

THE INDUSTRIAL IMPLEMENTATION OF VR: LESSONS FROM JAPAN

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ABSTRACT: Virtual reality (VR) allows the interactive real-time viewing of 3D building models and can greatly facilitate the process of visualising, evaluating and communicating new building designs. Though its use has been widely researched by the academic community, the transfer of VR techniques into the construction industry has been slow.

To understand and hopefully accelerate industrial adoption, the experience of leading industrial users has been analysed through a cross-cultural comparison. To investigate their computer-aided design (CAD) and VR use, interviews were conducted with three large Japanese house-builders, on a study visit to Japan in June 1999. The findings of the study are contextualised, through comparison with the use of CAD and VR in British house-building, to provide a greater understanding of the constraints and opportunities for VR implementation.

It was found that advanced 3D CAD and VR techniques are being used extensively in the house-building sector of the Japanese construction industry. Unlike in Britain, VR models are used to aid the house design and customisation process in consultation with the customer, and are created before the customer signs the contract. The reasons for the faster uptake of VR and the integration of VR use into the existing company structures and practices are considered.

The wider implications of the findings for the future industrial use of VR in the construction industry are discussed, and the paper concludes by setting out lessons that can be learnt from Japan.

KEYWORDS: virtual reality, industrial adoption, CAD, VR, Japan, house-builder

1. INTRODUCTION

House-building is a sector of the construction industry that is suitable for the study of VR introduction as it uses a semi-standardised products in a repetitive manner (Hooper, 1998) facilitating the prototyping of a VR system. Research at Loughborough University has investigated the attitudes of British house-builders towards VR (Whyte *et al.* 1999), the use of VR systems for the layout of housing developments (Whyte *et al.* 1998), and the implementation of VR in a British house-building company.

Innovation in house-building processes is being considered in Britain following the government report *Rethinking Construction* (Egan, 1998). Innovative house-building techniques, such as lean-production, customer focused product development and supply-chain management, which are being explored in British (Barlow, 1999; Gann, 1996; Roy & Cochrane, 1999; Roy & Gaze, 1999) and European projects (Atkin & Wing, 1999), are similar to techniques already used in Japan. Though such techniques are used alongside advanced IT and VR technologies in Japan (Palmer *et al.* 1998), the role of IT in the adoption of innovative house-building processes has not been sufficiently investigated.



In this paper a multiple case study of VR use in Japanese house-building companies is presented and the results are contextualised through a comparison with the previous findings of VR use in the British house-building industry.

2. JAPANESE HOUSE-BUILDING

The larger Japanese house-building companies are often members of inter-firm networks, with “lifetime employment” policies for their staff. They operate in a particular market for land and housing with little regulatory requirements. These conditions are briefly discussed in this section to facilitate interpretation of the case studies.

Members of large conglomerates or inter-firm networks (*keiretsu*) are linked through inter-corporate shareholding, investment and the exchange of personnel, and provide preferential markets for each other’s products (Masaki, 1998). The organisation of these inter-firm networks has been described as ‘horizontal’, where the group is added to by progressive diversification or ‘vertical’, where networks are based on the supply and distribution chains (Edward & Samini, 1997). Keiretsu diversified into housebuilding in the 1950s and 1960s as changes in other industries, such as the chemical and steel industries forced them find alternative markets for their products (Matsumura, 1988).

Large size firms in Japan offer stable employment (“life-time” employment) and the prospect of moving up through the ranks to male members of staff (Morris, 1996). As recruitment depends upon personal ties and recommendations there is no desire to reduce intake (Yoshimura, 1997) and companies try very hard to keep their employees. Companies do not aim to minimise the number of people, but to maximise output.

Land is extraordinarily expensive in Japan. For example, the average price of residential land in Tokyo was 560,000 yen (£3027) per square metre in 1994, compared with 30,000 yen (£162) per square metre in London (“Japan 1999”, 1999). Land is often passed down from generation to generation, though the house on that land may be rebuilt every 25 years or so (Matsumura, 1988). There is virtually no second-hand market and a large percentage of new build housing is rebuilt, built on brown-field sites already owned by the client.

Planners are not concerned with regulating the appearance of the developments, as they are not considered permanent. Planning control by the Ministry of Construction and Local Authorities in Japan only concerns the volume/land-use capacity and some sanitation, health and structural stability conditions (personal communication with Prof. Matsumura).

3. METHOD

A two-week study visit to Japan was used to conduct case studies, investigating the use of advanced visualisation techniques and virtual reality within house building companies. Letters were sent or emailed to the top 10 house-building companies in Japan and from the response to these, three case studies were arranged, with Sekisui House Ltd., National House Industrial Co. Ltd. and Mitsui Home Co. Ltd. A semi-structured interview protocol was produced and semi-structured interviews were used as the primary data collection technique.

The data collected in the interview was supplemented by secondary sources of information, such as company reports, publicity and web pages.

4. RESULTS

Introduction

In this section the characteristics of Japanese house-building companies and the use of VR and advanced computer graphics techniques found in the case studies are summarised, with the extent of the supporting evidence indicated.

- **Sekisui House Ltd.** is Japan's largest house-builder, and also possibly the largest house-builder in the world, building 75,740 houses in 1997 (www.sekisuihouse.co.jp). It was created in 1960 and now has 14,576 employees (Toyo, 1998) and a capital stock of 182,458 million yen (as of January 31, 1998). Facilities such as the Housing Science Hall, Institute of Housing Science, Tokyo SHIC City, and the comprehensive housing R&D institute "Nattoku Kobo" are available for customers to come to and learn about the house-building process.
- **National House Industrial Co. Ltd.** is now the 4th largest builder of prefabricated homes in Japan. It was established as the housing division of the Matsushita (Panasonic) group in 1963 (http://www.panahome.co.jp/cam_t/english/cam_e.htm). It has 3,782 employees.
- **Mitsui Home**, which was established in 1974, uses the two-by-four construction method, which originated in North America, and is the largest 2x4 housing manufacturer in Japan (http://www.mitsuihome.co.jp/INDEX/e_index.htm). 2x4 housing construction uses platform timber frames with structural components made in factories and is similar to what is known as 4x2 timber frame in the UK (Bottom, D. *et al.*, 1996).

Similarities and Differences between the Cases

The similarities and differences between the three companies' organisational structure and approaches to design, CAD use and VR/advanced visualisation is summarised in **Table 1**.

The structure of the house-building companies is hierarchical in all 3 companies, with a head office, regional offices and sales offices, and an infrastructure of supporting factories, research laboratories and customer care centers. Customers own the land and can choose a house-builder according to the quality of the housing. This means that the competition between the house builders is based on the quality of their ability to fulfil the customers' requirements.

House layout design is customised in the sales offices, only being referred to a regional or head office in the case of difficulties being encountered. Some basic standard house-types, which are designed in the central office are used, but these are customised and altered according to customers' requirements.

	Sekisui House Ltd.	National House Industrial Co. Ltd.	Mitsui Home Co. Ltd.
Company structure	<ul style="list-style-type: none"> • Head office, more than 200 regional offices, 6 factories, research laboratories, customer facilities, publishing business and library 	<ul style="list-style-type: none"> • Head office, 8 regional offices and after care centres, 86 associated dealers, 6 factories, human resource centre for staff training 	<ul style="list-style-type: none"> • Head office, 20 design offices, 60 sales offices
Design	<ul style="list-style-type: none"> • Design customised in regional offices 	<ul style="list-style-type: none"> • Design customised in regional offices 	<ul style="list-style-type: none"> • Design customised in regional offices
CAD use	<ul style="list-style-type: none"> • For drafting and not for design • 20 years 	<ul style="list-style-type: none"> • For presentation and design • 10 years 	<ul style="list-style-type: none"> • For design • 10 years
VR and advanced visualisation use	<ul style="list-style-type: none"> • For customer presentation • Used as final zone of customer care centre, Nattoku Kobo. • Used for 3 years • Modelling - “<i>time consuming</i>” as no data transfer between CAD and VR • Presentation with a computer operator and sales presenter • Used before contract • Hardware: SGI 	<ul style="list-style-type: none"> • For customer presentation • Used as part of part of customer care centre, in Osaka. • Used for 4 years • Modelling - 1-2 hours per house, from 2D CAD drawings (using library of components) • Presentation with a sales presenter, who acts as the computer operator • Used before contract • Hardware: PC 	<ul style="list-style-type: none"> • For customer presentation. • Available in customer care centre or can be taken away on video • Used for 3 years • Modelling - about 1/2 day per house, including data transfer and manual corrections • Presentation with a computer operator and sales presenter • Used before contract • Hardware: SGI

Table 1 Similarities and differences between the cases

CAD has been used for 10 years or more in the companies studied. All of the companies use computer operators for inputting designs into the CAD software and in one CAD is used solely for presentation and not for design.

VR and advanced computer graphics techniques are used by all three of the Japanese house-building companies considered in this study, having been introduced 2-3 years ago. Customer presentation is the main use for such techniques and VR is not used in isolation but is used with a suite of other computer and low-tech tools to present and explain the house design to the customer and allow design customisation. All three companies have presentation centres where customers can experience VR models. When presenting VR models to the customer, 2 out of the 3 companies used both a computer operator, who did not contribute to the discussion, and a sales person, who led the presentation. VR is often used before a contract is signed.

An example of a VR package, the software package COSMOS (Customer Oriented Structural Modeling of Sekisui house) is customised for the viewing of Sekisui House original components such as doors, sashes and textures, thus allowing detailed models to be created for simulation. It is easy to operate and can be used to show the view from a human viewpoint and also from an arial view of the house floor. Features include smooth-move cameras, interactive manipulation (replace objects, change textures), and libraries of

furniture, which can be added to check the scale. The software has a default setting of a realistic human eye-level though the operator can change the eye-level of the viewpoint, the viewpoint is fixed to the realistic human eye-level for walkthroughs with customers.

However the software is not so easy to operate in terms of model creation. There is no easy way of translating CAD drawings into a format understood by the software and model creation is a time consuming process. The models are currently fully built in the COSMOS software, by an operator using as a guide a paper drawing printed from the CAD model. First the operator selects the zone for the planning for example the living, dining or kitchen area, then adds the walls and uses codes to insert different types of door and openings into the walls.

First introduced into Sekisui House in 1997, more than 8,000 customers have experienced the COSMOS software. It is demonstrated to customers in the customer care centre at “Nattoku Kobo”, which comprises 10 different zones on 4 floors. Customers are initially taken to the top floor of the show room where there is an orientation zone, in which there are displays about the history of housing and the different kinds of housing available in different parts of the world. As they pass through this, and the other zones, which look at housing quality and environment, structure, lifetime home, storage, equipment, space, kitchen and interior and exterior co-ordination, they slowly build up a more and more detailed picture of their new house. There are interactive displays and maquettes that allow the house to be explored at different levels. For example, in the storage zone, it is possible to move full-scale storage units up and down the wall to determine the most suitable height. In the kitchen zone it is possible to move units around in a 1:200 scale maquette. As the customer makes design choices these are entered into the CAD package.

The computer graphics demonstration room is in the final zone at “Nattoku Kobo.” VR is demonstrated within the room and used to present the design of the whole house to the customer. The demonstration builds on previous discussion between the customer and the sales representative.

The computer graphics demonstration room resembles a boardroom, which has a large screen mounted on one of the walls. The display environment has been carefully tailored to be conducive to consensus building. An operator, sitting to one side navigates around the model, responding to the nature of the discussion but remaining unobtrusive.

5. COMPARISON OF CAD AND VR USE IN BRITAIN AND JAPAN

Previous work on CAD and VR use in British house-building (Whyte *et al.* 1998, 1999) has found that British housing developers are now interested in VR use, however, as shown in **Table 2**, there are considerable differences between Japanese and British house-builders’ operations, CAD and VR use.

Japanese house-building organisations have a more extensive infrastructure of customer facilities than their British counterparts and they may also have research laboratories, human resource centres and libraries. This infrastructure of facilities reflects the vertical integration of the supply chain in Japanese house-building and the importance of design quality as an area in which Japanese house-building companies can obtain competitive advantage.

	British House-Builders	Japanese House-Builders
Company operation	<ul style="list-style-type: none"> • Head office and regional offices • Operates as a developer and a house-builder • Design altered in regional offices to fit planning regulations 	<ul style="list-style-type: none"> • Head office, regional offices, customer facilities, and factories, possible research laboratories. • Operates as a house-builder • Design customised in regional offices to suit the customer
CAD use	<ul style="list-style-type: none"> • For drafting and design • Less than 10 years 	<ul style="list-style-type: none"> • For drafting and not for design • More than 10 years
VR use	<ul style="list-style-type: none"> • Seen as useful for explaining the site layout, both within and without the organisation, to non-technical staff, planners and customers. • Use beginning to be explored • Efficiency in model creation required • Presently within the organisation • Interest in VR for marketing, followed by communication with planners and refining the design idea, and the use of VR at the early design stage • Hardware: PC computers used • Concerns about the use of virtual reality to give more information seen as problematic as it might lead to claims later 	<ul style="list-style-type: none"> • Seen as useful for explaining the house design to the customer through customer presentation • Used for 2-3 years <ul style="list-style-type: none"> – Used as one of a range of techniques to describe design intent – Model creation takes between 1 hour and 1/2 day • Inefficiency in model creation tolerated • Computer operator navigates the model and a sales presenter discusses the design • Used before contract • Hardware: SGI and PC computers used within the organisations • Use of virtual reality to give more information seen as a way of reducing claims later

Table 2 Comparison between Japanese and British House-builders

Japanese house-builders build houses predominantly for customers who already own the land and are not concerned with site layout but operate in a manner similar to popular interior design stores such as IKEA or HABITAT, selling a lifestyle commodity product. In contrast, British house-builders act as developers as well as house-builders, selling the land and the house to the customer at the same time. Whilst in Japan design is customised in the regional offices to suit the customer, in Britain it is customised to fit local planning regulations.

The Japanese house-building companies visited were all early investors in CAD and IT software. CAD packages have been used for longer than in the British house-building industry, where there was little CAD use in the late 1980s (Thorpe, 1992). Contrary to expectations the CAD use in Japan was found to be less automated than in Britain, due to the lack of need for time efficiency.

It was found that advanced 3D CAD and VR techniques are being used extensively in the house-building sector of the Japanese construction industry, where they have been used for 2-3 years. Unlike in Britain, VR models are used to aid in the house design or customisation

process in consultation with the customer, and are created before the customer signs the contract.

The contrast may be explained by the different competitive strategies of Japanese and British house-builders. Planning is not as important in Japan as houses are considered as temporary structures. Although the government, which develops new towns in Japan, commissioned VR models of layouts of new housing schemes, housing developers are not exploring this. As obtaining planning permission for sites in prime locations is more important to the British house-builder, VR models have initially been considered by the industry as tools to facilitate the visualisation of site layouts. The importance of visualising house design may increase however, as the basis for competitive strategies change (Barlow, 1999), where some companies are using or exploring customer-focused product development techniques (Roy & Cochrane, 1999).

Issues of model building, investigated in previous papers (Whyte *et al.* 1998, Whyte *et al.* in press) were investigated in Japan. In contrast to expectations Japanese house-builders were not using sophisticated modelling approaches and modelling was a time consuming process. Some inefficiency in computer use is tolerated as Japanese lifetime employment practice reduces the need for efficiency drives and may reduce the priority given to developing effective translation software or techniques. The Japanese house-building companies studied used little automatic transfer of data between CAD and VR software packages, with one company building the VR models from scratch within the VR package itself, whilst the other two used some data transfer and libraries of components. This acceptance of inefficiency in model use is different to the situation in Britain, where research has been conducted into efficient modelling techniques for VR use in the house-building industry (Whyte *et al.* 1998).

6. CONCLUSIONS

Uptake of VR and the integration of VR use into the existing company structures and practices have been faster in Japan than in other countries. Use of VR has developed to support the effective customer-focused product development and supply-chain management seen in the vertically integrated Japanese house-building industry.

Changes in British house-building are making the land-based competitive strategies of builders less appropriate (Barlow, 1999) and house-builders may need to invest in innovative house-building techniques to be competitive in the 21st century. Innovative techniques are being explored in British and European projects, and lessons can be learnt from the Japanese use of VR to support these techniques:

VR is useful for explaining design to the customer – Better visualisation tools may be required for customer-focused product development and to allow greater customisability. VR is used in Japan to allow the customer to visualise and participate in the design of the house by customising standard house designs through the choice of a range of components. Thus VR is used for customer-focused product development in Japan and house-building and construction companies wishing to implement this technique should consider the use of VR to support it.

VR is useful as one of a range of interactive techniques – VR was used in Japan as one of a range of techniques used to describe the house design. It did not supersede or replace other techniques, such as the use of full-scale models and maquettes. This suggests that VR cannot

be expected to provide a quick technological fix, but can be used to augment the effectiveness of traditional media. Different people may respond differently to different methods of presenting spatial data and providing a range of representation of design allows all customers to reach a shared understanding of the design decisions that are made.

The interface to VR models should be intuitive – In Japan the technical aspects of VR were not presented to customers, but were down-played allowing the customer to focus on the design. Navigation in the model was aided by a map, or overhead view, and/or was performed by an operator, thus the customer was unlikely to get lost in the model. There was also the possibility of juxtaposing plans and perspective views in the VR model, thus allowing the customer flexibility in the way that they used the software.

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