Invited Paper

Web-based Collaborative Working Environment and Sustainable Furniture Design

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Abstract

To meet the demand of online collaborative design, a Web-based Collaborative Working Environment (CWE) has been developed. An approach to enhance sustainable furniture design by utilizing the CWE is proposed. In this paper, the CWE framework is briefly presented, which consists of upperware, middleware and resource layers; then three key aspects of sustainable furniture design by utilizing the CWE are presented, including material and manufacturing processes selection, design for disassembly and damaged furniture return, followed by an example of damaged furniture return using the CWE to further illustrate the approach.

Keywords:
Collaborative Working Environment, Web/Internet technology, Sustainable Design, Furniture Design

1 INTRODUCTION

It usually requires team work to successfully conduct product design through the total design process, and the team members are often geographically dispersed, which requires collaboration amongst different sites. Such situation places a great demand for Web/Internet software tools/techniques to effectively support the representation, collection and exchange of product information during the design process [1].

Along with the development of Web/Internet technologies, the Web based collaborative design was initially based on the first generation of Web technology, such as CGI, Servlet, etc. Leslie [2] described an approach to apply Computer Supported Collaborative Work (CSCW) technology for the product design and development process. Within this approach, the virtual integrated product design is viewed as a distributed and iterative process that involved significant sharing of information early in the design processes. Such systems have integrated applications and databases distributed at different locations. These systems are primarily closed systems, i.e. only selected users are allowed to access.

In order to get the full benefits of object-to-object interactions, the collaborative design integrated the second generation Web/Internet technology, such as Object-based Modelling Environment (OBME), Remote Method Invocation (RMI), and Common Object Request Broker Architecture (CORBA).

In OBME, an application at one location provides live services that can be used by other users at different locations through Internet/Web tools. End users can also develop new applications using the existing services provided [3]. In addition, several commercial Internet/Web infrastructure development tools, such as WebSphere by IBM and WebLogice by EBA, have also been introduced to reduce the efforts for implementing service-based Web applications.

Roseman and Wang [4] presented open-system architecture for a collaborative CAD system supporting virtual product development. The system contains a reusable software package or application, which is designed as the component agent. All the standard applications have two main parts, the implementation and the data. The interaction between two applications is achieved through the database. In that system, the ORB, COM and EJB, which allow the components to work together, are called 'middleware'.

Kan [5] described a Web-based Virtual Reality Collaborative Environment (VRCE), which was developed using VNet, Java and Virtual Reality Modelling Language. The system provided a portable, low hardware demand and customizable system with a set of comprehensive functions that facilitates virtual collaboration for product design. VRCE, using client-server architecture, for clients with low computing power can connect to a more powerful server, so that more computable or process job can be delivered into the server [6].

With the development of Web/Internet technologies, such as Grid, Web services, Wireless computing, peer to peer and mobile agents, combination of multiple Web/Internet techniques to form a more powerful collaborative working environment (CWE) has been emerging, which is known as the third generation of Web technology. As an emerging Web technique, it has been attracting researchers' great attention due to its great advantages for application in collaborative product design and manufacture. For example, Wamg and Zhang [7] proposed an integrated collaborative approach for complex product development in distributed heterogeneous environment. Xiong, et al [8] developed a Service Oriented approach for software sharing, consisting of three components: Application Proxy Service (APS), which provides a surrogate for a running shared application process to control access to it; application proxy factory service and application manager service. In an Internet environment, multiple users can access a Web service with any client at the same time.

The Advanced Design and Manufacturing Engineering Centre at Nottingham Trent University has been actively involved in the application of CWE into collaborative design and manufacture, for example, the project of Web-enabled environment for intelligent manufacture supported by the EU-Asia IT&C programme [19], development of mobile collaborative environment for product design [20], and CWE for furniture design [11]. The research reported in the following sections is resulted from their efforts to apply the CWE into sustainable design with particular concern of furniture design.

2 FRAMEWORK OF WEB-BASED CWE

As shown in Figure 1, the CWE consists of three layers: Upperware, middleware and resources. It connects with the applications via the upperware.

Upperware: The upperware layer interacts with the applications to provide specific services for collaboration enabled by the middlewares and the tools. It has the following functions:

- Coordination of the utilization of multiple middleware techniques including Grid, Web services, mobile agent and meta-data techniques.
- Process control of concurrence and consistency as well as synchronous and/or asynchronous messages. Process, elements (security, services, monitoring, etc) can be shared across applications to provide horizontal services to decouple these reusable application components, will facilitate more rapid changes in these processes.
- Group Task Coordinator is responsible for the task assignment of each requester, monitoring the action state of each requester and accepting the communication request and service from each provider.
- To provide an interface to the applications and to establish the connection between the applications and the middleware techniques specified in the underlying layer.
- To support plug and Play, in this field, a knowledge based module will be developed. Investigation will be carried out to help integrate dynamic plug and play for better system performance.

Underlying middleware: The underlying middleware is a class of software technologies to manage the complexity and heterogeneity inherent in the distributed systems. It is defined as a layer of software above the operating system but below the application program that provides a common programming abstraction across a distributed system and connects parts of a distributed application with data pipes and then passes data between them. It has two parts:

The first part mainly aims to coordinate four main enabling middleware techniques including grid, Web services, mobile agents and meta-date technologies. Each of the middleware techniques has different advantages and the combination of multiple middleware techniques will enhance the functions of the system. The task to make decision when to use which technique will be carried out in the upperware layer. The second part is to provide resource management in the system. It will provide functionalities to publish, search, locate and wrap to coordinate the resources, and to control the transmission of all feature model resources in the system.

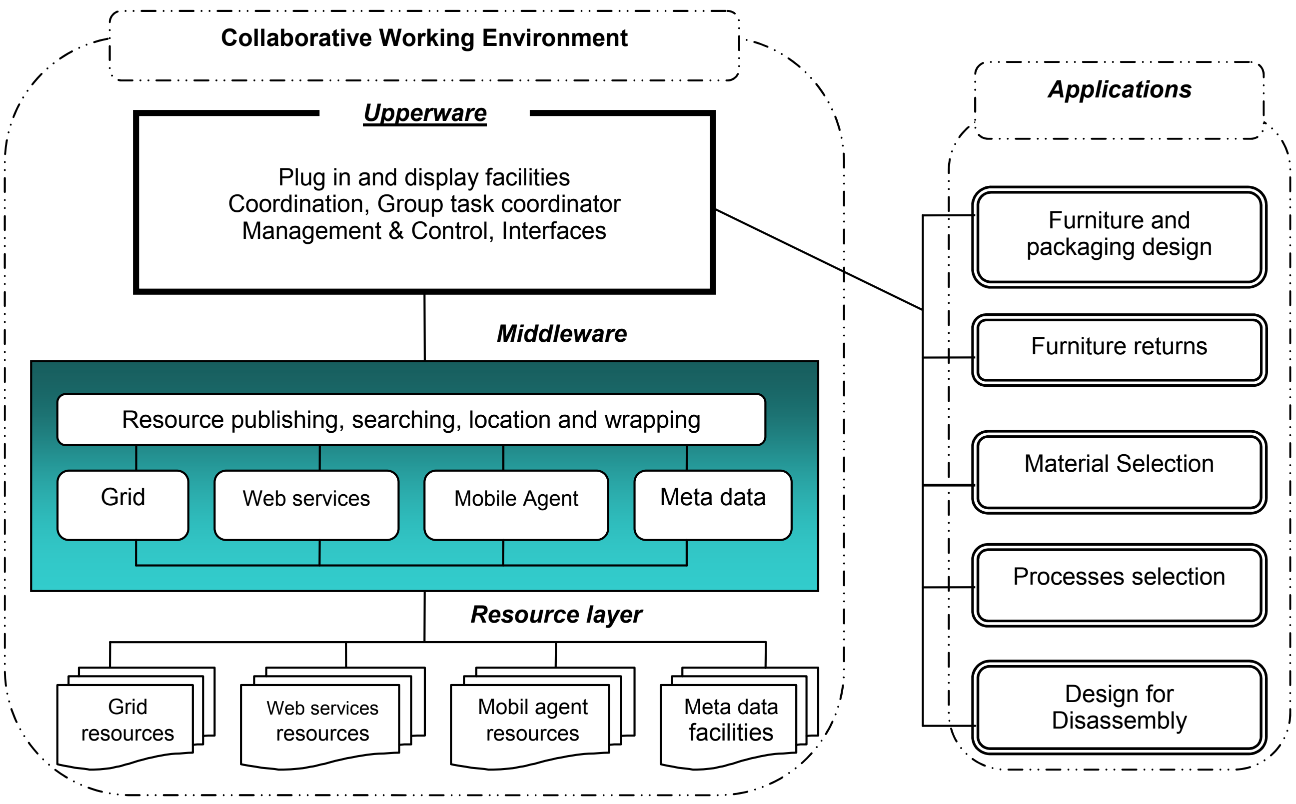


Figure 1: CWE framework

Resources layer: The physical resources would be wrapped into specific technology enabled ones so that they could be recognized by the collaborative working environment, and four kinds of resources are supported by default: Grid, Web Services, mobile agent resources and meta-data facilities. These resources independently exist in the system.

The CWE has been utilized in areas such as mechanical design [21], furniture design [11] and inventory management [12], but it has not yet applied to sustainable furniture design. In this research, the important feature of the CWE, its plug-in function, has been utilized to enable the flexibility for external applications to join the CWE. As shown in Figure 1, the external applications currently considered include furniture and packaging design, furniture returns, material selection, production process, and assembly.

3 SUSTAINABLE FURNITURE DESIGN SUPPORTED BY WEB-BASED CWE

Web-based CWE, as it has been explained previously within other areas, can facilitate the on-line exchange of heterogeneous data among geographically distributed collaborators within the total furniture design process. This platform can also be used to assist the design and development of sustainable furniture designs and packaging, thus leading to sustainable practices within furniture companies. This can be done through enhancing the exchange of data between collaborators and software/databases through Web-based platforms. Thus, Web-based CWE can assist with three critical areas within the design of sustainable furniture, namely:

- Selection of materials and manufacturing processes
- Design for disassembly
- Furniture return and damages

3.1 Selection of materials and manufacturing processes

The need of more sustainable design practices within furniture requires easier access to more data in order to carry out better informed design decisions in relation with sustainable practices. There is a need of tools that can assist the design process taking into account the selection of materials and manufacturing processes within the furniture industry with environmental issues in mind. Although, there are already software in the market (SimaPro, ECO-it, etc.) that can estimate the impact the product will have before it has been produced, these software are stand alone tools that have not yet been integrated within Web-based CWE, thus reducing the scope and access of this data produced to more varied and geographically distributed people involved in the design and development processes.

3.2 Design for Disassembly

As indicated in its wording, *Design for Disassembly* makes the furniture easy to be disassembled, which can also reduce the impact of furniture in the environment. Guidelines about design processes that help to reduce the total number of furniture pieces and how these are assembled are important in order to allow shorter and easier disassembly processes, which may lead to higher rates of recyclable and remanufactured parts.

3.3 Furniture returns and damages

Better and more effective management of information related with furniture damages during deliveries and handling, can improve/eliminate furniture returns within distribution processes. The CWE, as it will be seen in the following section, can assist in reducing the number of furniture returns, through the provision of a platform that can support designers to make more informed design decisions, thus improving the furniture design structure, packaging and delivering styles. This can be done through systematic and effective recording of data that can then be exchanged through platforms such as the CWE.

4 FURNITURE RETURNS

4.1 Furniture returns overview

Furniture returns remains an important issue within the furniture industry, returns rates are considered to be of 5-15% in the furniture industry, caused during transit, delivery and storage [13]. It affects negatively the economy of the company and the environment, as it produce incremental costs due to additional processes (finishing, assembly, manufacture, and packaging) as well as the subsequent increment in energy expenditure. In addition to this, it produces customer dissatisfaction, thus decreasing sales. Current legislation related with packaging waste [14], Producer responsibility obligations (packaging waste) regulations 1997 and, Directive 94/62/EC on Packaging and Packaging Waste, as amended by Directive 2004/12/EC [15], already are pressing companies towards a more sensible management of their waste packaging, which means that companies have to be more aware and implement more efficient management strategies in order to create more efficient and fit-to-purpose packaging, which not only will produce environmental benefits but also will increase their turnover by 4% and even be as high as 10% in some companies [13]. It has also been observed that there is a lack of feedback between companies and retailers/users in order to solve the problems related with inadequate packaging and products returns [16] which reinforce the need for a more efficient and sustainable system that improve the communication between these collaborators within the Total furniture design process in order to carry out better informed design decisions by furniture designers, packaging designers and logistics of the company.

4.2 Damages found in furniture return

Furniture returns are produced because damage is caused in furniture during its transit, delivery and storage. Inappropriate handling, packaging (under-packaged or packaged in wrong areas) and storage, can lead to different type of damages. In a report carried out by FIET [17] seven types of damage were identified, namely: Breakage, bruising, scratching, abrasion, soiling, discoloration and climatic degradation.

These types of damage can be solved through adequate: packaging, furniture design structure and methods of handling, delivery and storage. Thus, all these design and development processes have to be informed about the quantity and quality of damage that are found in furniture after being distributed.

The main distribution hazards found by FIET [17] during the transit, delivery and storage were: Shock, vibration, compression and climatic.

During the transit, distribution and storage of furniture, distribution hazards take place leading to furniture damages (see Figure2).

In order to understand why damages are produced, distribution hazards have to be matched with furniture damages, so a cause-effect can be identified. This is not possible with current practices in the furniture industry where information about damages is not recorded through a database, which could be used in real time by other departments involved in the design and development of the furniture, packaging and distribution methods. There is a lack of database platform in order to record and share this information between in-house and external departments/collaborators.

4.3 Models to reduce furniture return

Traditional processes of furniture return are based on feedback of general information related with the damaged furniture, without any precise description and record of the type of damage in a database. As a result, the company and the departments involved in the design and development of the furniture design, design packaging and distribution methods cannot take informed design decisions, and the distribution hazards and, therefore damages, will take place in future deliveries. As it can be seen in Figure 3, when a piece of furniture is damaged, the retailer or user inform (feedback) the company in order to receive another brand new piece. This information is obtained by phone, fax or e-mail, and usually is very general, thus being difficult to analyze the problems in order to find a solution. When this information is not recorded in a systematic manner in a database, the information is lost and it might not be transferred to the different departments involved in the design of furniture, packaging and distribution methods.

The introduction of the Web-based CWE for management of data related with the type of damages suffered during the distribution processes can provide a platform where information can be systematically recorded and exchanged within different distributed locations within the in-house departments or external collaborators or departments (Figure 4).

The furniture return process supported by the Web-based CWE is based on the same structure used in the platform for the Total Furniture Design process [18], but this model is more focused on the specific application towards the management of data related with the furniture return process between different collaborators of the Total furniture design process.

Figure 2: Factors that influence furniture damage.

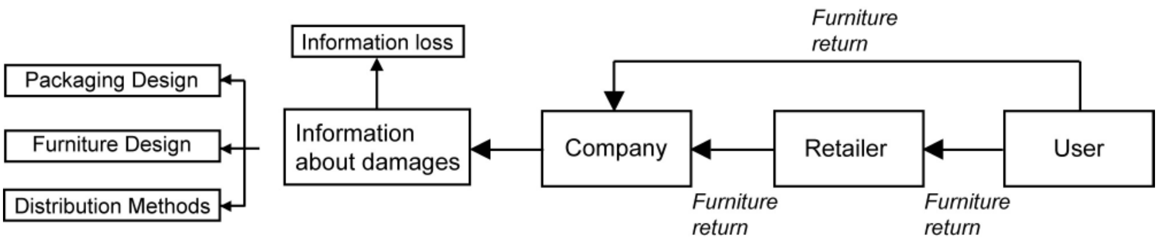
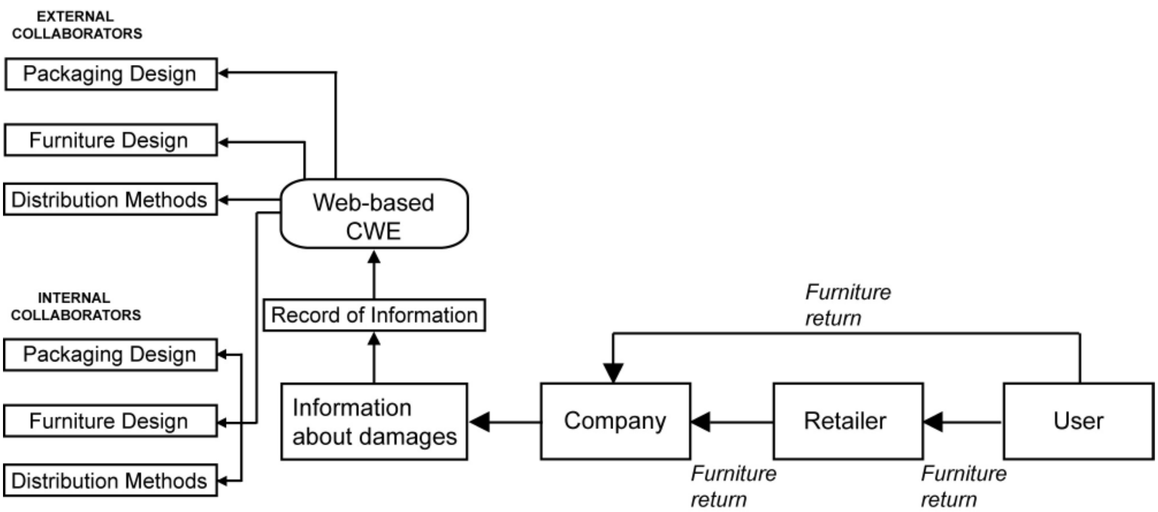


Figure 3: Traditional furniture return model.



4: Furniture return model supported by Web-based CWE.

4.4 Advantages of the integration of Web-based CWE for furniture return

The integration of this model has advantages in comparison with traditional models used in furniture companies. The main advantages can be seen in the chart (Figure 5).

Traditional model	Web-based CWE
General report of damages	Specific report of damages
Data is not recorded	Data is systematically recorded
No platform available for sharing data	Platform allows to share data
Data is not accessible to all departments	Data can be accessed to internal/external dep.
Does not lead to elimination of furniture returns	It leads to elimination of furniture returns

Figure 5: Traditional model vs. Web-based CWE furniture return model.

Traditional models do not usually record the damages in a database, and when this is carried out, the information is very general and it cannot be accessed easily by other internal or external departments/collaborators in real-time. The integration of the Web-based CWE in furniture return allow more detail of the type of damage found in furniture, and the record of this data in a platform that can be easily accessed by other internal or geographical distributed team members. In addition to this, this data can be used to monitor the problems and improvements carried out in the distribution process as well as to provide better informed design decisions. The use of this model can lead to the improvement/elimination of furniture return, whereas in the traditional model, design decisions are less/no informed.

4.5 Example of furniture return using CWE

In order to show how a furniture return process takes place, what are the distribution hazards, steps during the transit and delivery, and how these are dealt with in traditional processes of return furniture in comparison with return furniture assisted by CWE, an example of a piece of furniture (chair) manufactured and finished through outsourced companies, and assembled and packaged with facilities in-house will be used. The model of the chair is basically made of a metal lacquered frame and a back-seat piece framed of wood and upholstered.

In a traditional distribution processes (Fig.6), the distribution hazards begin from the moment the chair have been assembled and is stored for packaging, storage and delivery. Once the parts of the chair are made and finished they are sent to the company to be assembled. Assembled chairs then have to be handled (transit) for its storage until they are packaged. During this transit period, the type of handling of the product can cause damage to the chair, i.e., scratching on the lacquered metal parts or on the fabric of the seat-back piece. Whilst the parts are stored waiting for assemble and packaging, exposition to direct strong sun or high humidity can cause damages to the chair such as discoloration of fabrics as well as tensions in wooden frame joints, caused by wood internal fibers movement. During the packaging of the chair, careless handling can dirty the fabric of the upholstered parts, as well as the use of adhesive tape on lacquered areas, which after long periods of time and heat can cause damage in the finish when the chair is unpackaged. In addition to this, the inadequate stacking of chairs and packaging in order to use the space more efficiently inside boxes can lead to scratches and bending of legs, when these are not properly protected and correctly positioned. The handling of the boxes and location of these in the truck can also lead to damage in edges of legs and upholstered parts due to impacts or weight pressure and movement when they are stacked. Long periods of time inside compartments under high temperatures can damage lacquered parts, especially if they are in contact with packaging materials that can adhere to them. It also can affect the structural parts by weakening the mechanical properties of the glue used for wood joints, as well as movements of the wood in joints, which can have aesthetic consequences in wood that have not been designed with these movements in mind.

Once the consumer (retailer/final user), receive the chair packaged and realize it has suffered damages, a report is sent to the company informing about general description of the damages on the phone or fax. It is here, where the information although can be filed (fax) usually get lost or is not introduced systematically in an accessible database where different teams and internal/external collaborators can access in order to improve and solve these damages caused by distribution hazards. If this is not done, the order then goes onto production without recording this information and making difficult the posterior analysis of the quantity and quality of problems found in furniture. Thus, new pieces will be produced with the same inadequate chair structural design, packaging design and distributed using the same distribution methods during delivery. Obviously, this will lead to more chair returns so any improvement will have been done. On the contrary, if an inspection and record of the quantity and quality of damages (Fig.5) through a web-based simple application (Figure 6) is carried out when the chair is received; then this data can be exchanged through a Web-based CWE and accessed in real-time for other internal/external collaborators who are working in the design and development and can be used to inform future decisions in design which will lead to the elimination of damages in future distribution methods, thus reducing or eliminating furniture returns.

Thus, although the introduction of this quality system might take more time, as data have to be recorded, at the beginning, it would save time and money to the company as well as reduce the impact on the environment in the long term. Following the example, the damages found in the chair (breakage, scratching and bent legs) will be recorded in the return furniture application for Web-based CWE (Figure 7), it can be seen how the main types of damages found in furniture distribution can be selected after inspection of the furniture, as well as the intensity of the damage (intensity scale from 0-6) of each of these. In addition to this, the 3D model can be rotated in order to select visually the specific area that has been damaged according to the different types of damages found. There is also an space for other comments related with damages found that does not suit the main type of damages as well as the possibility to upload photos of the damages so collaborators can judge better what design decisions should be taken in future products, packaging or distribution style in future products and deliveries.

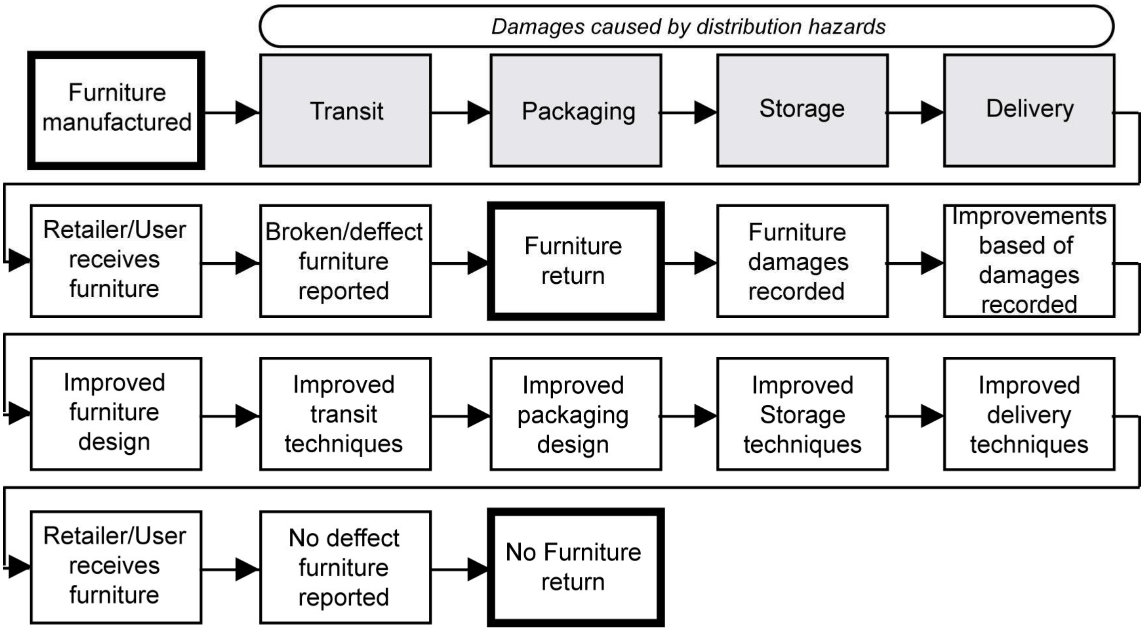


Figure 6: Furniture return process without/with the support of CWE.

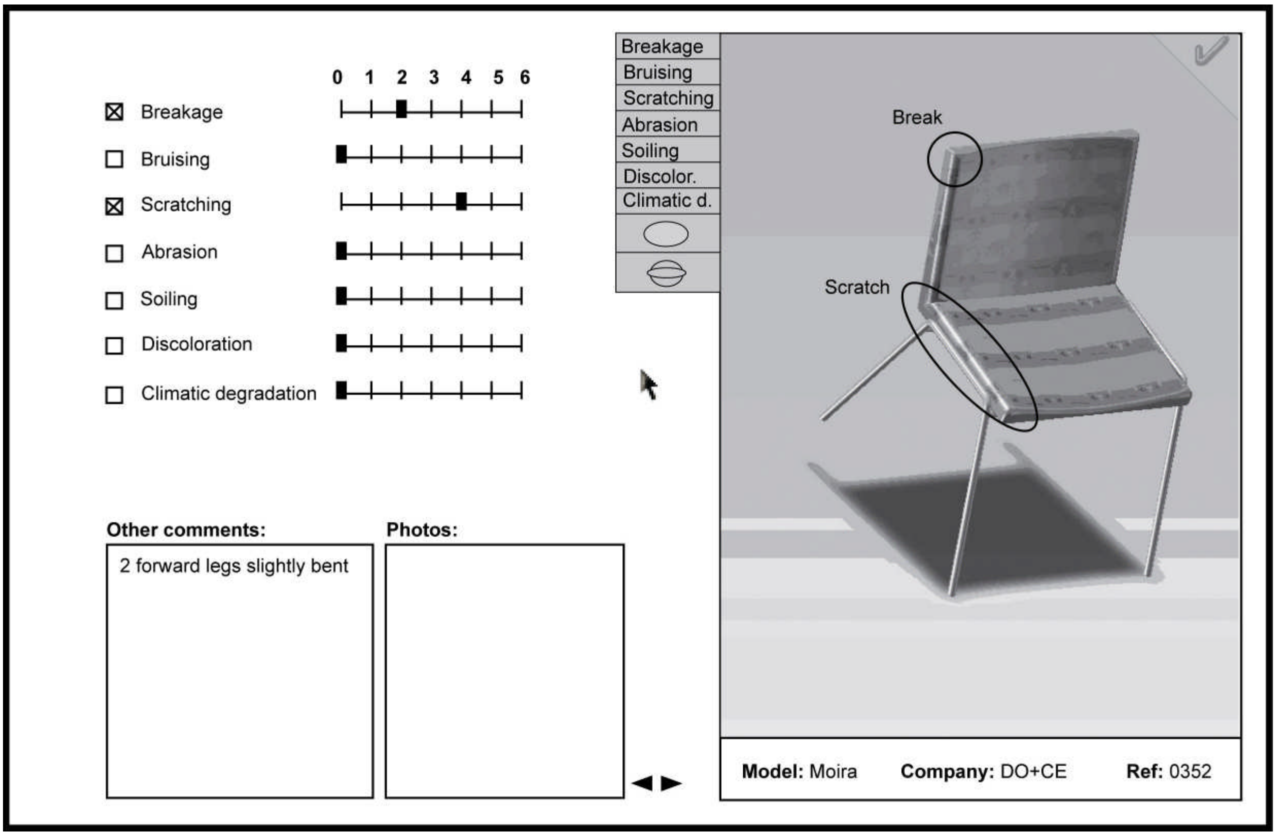


Figure 7: Screen capture of Web-based CWE furniture return model application

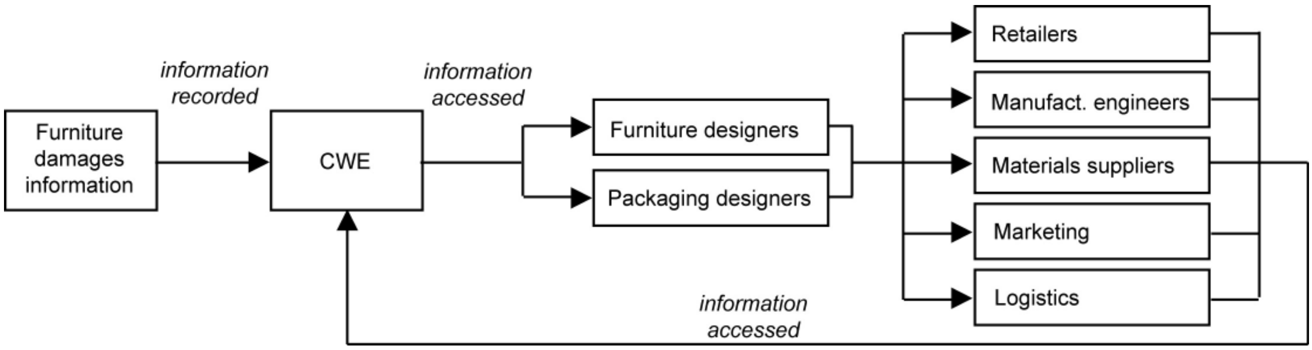


Figure 8: Exchange of data between collaborators using Web-based CWE for furniture return.

This information can also be used as an historic of damages for monitoring improvements, and for analysis of inadequate past design decisions. Likewise a quality system it allows the improvement of more efficient designs and methods.

The data recorded then can be accessed in real time by all the collaborators in the design and development of furniture and packaging. Thus, breakages in the edges of the wooden frame of the upholstered frame could be solved through reinforcing packaging cushioning in those areas in the packaging or by rounding the design of the chair in order to avoid edges. Bent legs can be produced by compression power when boxes are stacked in the truck, so more rigid frame boxes, more rigid legs sections or different type of stacking the boxes (less weight on the top or avoiding high heights) can result in improvements. On the other hand, scratching on the sides of the seat can be solved by different stacking positions, or by increasing the cushioning in those areas. Again, the design could also been modified if the other solutions result in expensive changes, It is here, where different design alternatives are 'weighted' depending on price, materials, processes, etc,; and where the easy access of this data from external (may be geographically apart) collaborators (suppliers, engineers, marketing, etc.) can help to make more informed decisions backed by their expertise in their areas. This information can not only be transferred to these collaborators in form of specifications, but also can be accessed by them individually in the original form when it was obtained (Figure 8).

5 CONCLUDING REMARKS AND DISCUSSION

The research reported in this paper is to apply the CWE into sustainable design with particular concern of furniture design. The CWE framework is briefly described first, then three key aspects of sustainable furniture design by utilizing the CWE are presented, including material and manufacturing processes selection, design for disassembly and damaged furniture return, followed by an example of damaged furniture return using the CWE to illustrate the approach proposed.

As a new generation of Web/Internet techniques, CWE has been utilized in areas such as mechanical design, furniture design and inventory management, but it has not yet been applied to sustainable furniture design; therefore, the research reported in this paper is a novel contribution.

Web-based CWE can facilitate the on-line exchange of heterogeneous data among geographically distributed collaborators within the total furniture design process, and, hence, it can assist the design and development of sustainable furniture designs and packaging, thus leads to sustainable practices within furniture companies. The research reported in this paper currently concentrates on the three aspects mentioned above; however, more aspects will be further addressed.

In this research, the important feature of the CWE, its plug-in function, has been utilized to enable the flexibility for external applications to join the CWE. The external applications currently considered include furniture and packaging design, furniture returns, material selection, production process, and assembly

Damaged furniture return is used as a vehicle to demonstrate of the CWE approach for sustainable total furniture design. It may be argued that in some cases, it costs more to return damaged furniture to the manufacturer in comparison to other means; however, it has been used by some companies in practice, particularly for those expensive classic furniture products. Also, it is an important way to protect our environment by reducing the waste, and, hence, the CWE for sustainable furniture design is a useful sustainable technique.

The research is at its early stage, and a simple product, a chair, is used in the example for illustration purpose only. More complex case studies will be developed at the next stage of the research in order to explore more features and advantages of the approach proposed.

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