes and, likewise, navigate interactively inside the building under construction.

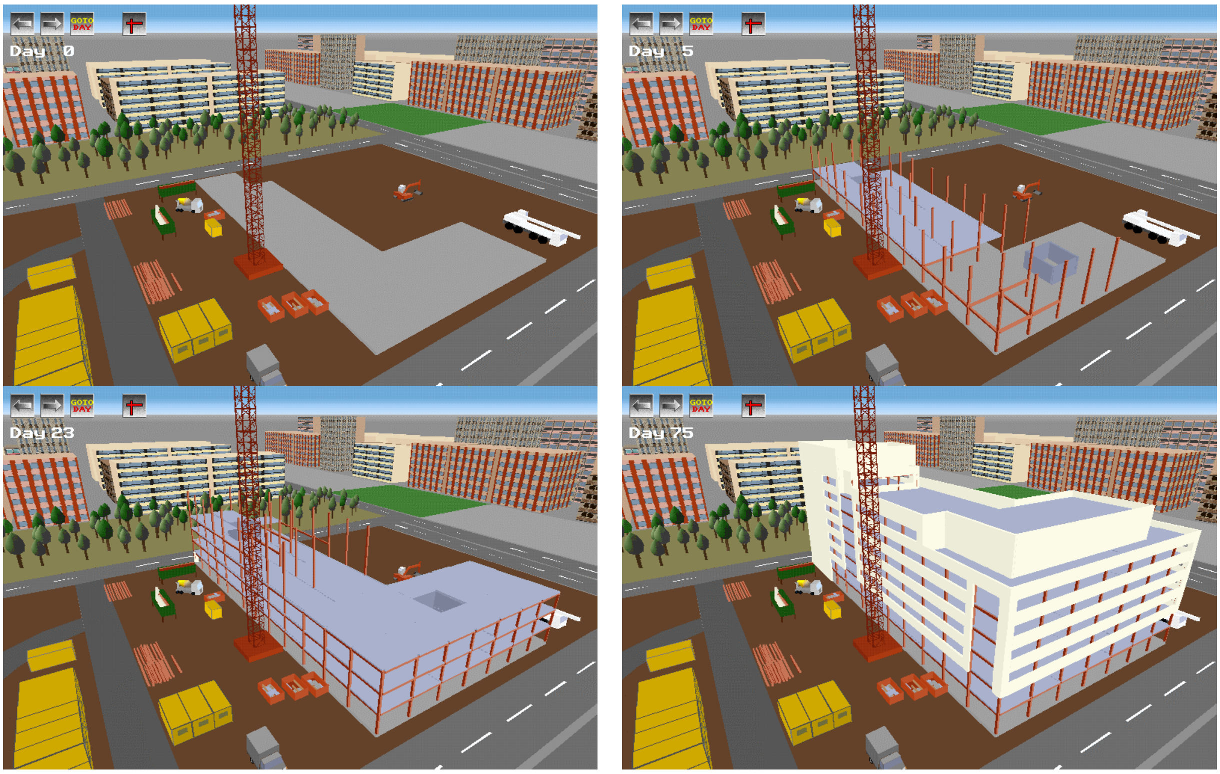

Figure 4 - Time based simulation

ADVANCED PROCESS BASED COMMUNICATION

Detailed construction simulations and visualisations

In many cases the product based construction process communication is not enough - for example, when the analyses of site logistics, the sequence and timing of activities and spatial conflicts of succeeding phases are demanding more detailed modelling of the work flows. Process based visualisation is composed of a constant flow (stream) where as the product based visualisation consists of series consecutive images (snap-shot).

To avoid bottlenecks at the site, the work area of each activity needs to be studied and the succeeding activities have to be synchronised not only based on the time they take but also based on the area they require (Figure 5). The minimum amount of work area for uninterrupted activity performance can clearly vary between construction activities. During the construction process the activities release work area according to their relative production rate. Gray and Little (1985) developed common rules and concepts for determining the described effects. These rules can be used as a possible generic starting point for a detailed construction process simulations and animations when one needs to get an improved understanding on how various construction activities interact with each other and the possibilities for their maximum overlapping. Different space requirements by activities are described in Riley (1994). Akinci (2000) has presented an approach for analysing spatial requirements of construction activities.

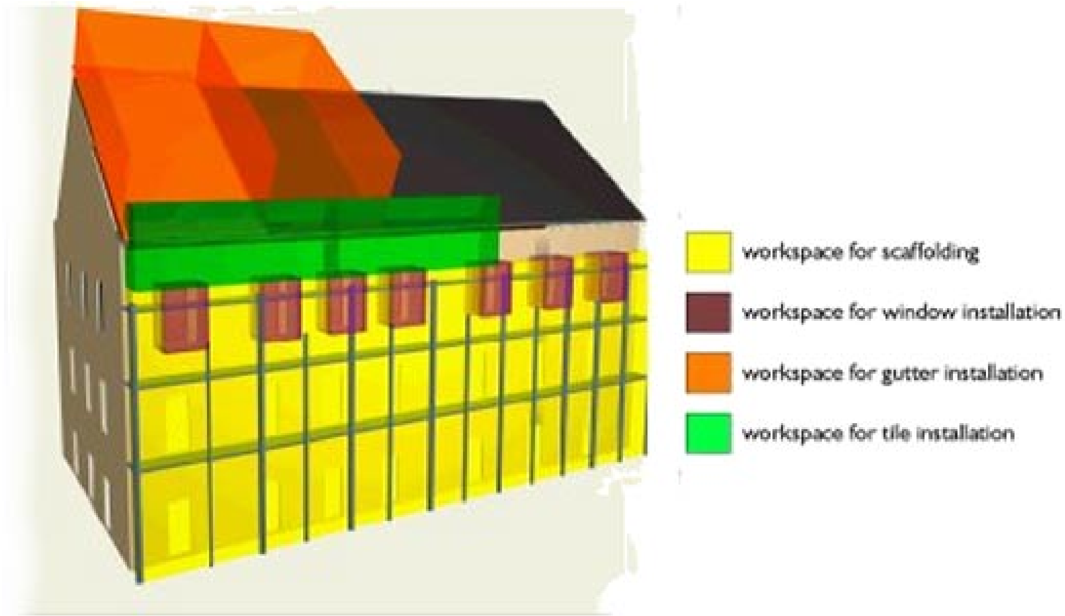

Figure 5 - Snap-shot of 4D visualization showing workplaces (Stanford University, http://www.stanford.edu/group/4D/4D-home.htm)

Telepresence technology
Telepresence in construction technology means the transmission of an interactively-controllable live picture from a remote construction site to any place where the situation on site needs to be viewed. The ultimate goal is to provide an experience of being present at a real physical location remote from one's true physical location. Typically a digital video camera is used to produce live video stream. Additionally, with specific telepresence equipment, the user can interactively turn the camera, zoom the picture, take snap-shots, change camera (if several cameras are used) etc (Figure 6). This is an important opportunity for the companies operating internationally or in a geographically big country having continuous needs to solve problems or just the view the situation in a site far away from central offices or meeting venues.

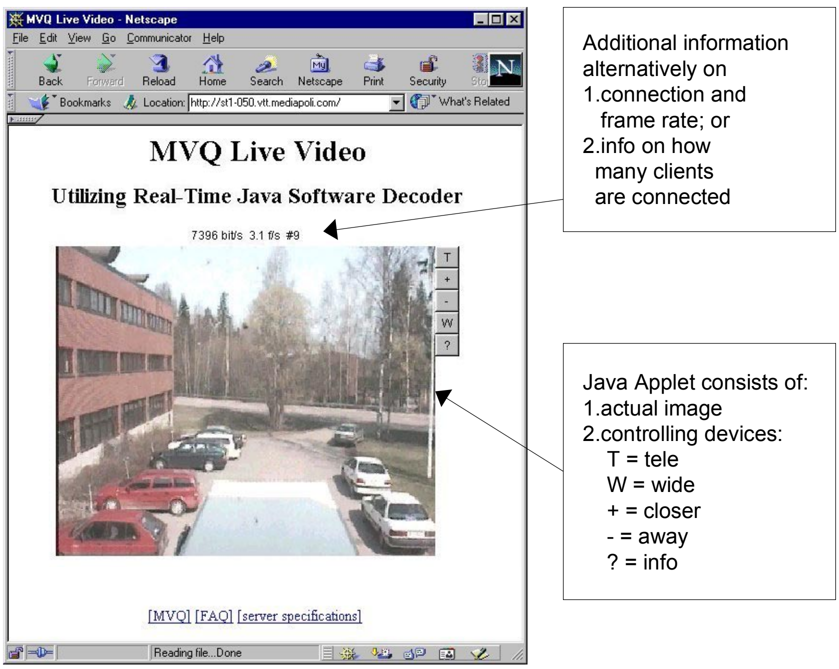

Figure 6 - Telepresence, live video stream

Augmented reality
Augmented reality is a combination of a 4D model and a telepresence stream (Figure 7). Telepresence is a technology that provides a possibility to feel present in a remote location, usually with the help of a digital video camera. Applying augmented reality, a 4D model and telepresence image can be viewed together and synchronised in a way that the user can easily compare the planned schedule and actual performance (Retik et al, 1997) . In addition, the 4D model could be used as a pointing device for telepresence equipment. To receive additional information on some detail on site, the user only needs to point to the place in the 4D model. Next, the telepresence equipment would provide the appropriate video stream from site or via model details further information can be accessed, i.e. some documents linked to the details.

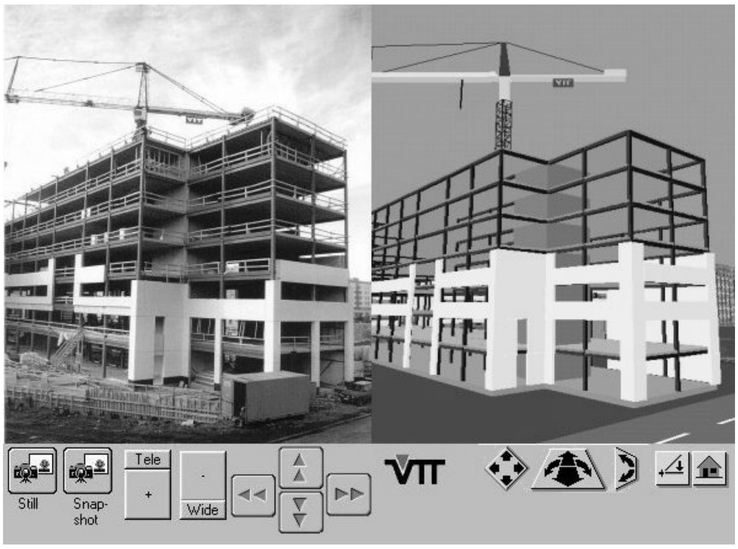

Figure 7 - Augmented reality demonstration - a telepresence video stream from construction site and vr-image combined

CONCLUSIONS

Communication problems and challenges in construction are mostly omitted in the current main stream IT research and development efforts, despite the crucial importance of communication for successful projects. It is obvious that widespread 4D applications in construction can enable much more effective communication between project partners compared with the current situation. For reaching this, the research and development efforts should be clearly focused on case studies and piloting where construction practitioners try to apply the prototype tools by themselves.

Integration of 4D scheduling with the companies' working practice enables new improved planning processes having clear potential for significant benefits. The benefits are mainly due to improved communication making possible easy access to other necessary people, e.g. subcontractors, material suppliers and representatives of client, involved in schedule preparation and analysis. The whole temporary construction project team would take advantage of the improved practice.

REFERENCES

Aalami, F. and Fischer, M.. 1998. "Joint product and process model elaboration based on construction method models in Björk, B-C and Jädbeck A. (eds.) "The life-cycle of IT innovations in construction – Technology transfer from research to practice", Proceedings of CIB78 conference, June 5-8, Stockholm, Royal Institute of Technology, Sweden.

Akinci, B., 2000. “Consideration of Spatial Requirements of Construction Activities and Analysis of Time-Space Conflicts Using Production Models”. PhD thesis, Civil and Environmental Engineering, Stanford University, Stanford, CA.

Björk, B-C. 1995. “Requirements and information structures for building product data models”, VTT Publications 245, Technical Research Centre of Finland, Espoo.

Froese, T., Rankin, J. and Yu, K. 1997 “Project management application models and computer-assisted construction planning in total project systems”, International Journal of Construction Information Technology, 5(1), pp. 39-62.

Gordon, T. 2000 “The Risks of Effective Communication”, Gordon Training International, training course material.

Gray, C. and Little, J. 1985 “The classification of work packages to determine relationship between design and construction”, University of Reading, Department of Construction Management, Occasional paper no. 18.

Hendricks, R.W., and Sterry, L.F. 1996. “Communication Technology”, (3rd ed.), Menomonie, WI: T & E Publications.

Lahdenperä, P. (1995) Reorganizing the building process, VTT Publications 258, Technical Research Centre of Finland, Espoo, Finland, 210 pp.

Levitt, R.E., Kartam, N.A. and Kunz, J.C. 1988. ”Artificial intelligence techniques for generating construction project plans”, Journal of Construction Engineering and Management, 114(3), pp. 329-343.

Retik, A., Clark, N., Fryer, R., Hardiman, R., McGregor, G., Mair, G., Retik, N. and Revie, K. 1997. “Mobile hybrid virtual reality and telepresence for planning and monitoring of engineering projects”, Proceedings of the 4th UK Virtual Reality Interest Group Conference, Brunel University, pp. 80-89.

Riley, D. 1994. “Modelling of the space behaviour of construction activities.” PhD thesis, Dept. of Architectural Engineering, Pennsylvania State University, PA.

Turner, R. 1993. “The handbook of project-based management”, McGraw-Hill Book Company, UK.

Wigand, Rolf T. 1997. Electronic Commerce: Definition, Theory, and Context. The Information Society, 13, pp. 1-16.

Zozaya-Gorostiza, C., Hendrickson, C. and Rehak, D.R. 1989. “Knowledge-Based Process Planning for Construction and Manufacturing”, Academic Press, Inc., USA.