Deakin Research Online

This is the published version:


Available from Deakin Research Online:

http://hdl.handle.net/10536/DRO/DU:30005372

Every reasonable effort has been made to ensure that permission has been obtained for items included in Deakin Research Online. If you believe that your rights have been infringed by this repository, please contact drosupport@deakin.edu.au

Copyright : 2004, AUBEA
ABSTRACT

Demolition has recently been more concerned with the potential damage to the environment by its generated wastes. Waste exchange is apparently the main means by which the problem is currently dealt with. There is little or no consideration on wastes during the planning or designing stage. By utilising a knowledge system and visualisation technologies, a waste management plan can be integrated into the 4D model so as to effectively promote the interactions between demolition waste demanders and the demolition designer. As a result, the 4D visualisation provides not only the graphical schedule for the demolition process, but also the waste handling plan and waste production schedule. This research aims to analyse the integration technology of a waste management plan and the 4D visualisation model for a demolition project and to discuss the related technical and management issues. The integrated demolition visualisation enables to facilitate waste handling during the demolition processes thus to achieve environmentally friendly demolition.

Keywords: Demolition planning, demolition scheduling, demolition product database, 4D visualisation, just-in-time demolition, waste minimisation

INTRODUCTION

Demolition projects for either commercial or residential buildings produce numerous environmental pressures. In particular, demolition waste materials are sent to landfill directly in many projects, which is the major portion of domestic solid waste (Australian Bureau of Statistics 2003). Waste exchange is an effective manner to enable and promote waste reuse and recycling. However, the lack of a waste exchange plan can cause the inefficiency of an exchange system. Setting up a waste exchange plan ahead of the demolition project implementation is an approach to promote interactions between the demolition designer and waste demanders thus to improve the quality of waste exchange. Demolition exchange plan can be made through a web-based exchange system, where the system collects the waste demanders’ requirement and presents to the demolition designer (Pun et al. 2003). The building demolition can then be optimised to satisfy the requirements and to minimise the wastes.

Demolition is more demanding in time, space, safety and environmental concern compared to construction. This situation proves the significance of demolition project scheduling. In recent research and practices, 4-Demontional (4D) visualisation for construction, which is the integration of 3D building model with construction project
schedule, has increasingly been discussed and applied. Its visualised project schedule has many benefits in detecting design mistakes and gaining project understanding. For the same reason, 4D visualisation should be applied into demolition projects to improve the demolition design. To further exploit the advantages of 4D visualisation, a waste production schedule can also be integrated into 4D visualisation. As a result, the final outcome of 4D visualisation for demolition is not only the graphical schedule for the demolition project, but also the graphical schedule for secondary building materials and components production and the allocation plan for demolition wastes. This paper aims to explore the concept and development of 4D visualisation for demolition. Firstly, it gives the background and brings out the concept of 4D visualisation for demolition. Then, the technical requirements for the visualisation are discussed. Furthermore, the paper discusses the implementation of the visualisation followed by a conclusion section.

DEVELOPMENTS OF VISUALISATION IN DEMOLITION

Visualisation is widely utilised in construction industry, in particular in modelling and designing for building construction. On the other hand, building demolition, usually regarded as the reverse process of building construction, is rarely considered to apply visualisation due to its simple and straightforward approach. However, demolition technology is developed rapidly due to the increasingly emphasised environmental concern. The physical process of demolition is becoming much more complicated. More issues that are not directly related to the construction project need to be considered such as legal issues, safety assurance, environmental protection, hazardous material handling and waste reuse and recycling. There is a need for a systematic and holistic management approach to guide building demolition. Among various management manners and aiding facilities, visualisation is an efficient tool to facilitate building demolition project management and to address many technical issues.

Development of Visualisation in Construction

Visualisation has been applied into construction industry for more than thousand years; and it is rapidly developing following the development of information technology. From hand drafting to Computer Aided Design (CAD), architects and designers utilise visualisation to help in building design and modelling. Modern computer visualisation applications used in construction can be roughly divided into two categories, drafting system and modelling system. While a drafting system holds a representation of two-dimensional graphical images or line diagrams, a modelling system holds a representation of the form and the location of real objects. With an object-oriented system, a modelling system can be easily further manipulated, which makes the model much easier to change to cope with the change in a construction project.

The 4D modelling refers to the integration of individual components under a 3D model with scheduled activity start and finish dates. The 4D modelling allows for a
visual simulation of the building construction viewed through a space and the fourth dimension of time (McKinney et al. 1996). Therefore, 4D models are usually presented in animations. A 4D model is a graphical presentation of a project schedule, which is normally presented with Gantt chart. Construction activities, used to be shown as bars, are all visualized to simulate the reality. Furthermore, these activities are shown in the 4D model as the movement or change over different building components. A construction activity is normally linked to a building component and its representation in 3D model manually, or by a knowledge-based system capable of integrating graphical and non-graphical information (McKinney 1996).

Apparently, 4D visualisation has many advantages over the conventional critical path method based scheduling, typically the Gantt chart. It is also used in other fields rather than project scheduling. Using 4D visualisation can detect the inconsistency of master schedule’s level of detail, the omission of activities in schedule, incorrect precedence of the schedule and problems with time-space conflict (Yerrapathruni 2003). In addition, 4D visualisation allows the project team and other project related personnel to communicate in a graphical way. These advantages directly or indirectly reduce the project cost and time, while they improve the project design quality and productivity. On the other hand, using 4D construction has its drawback. To implement 4D visualisation is a technically expensive activity (Teicholz 1999). There are enormous resource and time spent on making a 4D visualisation. Therefore the pressure is increased on the project budget. Furthermore, the quality of 4D visualisation is hard to assure and the performance is very difficult to measure (Rodgers 2003).

Just-in-time Demolition

Demolition is the last stage of the building lifecycle. However, when demolition for a building is practically considered, it is always regarded as an independent project. Although it is seen as the reverse process of construction, demolition has some instinct characteristics over construction. It has its unique issues that are not always considered in construction, such as waste disposal, reuse and recycling. Furthermore, demolition technologies are different from building technologies.

As an independent project, a building demolition contains several stages with different targets. For example, a demolition project should start with planning. It includes making the decision of demolition, searching alternatives for demolition such as relocation and refurbishment, and selecting demolition technologies including demolition by machine, by hand, by chemicals, and by deconstruction (Abdullah and Anumba 2002).

Demolition of a building is a complex process. It contains various demolition activities with certain precedence. For example, the removal of building roof has to be done ahead of the removal of building body. Similar to a construction project, these activities are put in a certain order into a demolition schedule, by which building components are removed or changed over the project period. It is certainly possible to develop a 4D visualisation simulation for building demolition by integrating the
demolition schedule and the 3D building model composed with building components. It has the same benefits of using 4D visualisation in a construction project, such as detecting errors in project schedule and safety related simulation. Moreover, with appropriate implementation and application, the 4D visualisation can facilitate the waste exchange process, which is a major mechanism to handle construction and demolition waste (Chen et al. 2003).

Waste minimization is the motivation of many newly developed demolition technologies including deconstruction. Due to the increasing environmental pressure, the building components and materials generated from the demolition project are meant to be reused or recycled to a maximum. The waste materials and building components can be consumed in projects whose specification can fit in secondary materials such as road and car park construction. Apparently, the reutilization strongly depends on the market demanding, and importantly, the information of availability. Web-based waste exchange systems serving as waste exchange platform are increasingly popular. A waste exchange system serves as a waste information hub, where secondary material and components demanders can find the information of supply, and vice versa (Liu and Pun 2003). The high availability of Internet guarantees that everyone can release and retrieve information from the system.

It is argued in previous research that waste exchange should be placed ahead of demolition project implementation (Pun and Liu 2003). In this approach, waste exchange is the most significant part of a demolition project. As shown in Figure 1, waste exchange can be regarded as a process to collect the views, opinions and requirements from waste material demanders before the actual demolition project starts. In most cases, the requirements of waste material and component demanders involve the quantity, specification, quality, and delivery time of wanted material. Waste materials and components are treated as manufactured products. There are several benefits associated with such a procedure. It makes the waste exchange system more effective and efficient. It also allows waste materials and components to be produced satisfying the prospect of the demanders. In most cases, it will shorten the project schedule and save storage for waste material. The proposed demolition approach is regarded as Just-In-Time (JIT) demolition as the waste materials and components are treated as products in Just-In-Time manufacture.
Analysis of Visualisation for Demolition

Under the JIT demolition approach, the development of demolition visualisation is beneficial to the demolition project in various ways. Firstly, the requirement from the demanders that specifies the quantity of wanted materials or building components can be illustrated in the building model, thus in the 4D visualisation. As a result, the project team can obtain information about customers' requirements from the 4D demolition visualisation. They can also be aware the destination of specified building component. Since customers’ requirements are linked to building components, they are likely connected to the project schedule. As a result, the production of waste components and materials from a specified waste consumer are scheduled and visualized. The transportation for waste from the project site and the waste consumer can be scheduled. Secondly, because the requirements of waste consumers are visualized and highlighted, it could be easily acquired from the visualized schedule which parts of a demolition building are to be reused or recycled. Under different required outcomes for different portions of the building, different building technologies can apply to achieve a cost-efficient process. More resource and time should be spent to dismantle the building parts whose quality needs to be ensured. Finally, just like visualisation in construction, visualisation in demolition can fix up problems within the schedule, such as wrong precedence and omitted activities. Figure 2 compares the differences of required information to develop visualisation in construction and demolition.
Figure 2: Comparison of 4D visualisation in construction and demolition

(a) Building model → Construction schedule → Construction visualisation
(b) Waste requirement → Building model → Construction schedule → Demolition visualisation

TECHNICAL REQUIREMENTS FOR DEMOLITION VISUALISATION

Demolition Product Requirement Database

The requirement for waste materials and components of a demolition project has to be captured from the demanders. From a brief investigation of the building to be demolished and an initial estimation of materials and components to be generated from the demolition process, the estimated data published on a web-based waste exchange system. The material demanders can then reach the information by searching the database by location, time and other criteria. Those who intend to consume secondary materials or components to be produced in the demolition project then express their interests. These interests are expressed as requirements of materials and components, such as quantity, specification and delivery time.

To handle information of requirement for produced materials and building components from various prospects and various final users, a database needs to be developed as an information hub for controlling demolition product requirement information and handling demolition product delivery. The purchasing requirements on waste materials and building components from the consumers are the essential information to determine the demolition products. As a matter of fact, the qualitative requirement of demolition materials or components from a building is not as detailed as the requirement that describes those used in construction process. The relatively brief architectural design code system may be used to draft a demolition code system. A demolition code system, possibly complying international data standard such as IFC, could effectively identify project items. And very importantly, the project information including building materials and components can be effortlessly exchanged among the designer, contractor, auditor, recycler and other related personal. Linked with the demolition code system, a secondary building material and component qualification system should be built to classify and audit the materials or components. A certification based on the classification system could be helpful while material demanders describe their needs, and it is also helpful in the sense that gives
secondary material or component user psychological confidence and quality insurance about using such products.

The major contents of a demolition product database include the amount of waste materials and building components, the preferable delivery date and physical characters such as qualification code and dimensional information such as size, length and thickness. Except information about the products themselves, information of material and component consumers is also stored in the database. The related items include the contact information and possibly delivery address.

To fully and automatically utilise user requirements in constructing demolition visualisation, the isolated information about material dimension and quality cannot achieve satisfaction. Several knowledge bases should be developed to connect materials and components to actual building parts or objects. For example, the customer wanted lengthy timber bars may connect to a pillar located in the middle of the building. Therefore, this particular requirement can be pointed to the building objects and presented in a graphical building model or the physical building. A building model integrated with user requirements is the essential element for 4D demolition visualisation. In addition, the user requirement database can be connected to other knowledge bases to carry further functions. For example, to support E-commerce development for building demolition material or component exchange, knowledge about the pricing for secondary materials and components can be applied. The combined information can be applied to a web-based pricing and purchasing system or a biding system. Other possible assistant knowledge areas include safety handling instruction and embodied energy, which can be used to promote safety education and perform energy analysis respectively. The diagram of a demolition product requirement database and its relationship and connection to other knowledge bases and database are shown in Figure 3.

Figure 3: Database diagram for demolition user requirements
Demolition Process Scheduling

Demolition process scheduling is to determine the sequence of various demolition activities in which each demolition product is allocated with one or more demolition activities in one or more time intervals. Demolition schedules may be product-oriented or process-oriented. Both product planning and process planning can be scheduled using a scheduling tool and various resources can be analysed and reported under it. The demolition process representing the dismantling activities is strongly dependent on the building structure and the site environment (Liu et al. 2004). The principles of network analysis are used to determine and optimise the whole building demolition schedule. The technological and environmental precedence relationships of the dismantling process can be illustrated using a topologically ordered activity-on-node network, in which the nodes represent the dismantling activities and the arcs represent the precedence relations among activities. The optimal demolition schedule is then presented in bar charts in order for it to be easily understood. Similarly, different dismantling activities have to be defined according to many variables, including the type of building to be demolished, the dismantling techniques available, and the objective of the final products. Different environmental constraints such as obligatory levels of separation also lead to different dismantling activities. After the dismantling activities are determined, the resources necessary and the duration of the activities need to be specified in detail. The differing dismantling techniques and arrangements result in altered disposal costs and environmental impacts. So far, no methodology has been developed to estimate the resources needed for each demolition process, and discussion with engineers and front workers in demolition companies may turn out to be the main means used to attain such data.

The currently popular form of schedule in construction industry is Gantt chart, in which activities and their precedence are presented in bars and arrows. The graphical presentation makes easy for project team to gain understanding. Should the schedule need to be integrated with building model and other information, the schedule has to be prepared in a special form that is easily applied into integrating software. A possible solution is to store demolition activities into data structure with strict rules and formats on the content. The entries in a demolition activity may contain the name and duration of the activity, the relationship and precedence to other activities, the start date, and if possible, the resources involved in the activity. Until now, there is no official code system for demolition activities published. However, the code system and standardisation of demolition activities are crucial in demolition project management. In particular, an effective code system can save labour expense from demolition visualisation by easy and automatic information integration.

Building Model

Another important element required to develop demolition visualisation is the building model. It refers to the computer-based visual model for the building that is to be demolished. Due to the nature of demolition and limited human resource, the level of detail required in demolition might be lower than in a construction project. It is natural now to have a visual model for a new building, but it is less likely for a
demolition project that might be built several decades ago. The demolition
visualisation of these buildings requires that the 3D visual model for the buildings to
be built. The development of such a model is certainly time and resource consuming,
but it is critical and helpful in demolition visualisation.

As mentioned above, for the purpose of integration in building demolition
visualisation, the building model should be presented as objects, or components, in
both visual effect and descriptive expression. A building model is also blocks of data
structures that contain each building component and its dimensional and location
information.

A holistic building model for demolition should take full consideration the demolition
site. Since safety, both on site safety issues and public safety consideration, is
normally emphasised in a demolition project, the organised demolition site is a key
part of safety implementation. Other factors such as quality specification, security
assurance and environmental regulation require the site to be organised in a
systematic way. A research is needed to focus on the optimal design of the demolition
site to achieve risk minimisation, traffic reduction and high accessibility.

DESTRUCTION VISUALISATION IMPLEMENTATION

In order to achieve the integration between 3D building model and demolition process
schedule, a third party software is needed. This software is normally presented in a
knowledge-based application that is capable of integrating not only visual but also
non-graphic information (Fischer 2002). As mentioned above, several knowledge
bases are applied in the integration process in demolition visualisation development.

One knowledge base should be constructed to illustrate the positional and dimensional
information of a specific building component or certain materials on a demolished
building. The content might describe the position and amount of reusable windows
and doors of a building. The query results, which may be the position and dimension
of wanted material or building component, should then be shown on 3D building
model. This requires a building model to be constructed by aggregation of individual
objects. Under a 3D building model, customer wanted materials or components can be
shown in different colours and special annotations for describing further requirements.

Another knowledge base need to be developed to stores spatial relationships
imbedded in the 3D model and computer scheduling information. The information is
usually captured from the experience and knowledge of planning makers (Rodgers
2003). To produce the demolition visualisation, software package should be
developed and used to process the knowledge bases, integrate information and
generate animation.

There have been several approaches for 4D visualisation integration. Among them, a
popular approach is linking approach. In previous research, a 4D simulation module
linked the schedule data together with the appropriate building components resulting
in an interactive visualisation of the construction sequence based on Virtual Reality
(VR) technology (Alyazjee 2002). This approach can also be applied into demolition visualisation. The approach implies any changes to the design and schedules can easily be carried out without the need to recreate the 4D model from the beginning.

In the whole process for demolition visualisation, there are three major elements that need to be prepared, demolition user requirement, 3D building model and demolition schedule. The three streams of essential information combine together through a process engine equipped with knowledge bases and databases. The final visualisation outcome is the visual demolition project schedule. The visual schedule can be also used as an indication for demolition waste allocation, or secondary materials and components production schedule. The process of producing demolition visualisation is shown as Figure 4.

**Figure 4: Process of demolition visualization**

CONCLUSIONS

In conclusion, building demolition is undergoing revolution that is towards waste minimisation. Waste handling therefore needs to be considered in demolition planning and design phases. On the other hand, visualisation, as proven in building construction, has enormous benefits on building design especially on project scheduling.
A 4D demolition visualisation integrated with requirements of waste materials and components from demanders will improve the demolition project planning and design process. It helps to detect mistakes in demolition design and visually presents the schedule of waste production and the allocation of waste destination. To achieve the 4D demolition visualisation, three major project specific elements are needed. They are waste material and component requirement from demanders, the demolition process schedule and the building model. In the implementation of the demolition visualisation, several knowledge bases are needed to integrate non-graphical and graphical information into the combination. As a result, the composed 4D demolition visualisation serves as a graphical demolition project schedule and waste production schedule.

REFERENCES


