# EXPANDING THE ENVELOPE OF VISUALIZATION FOR COMMUNICATION IN CONSTRUCTION

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Distances between dispersed locations may be largely overcome through efficient use of modern data transfer and communication systems. Unfortunately the conclusions drawn from research and surveys carried out in the industry show that companies generally fail in using information technologies properly and that there is a significant communication gap - therefore coordination and cooperation gap - between the site offices and the main office due to data transfer lags and lack of visualized information. These breakdowns are generally due to failure in using the right technology, at the right place, at the right time. In this research paper, available visualization resources is investigated among Turkish AEC companies. The current status of visualization use for communication in construction firms is mapped and described. Information flow contents and types are analysed to determine which information in the construction process can be visually represented. As a future step of this ongoing research, a framework will be suggested for a web based communication system providing coordination, cooperation and follow-up of work between the offices through emphasis on visual information. The developed system will take into account mobile devices supporting the mobility in the sector and allows multi user access from each construction node and is designed to support the visual data transfer as well as project files.

Keywords: communication, visualization, web based information system.

## INTRODUCTION

This research is intended to evaluate the correct use of visualization tools and technology in construction projects to fill the communication gap between the site offices and the main office.

Construction sector has adopted visualization slower and at different levels of intensity compared to other industries, although substantial research efforts have been applied in the construction phase of the building process. An extensive literature review carried out by Sriprasert, E. and Dawood, N., 2001 shows that recent research mainly focuses on the supply of management and control information in favour of high level managers or planners. None of the papers considers what information site managers at the work-face actually need in order to perform the most important function of construction the actual building and managing the project, (Christiansson, Dawood, Svidt, (2002).

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Nielson, Y and Erdogan, B (2003) Expanding the envelope of visualization for communication in construction. *In:* Greenwood, D J (Ed.), *19th Annual ARCOM Conference*, 3-5 September 2003, University of Brighton. Association of Researchers in Construction Management, Vol. 2, 685-94.

In this research focus is on the visualization of information at the work face, attempting to expand the envelope of what can be visually represented, keeping or increasing the quality of information while enabling faster and easier understanding.

A system enabling data transfer best fitting the sector might be developed and methods ensuring the efficiency of data transfer and quality of information might be designed along with required modifications in data flow. The system must provide continuous communication and access from each construction node and support visualization. Visualization and animation of the construction stages, starting from the beginning to final work will play an important role in the quality of decision making in all levels of a construction project.

## VISUAL COMMUNICATION

Visual and written communication can be considered as supports for one another. It is generally accepted that written communication had a pictographic origin, initially as pictorial representation of concrete objects. In most writing systems this simple relationship was later replaced by the concept that a pictographic symbol could be used for its phonetic value. This system – the rebus principle – led to the alphabets (Robinson, 1995). Simplicity of scripts, made possible by the alphabets' phonetic efficiency, has had an importance to human history that cannot be overstated. However, complexity and pace of human endeavours have increased immensely, especially in the last century, and there is a continuous increase in the need for information creation and flow. Meanwhile, technologies have evolved in the last decades that allow for creation and communication of information, or data, with such ease, that there is an overabundance of information in society, in organizations and in projects. Communication with the written word is no longer the best choice for all cases where there is a need for brief, understandable or particularly complex information. Due to the overwhelming amounts of written communication in a modern project environment, the support brought forward by visual means has become ever more essential.

In our present day, pictographic communication is still highly successful, for example in engineering in the form of drawings or diagrams. Such symbolic or logographic communication, however, is often extremely specific in the type of information it can convey. The effectiveness of symbols is inherently limited, they are most efficient when they represent objects and much less efficient in representing a process or activity.

Vision is the most highly developed human sense. Visualization is therefore a means of communication in which comprehension is instant, but also with considerable depth of the information delivered. It may typically be used for clarification of a subject that is difficult to explain in any other notation. Visualization has throughout history been a 'soft' discipline restricted to the areas of art and architecture. The term visualization often denotes a mechanism of the mind; to 'visualize' something is to make a picture in one's head of a complicated situation for the purpose of understanding or design development.

It is a communication method made possible by the progress in information technology. Computerized visualization is generally the task of rendering a 3D model into a 2D picture/animation, normally using one of the many software tools available.

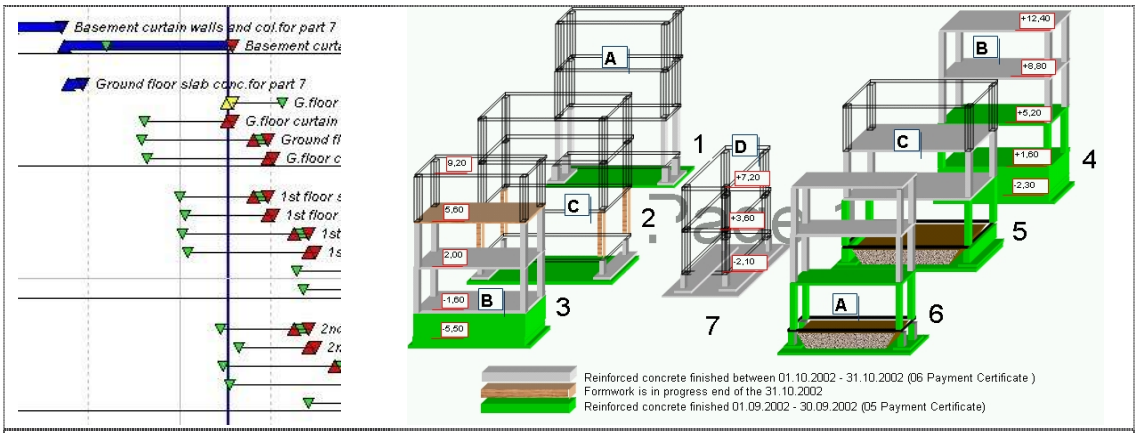



**Figure 1**: 'Graphical' and 'visual' representation of planning and progress

## VISUALIZATION IN CIVIL ENGINEERING AND CONSTRUCTION

For many reasons, civil engineering and construction has not adopted computerized visualization to the same extent as mechanical engineering and manufacturing.

Current methods of communicating building design information can lead to several types of difficulties; e.g. incomplete understanding of the planned construction, inaccuracies and clashes between components.

The building process, while being deeply rooted in centuries old traditions, is being imposed ever-increasing requirements in terms of schedule, value, quality and safety. This has lead to a tremendous rise in paperwork in typical projects. Adoption of novel management paradigms, such as TQM, PM methodologies, maturity and so on, result in an increase in required information, leading to ever-higher amounts of project data. The modern construction process craves for visual representation of information. Figure 1 shows an example where a Turkish contractor prepared a low-tech '3D view' of the building frame to display progress of civil works. The adjacent bar chart representation of progress is easier to read than a table, but the equivalent '3D' visual representation is easier still.

### Expanding the envelope

To counter information overload in construction projects we may attempt to expand the envelope of what can be visually represented. Given that visual information is easier to understand, the following question may be put forward: Which information in the construction process can be visually represented? Is it possible to visualize progress, design, a bill of quantities, methods, etc. What implications follow if the information is not communicated effectively? In which cases is it worthwhile to visualize something?

Visualization has the potential to positively effect on quality of the information, enabling faster and easier human grasp of a situation. It follows that visualization or animation of the construction stages, starting from the beginning to final work will play an important role in the quality of decision making in all levels of a construction project.

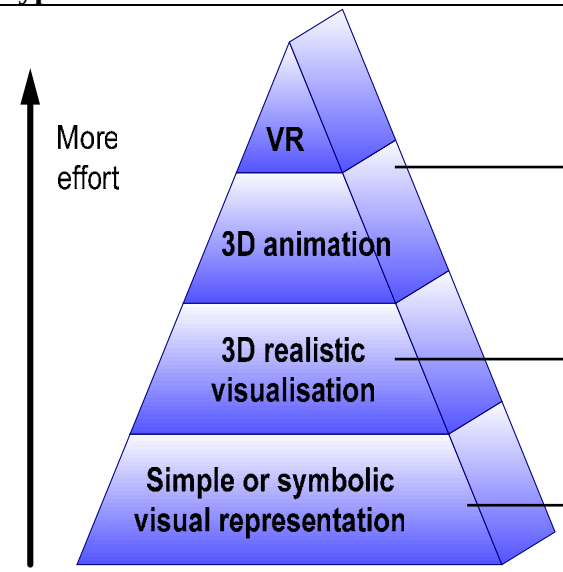
Among construction management researchers, visualization has long been identified as a major technological theme that may allow for development of the construction process. However, there are various impediments for implementation of visualization for communication. The present contractual relationships in construction do not favour non-written, nor visual information. Another problem of implementing visualization in construction is that many professionals are afraid of creating construction documents utilizing 3D Modelling. A professional in computer graphics may not be intimidated by creating 3D pictorial or animated information, but this is not the case for the typical professional working in the construction sector.

## A TAXANOMY OF VISUALIZATION THEMES

Broadly speaking, visual information can represent both objects in the real world or concepts. Some uses and benefits of visualization were put forward by Brown *et al.*1995 and Gallougher, 1994:

- We can simulate something in real life or we can convert abstract information into forms suitable for the human eye.
- Computer simulation allows the observation of phenomena that may be difficult or impossible to reproduce physically.
- Three-dimensional visualization techniques allow the examination of complex phenomena that may not be possible to see through the external surface of an analysis model.
- It can replace physical testing (at substantial cost savings).

The term visualization may designate, for example; Rendered CAD models, Simulations, Pictures, views, videos, and Virtual reality

| **Type of visualization** | **Example** | **Strategic impact for construction** |
|---|---|---|
|  | A situation where a site worker may interactively perform a virtual situation, like assembling a part. | Medium-high, but cost intensity is too small to develop VR environments for most situations. |
| | Walk-through of virtual facilities and buildings. Will display how the facility is going to look and function. | Medium-high. Lighting, acoustic, heating and thermal simulations and facilities management. |
| | Realistic representation of physical objects. Simple orbiting or functionality of a virtual item or location. | High. Design information can be communicated efficiently over IT/Mobile solutions. |
| | Graphical representation of information. 2D or '3D' display of progress etc. | Very high. There is a need for brief, understandable information to prevent information glut. |

## INTERACTIVITY

Handling of visual data in construction has normally been limited to passive observation, although in case of some implementation of VR changing of viewer/camera angle may be possible. There is scope for considerable improvement in the industry's performance if we go beyond the current use of CAD and VR packages that display passive "walkthroughs" and aim for a more direct and visual interaction with the design related data. Interactive technology can be used to consider lifecycle issues such as concept and detailed design, environmental impact, space planning, facilities management, security and constructability during design reviews. It will facilitate concurrent engineering involving planners, architects, designers, civil engineers, contractor and so on.

There is therefore a genuine need in the construction industry to explore the use of interactive computer modelling and simulation environments to improve e.g. client briefing and design reviews. Such environments – or virtual workspaces – can then be used to capture the client's needs and ensure the compatibility between the client's vision of the project and the resulting product/facility.

## VISUALIZATION AND THE CONSTRUCTION PRODUCT MODEL

Most research in the subject of virtual workspaces has closely associated visualization with the concept of a construction product model. The construction product model has only been realized in academic settings (Aspin, Liston, Cory). A construction team will comprise of many stakeholders, formed into a temporary project team. Some of the members in the project team can be geographically dispersed; virtual project workspaces that can unite highly qualified people without location restrictions. Such project teams need to pursue project processes efficiently, set up integrated communications infrastructure, and develop shared product models of the project they are constructing. Integration of design and construction studies aim to improve the value of the product with cost reductions. There is a legitimate case in the construction industry to explore the use of interactive computer modelling and simulation environments to improve the co-ordination and communication between the different project partners and stakeholders around a visual representation of the planned construction. Furthermore such interactive technology can be used to consider lifecycle issues such as concept and detailed design, environmental impact, space planning, facilities management, constructability during design reviews, involving all the stakeholders and to facilitate concurrent engineering. Construction product model and simulation environment will also contribute in the design evaluation at earlier stage, displaying what-if scenarios during the detailed design phase, and ultimately bridging the gap between design and engineering and construction.

In this research design and construction groups are being analysed, and their wish lists are being highlighted, in order to see what practitioners would like to see from a virtual workspace that would help in the design and construction phases of a construction project.

## INFORMATION SYSTEMS AND VISUALISATION

Visualization should take a greater role in transfer of information, but this may put some new requirements to the information system to be able to seamlessly handle visual information. The first stage in the design of an information system is a

**Table 1**: Visualization possibilities of some information types between design and site teams

| Information type | Possibility for visualization | Type of visualization | Impact for construction |
|---|---|---|---|
| Project general properties | Great extent | VR, 3D CAD | Large – better explanation of the project physical properties (the constructed facility) to external stakeholders. |
| Schedule – work programme | Partly | Simple or symbolic visual representation (Graphics, charts) 4D CAD | Depends on the complexity of the programme |
| Resource planning | Partly | Simple or symbolic visual representation (Graphics, charts) | Medium |
| Progress - what has been done | Partly | Simple or symbolic visual representation (Graphics, charts) 3D realistic visualization (images, video) | Large- better description of the finished work items |
| Progress - done vs. planned | General extent | Simple or symbolic visual representation (2D &3D Graphics, charts) Simulation | Large- easier evaluation of the progress |
| Method statements | Partly | Animation, Simulation | Large – better explanation of methods |
| Buildability problems (acoustic, thermal installations.etc) | General extent | 2D drawings, physical and 3D models, rendered images, video animations, virtual reality models | Large - better description of the work items, clarification of the design information |
| Construction problems requiring design revisions (from site to design office) | General extent | Images, video films | Large- better description of the problem will help to determine the solution |

definition of the operational requirements. Operational requirements must be defined in non-technical terms, for example in the form of functional or user parameters, after which the technological solutions may be chosen. In reality however, information technology has been developing so rapidly that the technical solution has been decided based on the latest technology. Research suggests that IS solutions are far from optimal, in terms of usability and cost effectiveness. Failures are generally due to failure in using the right technology, at the right place, at the right time.

In order to achieve this trinity, a system enabling data transfer best fitting the sector might be developed and methods ensuring the efficiency of data transfer and quality of information might be designed along with required modifications in data flow. The system must provide:

- Support for visualization.
- Continuous communication and access from each construction node
- Support for mobile IT solutions

The wish-lists of the stakeholders need to be considered. Which information types should be represented visually. Information types, extent of visual representation considering information quality, cost and time savings need to be examined. Table 1 show examples of mapping visualization to types of information in a construction project.

## INDUSTRY SURVEY

When thinking about such major issues as changing the principles through which information is transferred and represented, it is important to have a feeling of the industry's current practices and wishes. To establish the current situation as regards IT in general and visualization in particular within Turkish construction, an ongoing survey is being carried out. The construction sector has long been a key economic

factor in Turkey with a history of significant works completed both domestically and internationally. In our research the target groups are large and medium size AEC companies. The survey concerns the use of visualization tools and communication problems between the design and construction teams.

In construction worldwide there is a mind shift from viewing IT as a set of tools for internal efficiency to strategic technology redefining the boundaries of industries and application areas. It is realized that IT, properly implemented, reaches beyond improving discrete processes. Rather IT is evaluated strategically, as has been done in other large industries where IT strategy and business strategy are inseparable. Clearly, the 'strategic perspective' must justify an implementation of visualization, as for any other information technology. Therefore, the alignment between the company (business) strategy and IT strategy of the interviewed companies are also investigated and the effects of this relation on the efficiency of the IT applications are examined.

To gather information, interviews with open-ended questions are conducted and also a questionnaire was designed, including the following categories of questions. The interviews were conducted with the top-level managers responsible for the IT applications in the company. The questionnaire had built-in flexibility so that respondents could include additional comments or real-life stories, for example buildability problems or site construction outside of design intent due to erroneous or insufficient information. The survey is aimed at:

**IT Strategy**

- Vision and strategy
- Nature of IT support
- Centralization-decentralization approach of the company

**Architecture and Visualization**

- Goal-setting
- Information transfer
- Head office – site office information transfer
- Which information – in which format
- Making use of Web?
- Is visualization used
- Visualization and communication tools available
- Examining how/what visualization is performed
- Virtual reality used in any form?
- Buildability areas with potential problems during construction
- Collaboration between site team and design team in solving design problems
- How do you inform head office about a problem on site
- Do you use shared databases in any form
- Highlighting the pitfalls met during the planning or implementation stages
- Identifying what kind of benefits the firm gained by implementing visualization techniques
- Assessment of visualization and communication tools and methods.
- Wish-list

**Emerging technologies**

- Company's approach to emerging/new technologies

- Any investigation into emerging technologies in general
- Any investigation into new telecommunication and wireless

## RESULTS AND DISCUSSION

In the construction industry, the current clarification information used is limited to 2D drawings, written statements, face-to-face meetings. According to the results of this survey; just a few construction companies are using physical and 3D models, which are limited in use. More than 60% of the design companies interviewed are using simulation tools, but almost none of the contracting companies interviewed are using any simulation tools, although certain IT tools and digital photographs are common.

The common methods of communication between the design and construction teams are mostly traditional methods and limited to 2D drawings, written statements, face to face meetings, telephone, fax and e-mail. Most of the buildability problems are due to insufficient understanding of the drawings and design details, poor communication, and conflicting design information. Construction delays due to the above mentioned problems account to about one third of the total project delay. Wish list of the site teams on the design information concerning buildability will be discussed in a future study, when the research is completed.

Only a few companies are using a few visualization tools, physical and 3D models. Design and construction teams of the companies who are using visualization tools and physical models have already experienced the benefits. They have less communication problems, less project delay time and cost. Also they experienced increase in the quality of information (more accurate predictive and clear information).

Less than 5% of the interviewed companies are using videoconferencing, not to provide communication between the design and construction teams but for the communication between the top level managers.

The most common communication media is e-mail. Transfers over e-mail include DXF files, text files, digital photographs, virtual models and simulation models as e-mail attachments between the offices. All have network system and multi user databases in their main offices and LANs at the sites. The large scale companies with strong centralization strategies have designed their communication system to access any information recorded on site (generally material, labour and equipment data) from each office immediately. But these are not stored in visual format. However there is a great potential to benefit from the visual data collected on site. Other than 20% of the companies interviewed until now had a traditional approach towards the use of new wireless technologies and integration, but they were more interested in visualization methods.

More than 60% of the design companies interviewed are using simulation tools to exchange information between design and construction teams and for scheduling. For example in highway design projects, the client generally asks for a 3D simulation of the final project. These simulations are presented on a video animation showing the highway from the focus of a camera either on a plane flying over or on a car travelling on the highway designed. The geographical characteristics of the surroundings, the existing structures are shown and the structures designed in the project – highway, viaducts and tunnels on the route, crossroads, bridges, and expropriation etc. – are demonstrated by using CAD tools and 3D modules of CAD.

On the other hand the contracting companies interviewed are not using the simulation tools but they all communicate through digital photographs taken at site and sent to the main office via e-mail. One of the interviewed companies used cameras taking steady images in each 30 or 60 seconds and sending them to the system and these photographs become available whenever a manager at the main office wants to check what is happening on site. Clearly this can be possible only if continuous communication is maintained in the company via lease lines, ISDN or intranets.

The simulation of the work progress in a virtual environment enables comparison of the realized work tasks versus planned work tasks and leads to rescheduling during the construction process. A dynamic 3D site can be constructed in the virtual environment. If the entire construction project can be reflected on the visual simulation environment then the integration and monitoring of site related activities will be much simpler and decision-making will be facilitated.

A study of strategic implementation of construction IT in general and visualization in particular will continue to be carried out to present a qualitative assessment.

## CONCLUSION AND FUTURE WORK

Visualization is a significant technological theme that may help in increasing the effectiveness of communication during the construction process. Continuous advances of IT have made it possible for many construction issues to be addressed by use of visualization at steadily lower cost. Our research is an on-going research of which this paper is a qualitative approach to evaluate use of visualization, computerized or otherwise, in Turkish construction.

Interviews and survey questionnaires were sent to Turkish construction companies (both site and design teams). We consider types of information that can be visualized; information content and quality, problems due to information clarification.

There will be cases where graphical or visual means are unnecessary, such as in cases where the necessary information can be presented in one sentence of text. There is an optimum level for implementation of visualization. This optimum point is project-specific, and furthermore dynamic, as the envelope of visualized information types is expanding, for example due to technological development. Nonetheless, this survey shows that use of information visualization and its tools is very low. The amount of information needed in projects is evidence that we are well below such an optimum point.

Construction activities are carried out by the collaboration of many parties often at different locations. There are many ways to help overcome conflicts and resistance, but effective communication is maintained as central to successful project performance. Traditional methods are increasingly incapable of providing fast and effective communication and in most cases modern networking and telecommunications has greatly increased the amount but not the quality of information. Moreover, project collaborators are not only engineers or architects meaning that using traditional 2D drawings and sketches is neither effective nor efficient when the overall project is considered from decision making, communication, time and cost perspective.

It is observed that computerized visualization mainly consists of 2D and 3D drawings, although in project design companies some simulations and animations are also added to these views. In contracting companies visualization is generally used for following

the progress at site from main office. We found no examples where visualization was implemented during construction stage to circumvent buildability problems, for collaborative design, information exchange with site, clarification of technical details or construction methods, etc. Project decisions are based on visualizations in cases where the purpose of the visualization is a presentation for the client; visualization does not leave the conceptual design stage.

The search for improved communication in construction projects is ongoing. Visualization is a means of improving representation of many types of project information. The question, of which information in the construction process can be visually represented, seems a logical one. What implications follow if the information is not communicated effectively?

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