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Evaluation of Simulation Based Design Tools for the Construction Industries

Final Report

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Disclaimer

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Summary

This report sets out the findings of a research contract carried out by NNC on behalf of the Health and Safety Executive to evaluate the use of virtual reality and simulation tools in design packages to assist in health and safety risk assessment and risk reduction in the design process within the construction industry. The project was carried out in two parts. The first part consisted of a series of interviews with representatives from a range of organisations operating within the construction industry to obtain their views on the current and potential use of simulation tools for assessment of health and safety matters in the design process. The second part involved a review of software packages and discussions with software vendors servicing the construction industry to determine how their packages could be used or developed to assist in the assessment of health and safety at the design stage. A number of conclusions have been made, together with recommendations for further work to achieve the goal of integrating health and safety into the design process

1 Introduction

1.1 Background

Industry in general is using computer based techniques to improve designs, shorten times to market, and reduce development costs and project risks. The same technology has the potential to reduce the health and safety risks associated with construction projects, but there is no formal guidance as to how this should most effectively be achieved. This project was aimed at evaluating the use of virtual reality and simulation tools in design packages to assist in health and safety risk assessment and risk reduction in the design process within the construction industry.

1.2 Methodology

The methodology adopted for the project was based on obtaining the views of a cross section of organisations. The first part of the project concentrated on organisations operating within the construction industry, whilst the second part concentrated on the software vendors servicing construction.

Given the size of the construction industry, it was not feasible in the first part of the project to contact all sectors, and it was agreed during the development of the project to choose three sectors.

The first sector was the steelwork industry, selected because of its practical involvement in the construction process. The second sector covered professional designers, i.e. architects and consulting engineers, selected because of their position to influence the design. The final sector was made up from client organisations as ultimately they own the projects and have a reputation to maintain.

Within each of the three sectors, the aim was to interview a representative from a large, medium, and small organisation, giving a total of nine interviews. The interpretation of large, medium and small organisations has been somewhat subjective, and has ranged from multi national companies to a three person organisation. In the steelwork and design groups, the number of employees was a useful reference, but it was more difficult in the client sector to classify organisations.

A total of thirty companies were approached by telephone with a view to arranging interviews. Interest and willingness to discuss the project was generally favourable, with only three out of the thirty declining to contribute in any way. Ten interviews were carried out, and the matrix shown in Table 1 indicates the distribution within the target groups.

There was some reluctance amongst medium and smaller client companies to be interviewed, and it will be noted that no interview was carried out with a medium sized client organisation. They felt they had little to contribute because they employed architects or other professionals to act on their behalf, particularly in relation to complying with the Construction (Design and Management) Regulations 1994. (CDM regulations - Ref. 6.)

In addition to the information gathered in the interviews, information received during telephone conversations with companies who were approached while setting up interviews has been included, particularly from what were considered to be medium sized client organisations. Significant contributions from a total of six such conversations are included, and it is believed the combination of telephone conversations and the face to face interviews has provided a representative picture of the client attitude to CDM regulations.

Experience within NNC and input from a recent conference on Virtual Reality in the Construction Industry, held at Teeside University (Ref. 1), has been used to complement the data collected from the interviews.

For the second part of the project, the decision on which software vendors to approach was determined largely by information gathered during the industry interviews, complemented by NNC's experience of the simulation market.

2 Industry interviews

2.1 Industry interview format - overview

The interviews followed a standard format involving three phases. The first phase was concerned with the scope of operations carried out by the organisation and their current practices for including health, safety and welfare in the design process. The second phase was in the form of a demonstration of the types of simulation tools which are currently available. The third and final phase was aimed at seeking the interviewee's opinion as to the relevance of these tools to health and safety issues with emphasis on use at the design stage.

Given the different nature of the organisations being interviewed, there were differences in the emphasis of the interviews. For example client organisations or contractors who were not carrying out detailed design had a different perspective as to the usefulness of simulation, potentially being a beneficiary rather than provider of the simulation. However for consistency, the same format of questions was used regardless of the type of organisation being interviewed.

There is a tendency when considering health, safety, and welfare to focus on safety and the prevention of accidents. This is understandable, as the effects of accidents are immediate and potentially life threatening. However, the longer term health problems of workers in the construction industry caused by such things as continued lifting and exposure to aggressive environments should be of equal concern to the industry, and these aspects were included in the interviews.

2.2 Industry interview format – Phase 1

In this phase discussions were based on questions to determine:

- The scope of operations carried out.
- How work is carried out (e.g. does the organisation follow an accredited QA procedure).
- How much influence they have on the design and method of construction.
- The current use of CAD and Design software.

- What procedures are followed for complying with CDM regulations.
- How is compliance with CDM at the design stage monitored.
- How Health and Safety issues are priced within project costings.

In most of the interviews undertaken, this phase concluded with a general discussion on the interviewee's experiences of working with the CDM regulations. All interviewees volunteered informative comments on how the CDM regulations operate within their spheres of work.

2.3 Industry interview format – Phase 2

The aim in this phase of the interview was to outline the range of simulation tools available. For this purpose, six short sequences from projects undertaken by NNC were shown on a laptop computer. Although not necessarily directly connected to the construction industry, these sequences were chosen to represent the various technologies, and encourage the interviewee to consider how the technologies could apply to their area of work.

The first sequence was an animation of a ship dismantling procedure, and is typical of 3-D visualisations achievable with popular modelling packages such as 3D Studio. This example was used to illustrate two points. Firstly the ease with which a sequence of events can be shown to aid understanding of the process, but secondly to demonstrate that such animation sequences are pre-set, in other words the person viewing the animation has no control of what viewpoint the process is seen from.

The next example was a 3-dimensional virtual factory, viewed with a web-based virtual reality viewer where the observer has a set of controls to allow navigation through the model. The observer can choose where to go in the model, and can revisit locations. An additional feature of this type of simulated or virtual world is the ability to link other information to the basic model being navigated. This can be in several forms, including links to other websites and databases. This was demonstrated by clicking on objects in the virtual world, and having a separate window displaying information such as service or supplier details. This could be extended to include issues associated with health and safety or other regulations etc. This example was referred to later in the demonstration in connection with the possibility of using a knowledge based system.

In the previous two examples, no attempt was made in the modelling to ensure the behaviour was physically correct, e.g. no account is taken of whether a lorry is capable of carrying the load placed on it. The next three cases demonstrated a simulation tool which takes account of the physics involved when simulating movement. The first case showed a simple crane lift in which the centre of lift was offset from the centre of mass of the object being raised, and the consequent sideways movement of the object. The next case was a personnel lift which was extended laterally until it toppled over. The final one was a model of a human falling down a flight of stairs. An important feature of this type of simulation is the ability to measure properties such as loads and accelerations during the simulation and have them output in graphical or digital form, and this capability was shown in the second and third cases.

The next example took the human factor involvement even further, and showed a simulation of how a human operator would carry out a maintenance task. In this simulation a mannequin with physical attributes carried out the operations involved in removing a cylinder head from a large marine engine. Aspects of human capability, such as reach and lifting capacity, as well as problems associated with access can be taken into account. This example was included to shown that physical tasks undertaken by construction operatives could be modelled to assess the stresses imposed on the human body. It was pointed out that, in addition to determining whether a specific manual operation can be carried out, this form of simulation has substantial potential for assessing the longer term effects on the health and well being of construction operatives.

The final topic discussed during the demonstration phase of the interviews was concerned with the concept of knowledge based systems. Potentially such systems enable designers to obtain or be prompted with relevant information about health and safety aspects of the project they are engaged on. A simple example is in the design of a steel frame, where the designer could be prompted to check that attachment points for netting or personal safety harnesses have been included. Reference was made back to the virtual factory example shown earlier as to the look and feel of such a system.

2.4 Industry interview format – Phase 3

The final stage of the interview sought the interviewee's opinion as to how useful or appropriate simulation could be in assessing the health and safety aspects of construction projects. For those companies with experience of applying simulation, this phase tended to concentrate on the benefits they felt they had achieved, and problems they had encountered. For those with little or no experience of simulation it was a case of discussing potential applications within their sphere of activity and the obstacles they foresaw in applying the tools.

3 Review of industry interviews – Phase 1

This section of the report summarises the information gathered during Phase 1 of the interviews under the headings described in Section 2.2.

3.1 The scope of operations

Given the wide variation in size of the organisations interviewed, the scope of projects undertaken covered the whole spectrum of construction from a few hundred thousand pounds to multi-million pound developments. One feature mentioned by all those involved in design aspects of schemes is the very tight margins on which the design phase operates. This reflects the low margins which prevail throughout the construction industry as a whole.

In the case of the smaller design organisations, they would 'buy in' specialist services, e.g. structural, electrical and mechanical engineers, where appropriate. The larger design organisations have most of the expertise in-house.

3.2 How work is carried out

Of the 10 organisations interviewed, six had direct design responsibility for projects. All six followed documented office procedures, although they were not all accredited QA procedures.

The remaining four organisations were not directly involved with design, but the two large organisations in this group did have QA procedures in place.

The medium and large steelwork companies were somewhat different from the other companies as they provide both design and construction services.

3.3 Influence on the design and method of construction

From a design point of view, the clients and the design organisations had considerable influence within the confines of planning approvals and functionality considerations as to the materials and form of the building.

The steelwork group were somewhat more constrained in the sense that they would only be involved in steelwork projects.

In terms of the method of construction, the steelwork contractors had a high level of involvement in how the steelwork would be erected.

It was the view of one of the smaller designers that it was firmly the responsibility of the contractor to determine the method of construction. Particularly for traditional methods of construction, the contractor had the knowledge and experience of the construction process and the availability and use of appropriate plant.

3.4 The current use of CAD and design software

All the design organisations used CAD to some extent, particularly as a means of communicating information with the various disciplines involved in a project. AutoCAD and Microstation were the two most common CAD systems.

The medium and large organisations in the steelwork and design groups also had specialist CAD and analysis packages, for example StruCAD and CSC FASTRAK.

3.5 Procedures for complying with CDM regulations

Information gathered from the client companies contacted for this project suggests the basic approach is to appoint a professional organisation to act on their behalf.

Larger organisations may well appoint a Client Agent and Planning Supervisor, and may go to a lot of trouble, including employing a Health and Safety Consultant, to assist their selection for these roles.

For smaller projects, clients may expect the architect to undertake the duties of the planning supervisor as part of the architect's duties, and at no additional cost.

Within the design organisations, the documented design procedures include the requirement for risk assessment under the CDM regulations.

3.6 Monitoring of compliance with CDM at the design stage

At the design stage there is a reliance on the professionalism of the people carrying out the work to undertake the work in an appropriate way. Design reviews, which are part of the documented procedures, include checks that health and safety risk assessment has been undertaken.

3.7 Project costing of Health and Safety issues

There will be aspects within the tender documents which can be related to health and safety, for example provision of protective clothing and use of plant for access. However as one architect put it, if there was a separate item for Health and Safety, he would be under pressure from some of his clients to cut it out.

3.8 Additional information from interviewees

The following observations were put forward by interviewees. There is considerable repetition in many of the statements – this has been deliberately left in.

In comparison with Building Regulations where a local building inspector will give a view or ruling on acceptability of a proposal and suggest acceptable alternatives, HSE are not available in a similar advisory role, but will appear if something goes wrong.

Health and Safety legislation is rather vague – "reasonableness" appears too frequently without giving real guidance. CDM has created a separate industry producing masses of paperwork.

A lot of energy and resource is put into projects associated with Health and Safety, but it is at the wrong end (meaning too much at the management and professional end, not enough with the actual construction operatives.)

The planning supervisor should be identifying abnormal risks, but in practice planning supervisors go overboard in producing information with the result that real risks (unusual situations) are buried in the piles of paper. This has been caused by the creation of the planning supervisor role which has been adopted by some people as a career change into producing interminable check lists.

CDM codifies what should be best practice. The prime responsibility for health, safety, and welfare on the construction site should rest with the constructor. The architect's job is to design and get the client what he wants, the constructor is the one best experienced to say how the work will be constructed. It shouldn't be the architect's job to say how things will be built.

Downside of CDM is it is too broad a net. Every time a project is done there is such a lot of repetition in the Health and Safety Plan. For traditional and established construction methods contractors know more about the methods of building and hazards than the architect, more about the construction plant available and its use. CDM procedures should be pointing out more clearly new or unusual risks.

A lot of what CDM is about is having procedures in place to examine and assess health and safety risks, and to ensure good communication of such issues to each organisation in the project. In practice, a lot of unnecessary, repetitive paperwork is produced which drowns out the real or special risks on a particular scheme.

Designers in general do not have a good understanding of risk and risk assessments. CDM Regulations may be partly to blame as the high, medium, and low risks are not easy to work with. Perhaps there should be two levels, significant risk and no risk.

Designers are slow to pick up on initiatives from the HSE in terms of changing materials or sizes of materials to reduce long term health problems. The focus tends to be on accidents.

CDM regulations should result in health and safety files which are helpful to constructors, rather than the typical 'backside covering' volumes of paperwork currently being produced. The reality on construction sites where small self-employed gangs of operatives are paid on a piecework basis means method statements and health and safety statements are signed but not read.

There is often too much generic information in the health and safety plan. All too often it doesn't get read because of the volume. Site specific information should be easily accessible and presented as a few sides of paper at most.

CDM regulations may not have significantly improved the health and safety record of the construction industry, but they have stopped the record getting worse given the increasing fragmentation and sub-contracting culture that the industry has experienced over the last few years.

Designers generally feel confident they are doing their bit in terms of complying with CDM regulations, and the larger client organisations concurred with this view. There is a limit to what can be done at the design stage - how do you stop people from breaking health and safety rules on site?

4 Current use of simulation tools

All large and medium organisations interviewed had an appreciation or experience of some of the simulation tools demonstrated in phase 2 of the interview. One of the design group had a team dedicated to producing 3D visualisations of projects and have been using this for some years in-house. The technique has been used for such activities as clash detection, lighting assessment and working in confined spaces.

All interviewees were familiar with architectural walkthroughs. This type of visualisation was generally regarded by the interviewees as a useful tool for communicating ideas and marketing, with the potential to impress prospective clients and statutory bodies such as planning authorities. Contributors also remarked they felt that to be effective in such situations the level of realism is important. At present the smaller organisations are not providing this as a run of the mill service to their clients, but they are aware of the increasing use of such techniques.

Examples of simulation were mentioned which were associated with aiding engineering decisions by producing drivers eye views, demonstrating sight-lines, assessing signage layouts, and checking visibility of proposed work from existing properties. In such situations, photo-realism was regarded as secondary to the engineering information obtained.

Several instances were reported where constructing the 3D computer model from traditional 2D drawings had highlighted potential construction problems.

Some of the increased use of visualisation has come about as companies take advantage of enhancements in the capabilities of CAD and similar systems. A good example being steelwork companies using StruCAD who are now providing isometric views of the completed framework as a matter of course to aid communication to fabricators and erectors. Obtaining the isometric view is more or less automatic once the detailing exercise has been completed, and is available at little or no extra cost to the provider.

There is a growing interest in linking visualisations to databases in the manner outlined earlier in the context of a knowledge based system. Some work has been done within university research projects as to how to implement such processes.

5 Potential use of simulation tools – industry perspective

This section summarises the comments and suggestions received during the interviews regarding the potential use of simulation in respect of health and safety issues. The comments have been grouped into three areas, visualisation (including interactive walkthroughs), physics based and ergonomic simulation, and finally knowledge based systems.

5.1 Visualisation

It was generally accepted that interactive walkthroughs have potential for helping identify health and safety risks. However the feeling was that the effectiveness would be very dependent on the amount of detail and realism that could be built into the model. The point was made that a hazard will not be identified unless it is built into the model, and to build it in means the builder has identified it.

A key factor to the use of this type of simulation is the ease with which the models can be created. It is unlikely at the present time that models would be created just for the purposes of assessing health and safety matters. However, if the models are being created for other reasons, then reviewing the model from a health and safety viewpoint becomes realistic.

A suggestion was made that these visualisations would be extremely useful for site inductions, and one of the design organisations has already provided walkthroughs of complex internal layouts to aid communication to site operatives prior to commencement of construction.

5.2 Physics based and ergonomic simulation

It was felt that the potential for use of this type of simulation was somewhat limited, particularly in day to day design work.

However the steelwork companies were interested in its use for assessing crane lifts. Another suggestion was for its use in developing training material to show for example the use of access platforms and the problems associated with overloading or over-reaching.

There was also an interesting suggestion as to whether ergonomic simulation could be used for assessing the long term effects of lifting, and correlation with medical information.

5.3 Knowledge based systems

There was considerable interest from the smaller design organisations in the concept of knowledge based systems. One of the major problems encountered by architects is the number of regulations that have to be balanced in the design process, e.g. security, fire escape routes, and health and safety. It is not uncommon for these regulations to act in opposition to each other. For example, from a security point of view, the fewer entrances to a building the better, whilst from the fire escape point of view, the more exits the better. If the concept of prompting designers with information about health and safety could be extended to include issues such as compliance with building regulations then the view was there would be an immediate take up of such a system on the basis of productivity gains.

There was also interest from this group in terms of addressing frequently encountered problems. It has been noted earlier that there is a reliance on designers to have a professional approach to ensure health and safety issues are properly covered during the design process. This reliance on experienced designers is fine until they move on, and valuable expertise is lost from an organisation. It would be of interest to both experienced and inexperienced designers as to how others had addressed routine but testing operations such as cleaning gutters of overhanging eaves, and having such information available in an easily accessible form would be of considerable value.

In the context of knowledge based systems, there is a wealth of knowledge and expertise within the HSE itself which could be of immense value to the construction industry. The important issue of how to provide access to this and other relevant information was taken forward into the second part of the project.

6 Potential use of simulation tools

software companies perspective

6.1 Computer software in the construction industry

Historically the construction industry has been very fragmented in its use of computer software, reflecting the fragmented nature of the construction industry itself. Numerous packages have been developed separately to address the requirements of the various disciplines involved in construction projects. Each package has evolved to suit its particular market with little regard for using the data at a later point in the project life cycle, and this has been particularly true for analysis and design packages.

Contracting organisations are however showing considerable interest in being able to bring together the various individual pieces of information that together comprise a typical building or other construction project. The initial driving force for this was to ensure compatibility between architectural, engineering, mechanical and electrical components so as to eliminate problems of fit. They are now moving on to consider construction planning and maintenance processes, but in many cases by the time the contractor is involved, the design has been completed and construction or maintenance problems are already 'locked in'.

An interesting comparison can be made with the situation in the Process Plant Design industry. The complex layout of structural members, process vessels and pipe-work has led to sophisticated plant design packages. At the core of these packages is a 'space utilisation module' which holds the assembly of all the components making up the plant. The sizing of pipes or structural members is done outside this core module, but once all the components are included it is possible to create virtual reality models of the plant. Utilising large format virtual reality display suites, groups of construction, operation, maintenance and health and safety personnel can review these models. However, it would appear that the main health and safety use is to check out operational issues such as fire escape routes, maintenance access etc., rather than initial construction issues.

6.2 Sample of construction industry software vendors and packages

During the industry interviews a number of CAD and design software packages were identified, and this has largely determined the software companies included in this part of the project.

Information about the software packages has been collected through a combination of product brochures, vendor web sites, and telephone conversations with vendors' representatives.

The software companies are listed in Table 2 and, for the purposes of discussion in this report, have been divided into 4 groups.

The first group is General CAD. Products in this group are best regarded as systems which are used throughout an organisation for the purpose of modelling and drawing production. Typically they include facilities for creating 3D visualisations, including virtual reality.

The second group consists of specialist analysis, design and detailing packages which tend to be discipline specific, for example structural analysis, steelwork detailing, and mechanical services design. For convenience this group is referred to as Specialist Design packages.

The third group is classified as Management or Information packages. This includes project management packages, and packages which collate data from various sources.

It also covers systems which provide information on aspects such as Building Regulations, Health and Safety Legislation, Contract Specifications. These are predominantly text based systems.

The final grouping is Integrated Systems, and to date packages in this group have been predominantly developed within the research environment. The key feature of these packages is the inclusion of links between packages from the previous three groups.

6.3 Software evaluation

As a general observation health and safety is rarely mentioned in software product brochures for General CAD and Specialist Design packages. Discussions with vendors from these groups confirmed that it is not regarded as a priority issue. As commercial organisations they are focussed on the provision of solutions which they can sell to their users. Much of the justification for adopting computer systems stems from the ability to improve product design by better analysis, or to derive productivity benefits associated with faster working, removal of repetitive tasks, elimination of errors etc.

Visualisation and virtual reality features are becoming more and more common within the General CAD and Specialist Design packages. Whilst this certainly has the potential to assist in identifying health and safety problems, its use tends to be at the end of rather than during the design process.

The concept of including health and safety rules in the design packages was clearly not something high on developers' lists of priorities. By implication it is probably fair to say that their users and prospective users are not pressing for health and safety features within the software.

In contrast, health and safety matters figure strongly within certain Management or Information packages. These packages are aimed at providing organisations with assistance in complying with the various regulations encountered in construction projects, but as pointed out earlier they are predominantly text based systems. Typical uses are the provision of check lists for health and safety assessments, guidance on applying the CDM regulations, and an electronic environment for creating health and safety plans and files.

This would suggest that the information needed to encourage designers to include health and safety issues at the design stage is available, but the information is not readily accessible in Specialist Design packages at the appropriate point in the design process.

The relationships between General CAD, Specialist Design, and Management or Information packages currently prevailing within the construction industry are shown in Figure 1.

The two way links shown between general CAD and specialist software packages have been developed to enable efficient interchange of information. These have come about through the desire of the General CAD and Specialist Design package developers to make their products attractive to end users by allowing re-use of data.

The one way links from General CAD and Specialist Design packages to the Management and Information packages have again been developed to enable data to be brought into packages to create things such as bills of quantities, production scheduling, stock control and so on.

The missing links in the commercial software arena are those which feed data from Management or Information packages into General CAD and Specialist Design packages. It is felt that it is this facility which will enable health and safety information to be presented to the designer at an appropriate time. The mechanisms for providing these links have been proven in 'demonstrator packages' developed in research environments, e.g. Refs. 2 and 3, within the context of Knowledge Based Systems. This is discussed further in the next section.

However, the overall impression of the current status of software packages in the construction industry is that health and safety information is not well integrated into the design process.

7 Knowledge based systems

It was reported earlier that during the industry interviews the concept of knowledge based systems attracted considerable interest from many of the people interviewed. Such a system would seem to offer the greatest potential for improving designers' awareness of health and safety issues, especially if it was based on a central source of information which could be accessed from existing General CAD and Specialist Design packages. This would overcome the need for each package developer to implement a health and safety option.

The question to be addressed is how to deliver the information.

7.1 University research example

In recent years a number of research projects have been carried out to demonstrate the application of knowledge based systems within the construction industry. One such example, described in (Ref. 2), was focussed on the design of tubular steel trusses.

The aim of this project was to develop a computer based decision support tool which would facilitate a construction-led approach to design. The designer can then assess the effects of design decisions on fabrication, transportation, and erection costs, and assess the constructability of designs. To achieve this, the information flow from each of the individual processes involved in the total construction process had to be integrated into the support tool.

Information was provided to the designer through a series of modules accessed through a central core. There were three main modules, a Structural Module to carry out analysis and design, a Cost Module to cost the production of the truss, and an Advice Module. It is this Advice Module which is of most interest to the present project.

The advice module contained knowledge based systems (KBS) to provide advice on design, fabrication and erection/CDM. The design KBS highlighted features which would contravene good practice. The fabrication KBS examined the layout and fit up of the truss and identified features which would adversely affect the fabrication cost. The erection/CDM KBS assessed the design from the transportation, erection and safety viewpoints.

Acquiring the information for the KBS in the Advice Module involved interviews with parties who could contribute to a particular KBS. The aim being the formation of a suitable set of rules which are subsequently manipulated within the advice module.

Third party software exists for the manipulation of the rules and decision making process which can be integrated into the central core for interaction with the designer. In this way the designer is provided with relevant information on all aspects of the design at the appropriate time.

7.2 The International Alliance for Interoperability

The fragmented nature of software currently in use within the construction industry was mentioned in the previous section of this report. In 1995, twelve companies involved in the Architectural, Engineering, Construction and Facilities Management Industry (AEC/FM) started the International Alliance for Interoperability (IAI). The common goal was to be able to work with each other's information without having to worry about the software being used. That membership of IAI is now over 600 companies in more than 20 countries is indicative of the interest in the concept. The IAI is now organised into Chapters, each of which represents an international region.

The vision of the IAI is to enable software interoperability in the AEC/FM industry.

The intention of the IAI is to specify how construction objects should be represented electronically. These specifications represent a data structure supporting an electronic model which is useful for sharing information between applications. Each specification is a 'class', and the classes defined by the IAI are termed 'Industry Foundation Classes' or IFCs.

The IAI does not write software, but it develops the IFC Object Model and specifications which software companies can use to develop applications. The various specialist disciplines involved in the AEC/FM are referred to as 'Domains', and Domain committees provide the structure for defining IFCs.

The two major general CAD system vendors within the AEC/FM market are supportive of IAI, and have already implemented published IFCs.

IAI could provide an environment for including health and safety information in individual components within the object definition for IFCs. Health and Safety has not been a domain to date within the IAI work, but there is no reason why it should not be so. One of the significant advantages of this approach is the vendor independent, user driven nature of the IAI activities.

Further information on the IAI is available in Ref. 4.

7.3 aecXML

Another possible implementation strategy is via aecXML. Interest in this approach is currently being shown by a number of organisations as a means of delivering up to date information at the right time in the design process.

aecXML is currently being promoted as a simple means of sharing data within the AEC/FM industry. Conceptually an aecXML 'wrapper' is placed around the object information, enabling the information to be shared with other aecXML compliant software.

The US Chapter of IAI has embraced the aecXML concept and has it as one of its domains, and software applications have already been developed based on aecXML as the data exchange mechanism.

The UK Chapter of IAI is similarly supportive of aecXML, and it has been recognised that some data will have to be handled locally because of national or local regulations.

As with the original IAI work, a major potential benefit is the ability to get information into the General CAD environment. This is the environment most likely to be used throughout the design process, and certainly most likely to be used at the preliminary design stage where the opportunity to influence the design is greatest.

Further information on aecXML is available in Ref. 5.

8 Conclusions

In general, designers within the construction industry are aware of, and in many cases make use of, visualisation packages. These visualisation packages are usually associated with General CAD and Specialist Design packages.

There is a general recognition within the design sector of the construction industry that Visualisation, including Virtual Reality, has the potential to assist in assessing health and safety risks associated with construction projects.

The potential for using Physics Based and Ergonomic Simulation in day to day design work is considered to be limited. However it would appear to have potential for use in application areas such as developing training material and guidelines on human factor capabilities.

The General CAD and Specialist Design packages currently in use within the construction industry do not provide features directly related to the health and safety aspects of design. Furthermore there is little evidence to suggest that such features will be implemented in the immediate future.

There is considerable interest within the design sector of the industry in the concept of knowledge based systems. Delivery of relevant information, including health and safety, at an appropriate time in the project life cycle is seen as a valuable aid to increasing productivity.

Technology is available, or is under development, with the potential to reduce the fractured nature of computer usage within the construction industry. These technologies could be used to facilitate the delivery of knowledge based systems to designers.

Without some form of encouragement from Government or the Heath and Safety Executive, the software vendors within the construction industry are unlikely to include health and safety features in their packages.

Whilst it is outside the scope of this project, it is clear there is considerable concern within the construction industry over the amount of paperwork involved in compliance with the CDM regulations.

9 Recommendations

To achieve the goal of having health and safety information readily available to designers during project design requires the HSE to be proactive in the provision and delivery of appropriate information.

In respect of providing appropriate information, the HSE should investigate the feasibility of structuring its health and safety knowledge and experience in a form suitable for use as a Knowledge Based System.

In respect of delivering appropriate information, the HSE should investigate in detail the available mechanisms for delivering its health and safety knowledge and experience to designers.

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- Oscar Faber, Manchester
- Paul Dinsdale Associates, Buxton
- Sir Robert McAlpine, Hemel Hempstead
- The Design Group Partnership, Manchester.
- Virtual Worlds, Bolton
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Ref	Title
1	CONVR 2000 – Conference on Construction Applications of Virtual Reality, 4th – 5th September 2000, University of Teeside. Editor Prof. N. Dawood
2	Yusof, K.O., McCarthy, T.J., Smith, N.J., and Tizani, W.M.K., (1997). A Decision Support System for Construction-Led Design. 4th American Society of Civil Engineers Congress on Computing in Civil Engineering, Philadelphia. June 1997
3	Walid Tizani, Darshan Ruikar, and Rob Smith. The 3D Virtual Building Design Tool. Conference on Construction Applications of Virtual Reality, University of Teeside. 4th – 5th September 2000.
4	IAI UK Chapter web site: http://www.iai.org.uk
5	aecXML web site: http://www.aecxml.org
6	The Construction (Design and Management) Regulations, 1994. HMSO, London.

Table 1 Interview Matrix

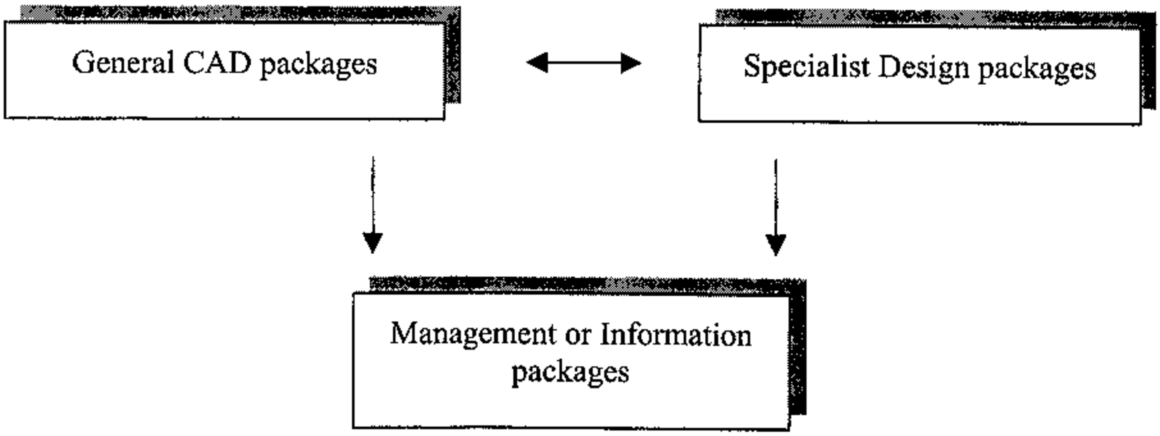
	Steelwork	Consulting Engineers and Architects	Clients
Large	1	1	2
Medium	1	1	
Small	1	2	1

Table 2 Software Vendors and Products

Software Vendor	Products
General CAD packages	
Autodesk Ltd Cross Lanes, Guildford, Surrey. GU1 1UJ 01483 462600	AutoCAD AutoCAD Architectural Desktop 3D Studio Viz
Bentley Systems 013444 12233	MicroStation MicroStation Triforma
Specialist Design packages	
CSC (UK) Ltd Yeadon House, New Street, Pudsey, Leeds. LS28 8AQ 0113 239 3000	FASTRAK S-FRAME and P-FRAME TEDDS 3D+ FABTROL
Strucad (UK) Limited Longchase, Moneyrow Green Road, Hollyport, Maidenhead, SL6 2NA 01332 207344	StruCad StruAnalysis GoData
CADCENTRE International High Cross, Madingley Road, Cambridge, CB3 0HB 01223 556655	PDMS REVIEWReality
INTERGRAPH Process & Building Solutions Delta Business Park, Great Western Way Swindon SN5 7XP 01793 619999	PDS SmartPlant Review
Research Engineers Draycott House, Almondsbury Business Centre, Bristol BS32 4QH 01454 207007	STAAD/Pro

Software Vendor	Products
Specialist Design packages - continued	
Oasys Limited Central Square, Forth Street, Newcastle. NE1 3PL 0191 238 7559	GEO GSA ADC STR
Nottingham University AIMS Research Unit, University Park, Nottingham. NG7 2RD 0115 951 4094	SafeVR
Management or Information packages	
ErgoSystems Southbank House, Black Prince Road London SE1 7SJ 020 7724 5200	CDM Range Planning Supervisor Principal Contractor Project Coordinator
Croner.CCH Group Limited 145 London Road, Kingston upon Thames, Surrey. KT2 6SP 020 8547 3333	Information Systems
NBS Services The Old Post Office, St Nicholas Street, Newcastle. NE1 1RH 0191 232 9594	Specification Software Building Regulations Approved Documents Construction and Building Abstracts
Integrated Systems	
Nottingham University School of Civil Engineering, University Park, Nottingham. NG7 2RD	3D Virtual Building Design Tool
UMIST Department of Civil & Structural Eng, PO Box 88, Sackville Street, Manchester. M60 1QD 0161 200 4609	IDS ICDS

Figure 1 Existing relationship between software groupings



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