4. Document Management in CLDC

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In current engineering practice, be it concurrent or otherwise, documents are the central mechanism for communicating, informing and instructing. Any attempt to engender a greater uptake of concurrent engineering in the industry has to recognise the central role of documents in process reengineering. The proper management of documents has the potential to greatly improve the design process in terms of efficiency and effectiveness. It is estimated (by document management system developers) that professionals in the industry spend 30 percent, or more, of their time managing documentation in current paper-based management regimes, and the source of much litigation in the industry can be tracked back to improper management of documentation. IT-based approaches can greatly impact on document management; however, to date the various aspects of IT applied to engineering have developed independently, leading to stand-alone product, process and document management systems. This development path, though productive in each individual area, misses the major gains that can be achieved from integration of all aspects of IT usage. This chapter shows that the proper management of documents provides information about all aspects of a project. It is argued that, through careful management, documents can provide the means to effectively co-ordinate work on the activities required to complete a project, and to determine how processes can be managed to greatest effect using concurrent engineering frameworks.

4.1 What is a document?

The meaning and scope of the word ‘document’ in the traditional design and construction process was always clear. A document was any collection of paper that related to a project. Several distinct styles of data layout were used to present information in these documents (see section 4.2). The physical nature of paper helped define its contractual and legal status as a document, but as we move into an age where an electronic representation of all traditional paper documentation is possible, the definition of a document becomes blurred. Some paper documents may not currently be able to be stored electronically (e.g., standards) and some forms of information that are sent electronically were not considered documents in traditional practice (e.g., e-mail or telephoned orders).

To help define the scope of electronic documents we use a modification of the paper document definition to specify that:

> *An electronic document records any transfer of information which occurs during a project, providing views of the project’s product model and supporting all processes in a project.*

This greatly broadens what can be considered as a document. It still covers everything which has a paper form, but also extends it to information transfers such as:

- phone calls
- a colleague's or third party advice
- project discussions
- data files used for a design tool
- video clips of the construction site

4.1.1 Document types required in construction

There are a number of documents traditionally generated and stored in paper form for construction projects. Their source and regarded status is as shown in Table 4.1.

Type	Author	Legal / contractual status
Brief	client / owner	high
Contract / commission	client	high
Drawings	designer / contractor	high
Specifications	designer	high
Bills of quantities	quantity surveyor	medium
Tender documents	designer	high
Valuations	quantity surveyor	medium
Payment certificates	designer	high
Program / schedules	contractor	high
Calculations	designer / contractor	medium
Site diaries	supervisor / contractor	medium
Change orders	client / designer / contractor	high
Progress records	supervisor / contractor	low
Claims/compensation events	contractor	high
Letters	all	high
E-mail	all	low
Fax	all	low
Request for information	contractor	medium
Confirmation of instruction	designer	medium
Notices	client	high

Table 4.1 Standard documents in a construction project (UK viewpoint)

For construction projects in which the design has often not been completed until hand-over (or beyond), forms of day-to-day communication need capturing. These include those shown in Table 4.2, all of which have contractual implications.

Type	Author	Legal / contractual status
Phone	all	low
Verbal order	client / designer	medium
Advice	all	low
Video / progress photos	all	low

Table 4.2 Communications in a construction project

4.1.2 Documents as the industry's knowledge base

Currently, documents and their management form the basis of the construction industry's knowledge base. All information about a project resides in documents. Decisions about a project (e.g., standards constraints, appropriate products) are based on information found within documents. A firm's library and the available published documents form the knowledge base from which the industry operates. The mark of a successful project is often how well this vast store of documents is managed, both within an enterprise and across enterprises on a project.

4.2 Paper-based document management

In current practice, documents are usually distributed, and held, in paper form requiring a costly and resource-intensive filing, retrieval and issue system. It is estimated that 30-40% of an engineer's work effort on a project is concerned with the management of documents. The scope and layout of documents are determined by practice and may be laid down in standards which differ from project to project, company to company and, of course, country to country.

Construction projects are characterised by their one-off nature and the rapid assembly and disassembly of the project team and their members, many of whom join during the project and depart before its completion. Many construction organisations are very small (1-2 persons) and may only be formed for the particular project, these organisations have in the main not made the transition away from paper-based systems. Even larger organisations have failed to embrace the idea of electronic document management and interchange, mainly because there is no industry accepted standard, there is incompatibility between systems adopted by organisations, and penetration is limited so that paper versions are anyway needed at all times.

Current practice therefore is for all documents, even those that have been generated or transmitted electronically, to be stored as paper for distribution and legal or contractual purposes. Individual firms then run different management processes for the documents pertaining to a particular project usually associated with a particular classification system to enable efficient retrieval at a later stage. This process is cumbersome and error-prone, explaining many of the problems in the industry with out-of-date versions, missing documents, etc.

4.3 IT-based document management

From very early in the commercial use of computers document generation and management has been a major function to be supported. The visionaries foresaw a world where physical documents were not required (with advertising slogans around the 'paperless office') and then as work was undertaken on product modelling systems they also prophesised the demise of documents themselves. As is often the case the visionaries' expectations of computers were far in excess of their capabilities and didn't take into account human factors in the application domain of their computer systems. It is clear that physical documents will not disappear and that documents as an information transfer mechanism on projects will be with us for many decades yet.

However, IT-based document management systems (DMS) can support many tasks on a project and there is a range of functions available in current DMS which would provide benefit for the construction industry in the short term. See for example, Wager and Winterkorn (1998) who present a summary of over 45 DMS categorised by potential functionality, along with user surveys and case studies, or Laiserin (2001) for a more recent view of surviving products and strategies in the market. However, as there is a very low uptake of DMS in the industry these benefits are not realised. The short term benefits which could be realised by utilisation of a DMS (a general overview is found in Laqua 1999) are mostly in the automation of non-value adding processes, e.g., automatic forwarding of documents to a set of team members on completion of a particular process or activity. Standard functions could also automate many of the tracking and verification activities required for dispute resolution by recording who received what documents, at what time, and by recording when the recipient opened the document. Standard functions will also allow security to be implemented through digital signatures to ensure that original versions can be identified and encryption should be used to ensure that unauthorised access to documents can be controlled. For example, Mokhtar and Bedard (1994) proposed a central database as the source of all technical documents to reduce the estimated 50% of problems in buildings which arise through decisions and actions taken in developing working drawings. They envisaged such a system helping through the production of integrated documents, through quicker communication of documents and through the production of document types which span disciplines.

Although an electronic document records any transfer of information it need not contain the full content of the information transfer. For example, an electronic document representing a verbal order is likely to contain the essence of the order rather than the whole audio capture of the conversation (though this may be recorded if required). In many cases the electronic document may capture a reference to existing paper documents which were utilised during the project, e.g., a firm's collection of printed codes and standards.

Related research projects include Turk (1994), Björk (1994) and Turk et al. (1994). These projects operated on the assumption that, as a preliminary means to achieving Computer Integrated Construction (CIC), a construction document management system (CDM) could be constructed. The CDM is seen as a short term solution, being replaced by full product management systems when the technology matures. A strong case is put for the need for explicit research work on development of CDM systems for the integration of documents within single projects across organisational boundaries. However, it is clear that different disciplines' views of a proposed building are irreconcilable with computerised tools, so even an integrated product database will not provide the ability to reconcile all views.

4.3.1 Functionality that can be supported

There are a number of fundamental activities that a DMS is capable of supporting, these include the following:

- **Storage and retrieval of documents.** Providing access to project participants to deposit or retrieve documents into the system. Can be tied with security systems to ensure only appropriate project members manipulate documents in the system.
- **Notification of document updates.** Linking process management into the handling of the documents to ensure that particular events trigger messages to particular members of a project team. This ensures tracking to identify who was notified of modified documents(e.g., a signed-off document).
- **Compatibility with paper systems.** Allowing a mix of electronic and paper documents to be incorporated in, or referenced from, the same system.
- **Common file formats or error-free conversion methods.** To allow all document types to be viewed or transformed. An industry accepted standard would greatly assist setting protocols for each new project and team.
- **Document access management.** Access is to be recorded and identity noted; whilst modification to a document should not be possible, it may be used as a template for a new version and that action recorded.
- **Version management.** Latest and earlier versions must be retrievable and must be able to determine the history of document revisions and those project participants involved.

- **Search functionality.** Full text search functionality in text based documents must be possible. The descriptive data sets identifying a document (meta-data) should be searchable and include all necessary information such as type, project, contents, originator, date (created/sent) etc.
- **Electronic signature.** An electronic signature will need to satisfy legal and contractual issues.
- **Markup.** Annotation, such as red-lining, can be applied to documents within the DMS.
- **Shared database.** Other users must share the document management system databases.
- **User friendliness.** A new user to the system should only require a short training period (measured in hours), which should be held on site.
- **File locking.** The system must be able to restrict access to a document when it is under modification, or identify who is currently working on a particular document.
- **Views.** Parts of a document, e.g. a drawing, must be capable of being viewed without the need to call up the whole document.
- **Legal aspect.** The document must be retrievable in such a way that the legal requirements for its authenticity are fulfilled, i.e. data format and visualisation software have to be formally specified and linked to the document content.

4.3.2 Different models of IT-based document management

Document management systems (DMS) have been developed in several major forms. This section examines the major features of the main categories of DMS to detail the benefits they provide in a project and the drawbacks associated with them.

4.3.2.1 Electronic Document Management Systems and Product Data Management Systems

A range of bespoke and commercial Electronic DMS (EDMS) systems have been developed for the industry over the past few decades. These systems mostly aim at the internal document management processes that need to be supported by the organisation and hence try to reduce the overhead of document management by their staff and improve the organisation's management of document processes on a project. While these systems can provide benefit within the organisation for document processes they are seldom as effective in use on a project. This is due to the remainder of the project team not having access to the chosen system, or not being happy to discard their own systems to use another system for a single project.

Manufacturing industries rely to a great extent on long term partnerships through an extended supply chain where it is feasible to install compatible electronic document management and transfer systems, and in fact may be a prerequisite for joining the partnership. The construction industry is, however, more likely to be comprised of short term relationships and sub-contracts, the duration of which may often be shorter than the time taken to produce the product (the constructed asset). Various contracts are continually formed, and disbanded, during the production process of the building, which makes it difficult to ensure that such an approach will be adopted by later parties.

Tangible benefits to these participating organisations e.g. improved product quality, timeliness and lower whole life costs, will encourage the more extended supply chain sub-contractors to embrace the concept, providing there is an industry standard. In fact, many organisations which provide products and components for the construction industry also supply other manufacturing industries more at home with EDM.

The major services offered by EDMS for engineering and construction are: the ability to manage CAD files; document capture through scanning and conversion; folders or cases for handling complete projects; recording document workflow to allow documents to be routed to users; distributed databases for interoperability; integration of other databases and computer networks; high security control; ability to handle large numbers of documents (in the hundreds of thousands); and the flexibility to manage compound documents of various types.

The types of document that can be recorded in electronic form could be maintained in a plain relational database system, which would be managed by all those people concerned with a particular project. However, if a domain specific system is implemented, with knowledge about documents and their usage, a much higher level of functionality can be supplied to the users. This can be seen in the commercial arena by the plethora of EDMS which are available for managing documents, over a hundred of which are aimed at engineering documents. Knowing the nature of the objects that it is dealing with, an EDMS can automate many document management tasks, such as logging document creation and modification times or automatically generating version numbers for modified documents.

Product Data Management Systems (PDMS) have the properties of an EDMS as well as further product specific functionality, the major components of which are: configuration control for products and assemblies; management of relationships between items (e.g., CAD and word processor files); control of variants versus standard products; change impact assessment and management; and improving the flow of application data.

Though there are over seventy-five readily available commercial systems aimed at engineering domains (IIC and Cimtech 1997), these have had very limited take-up in the construction industry. Most of the commercial EDMS are aimed at individual firms, and the total management of documents inside the firm, rather than at a project level with the recognition of multiple external partners needing to collaborate. The commercial EDMS vendors appear unaware of previous research into integrated design systems in the construction domain so their products tend not to support connections with product models. Most systems treat documents and their management as a totally disparate field from product modelling, though there are enormous overlaps in the information manipulated in both of these areas.

A recent research project tackling the interoperability issues in this area was the EC funded CONDOR project (Rezgui and Cooper 1998). This project aimed to specify a unified interface to a range of DMS systems so that the problem of multiple systems in use by the organisations coming together for a project could be overcome. The final system looks like a single DMS, though requests related to documents could be propagated to a wide range of systems sited in different organisations.

4.3.2.2 Internet-based DMS

A major new trend, as with many service-based systems, has been to repackage DMS systems into an Internet form. As DMS provide some form of groupware functionality (computer mediated human to human interaction) they benefit from development within a medium which provides open and affordable access to all potential participants in a project. The majority of Internet-based DMS are based upon the same principles, and proffer the same functionality, as the existing EDMS developments. They do, however, have the following important beneficial attributes:

- Affordable, pervasive, and consistent interface. The availability of freely available commercial web browsers on almost every type of machine allows a unified service to be provided to almost every potential user of the DMS. The service is guaranteed to reach all users across all platforms in the same manner.
- Simplified training for the DMS. By utilizing the web browser functionality and standard web protocols there is a large reduction in the training which needs to be expended in getting users up-to-speed with the DMS.
- Interoperability of DMS system components. As the DMS is based upon Internet protocols there is greater potential to link with related services and provide users with a greater depth of task support than a stand-alone DMS system can hope to achieve.

A major impact in this area has been the emergence of CAD-linked Internet-based DMS from all of the major CAD vendors. These sites have given industry professionals, utilising the same CAD system on a project, the ability to easily establish project specific document management across the whole project team.

The Internet community have also been interested in documents and have developed mark-up languages for the representation of documents in the Internet medium (e.g., HTML, XML, etc). Though these standards do not currently have the representational power to rival the standards used in construction (e.g., CAD representations) they can certainly represent the meta-data required for a DMS to perform its functions. For example, Zarli and Rezgui (2000) surveyed technologies for documents within virtual environments. They describe a general architecture for the construction of open and dynamic virtual environments, and recommend XML technologies for future developments in this area. DocLink (2002) defines a set of XML-encoded transactions enabling a standardised interface to DMS systems, similar to the CONDOR concept previously described. The XML approaches are also mooted as potential paths to reduce the amount of effort required (and hence pathway for errors) to enter attributes and classifications for all documents within a DMS system.

4.3.3 Legal aspects

The production and storage of documents on computer systems has become common practice in the manufacturing industry (and is becoming so in the construction industry) and will increasingly be used for business transactions such as ordering materials and plant. Codes of practice are a standardised method to ensure consistent and competent application of good practice for a particular purpose. For example, the British Standards Institution (BSi) Code of Practice ‘Legal Admissibility of Information Stored on Electronic Document Management Systems’ (BS PD0008 1996) covers issues such as systems planning, implementation, initial loading, and procedures for the use of the system. It pays particular attention to setting up authorised procedures and subsequently the ability to demonstrate, in a Court of Law if needed, that the procedures have been followed. However, legal or contractual admissibility of electronic documentation cannot be realised without the consent of the contracting partners. They need to feel secure when acting upon electronically transmitted data as opposed to waiting for the paper version to be delivered some time later.

The BSi Code of Practice also notes that image-processed documents are currently treated in the same way as photocopies or microfilm (i.e., as secondary evidence). In the adversarial legal system, the other party may try to discredit the integrity of the electronic document and the system on which it was recorded, as well as to dispute its content. There is a long tradition of trust in paper based documentation and limited knowledge, and therefore limited confidence, in electronic methods. In cases where an electronic document has been submitted, the Court will want to question its history in order to evaluate its validity and evidential weight. This forces organizations to ensure appropriate processes and tracking exist to ensure that their document management system will be recognized as providing the same level of reliability as paper-based processes.

Contracts entered into between the players early on in the process can be readily formed on the understanding that data will be exchanged electronically, perhaps as dictated by the client. Under traditional forms of construction contract, the design and construction phases are carried out by different organisations, each contracted to the same client. In such situations the client can impose a requirement that all data will be exchanged electronically. However, the client normally has little jurisdiction over the main contractor's sub-contractors and it is hard to envisage how the idea of EDM can be taken beyond that being exchanged between the client, the consultant organisations and the main contractor.

Yogeswaran and Kumaraswamy (1997) surveyed the major causes of construction litigation, many of which revolve around unclear and inadequate documentation. They detail how IT can be used to reengineer contract documentation to help reduce such claims.

4.3.4 Future IT directions

It is likely that IT-based DMS will follow a fairly conservative development path, with more features supported in existing systems, and greater interoperability offered across systems and to related services (Björk 2003 addresses 10 business research issues). However, a few IT advances provide future technical paths for DMS.

Looking to Internet technologies, the success of systems such as Napster and Gnutella point to the possibility of point-to-point topologies for DMS. This could provide greater control over document management for individual organisations, but also enable them to publish required documents for project collaboration. It also moves away from reliance upon a single centralised document server of one type to a distributed approach which would better suit the plethora of systems hosted by different organisations.

With the increased storage capacity available on PCs and servers within organisations and with compressed sound formats it is easily possible to record all utterances on a project as part of the store of documentation for a project (less than a terabyte is required to retain every conversation a person hears in their lifetime, Bell and Gray 2001). Though social considerations are likely to influence whether this becomes normal practice, it provides a further aspect which can be incorporated within a DMS.

4.4 Forthcoming roles for document management

As documents are not going to disappear in the foreseeable future it is worth looking to the processes in construction which could be impacted by continued use and integration of the evolving DMS available today.

4.4.1 Combining product, process and document views

Boundaries currently exist between project views of product, process and documents. However, there are inherent relationships between documents, data, and process and these are likely to become more intertwined. The first part of the document, process, and product triangle comprises the connections between a document and the activities which went into the document creation. Documents are part of the input to the majority of activities and are part of the output of many activities or processes in a project. This idea ties to previous work in the development of generic process maps for construction (BAA 1996) which are then specialised down to the actual project level with known teams and responsibilities. Current work on data standards provides the representational capability to manage the connections between process and related documents and products.

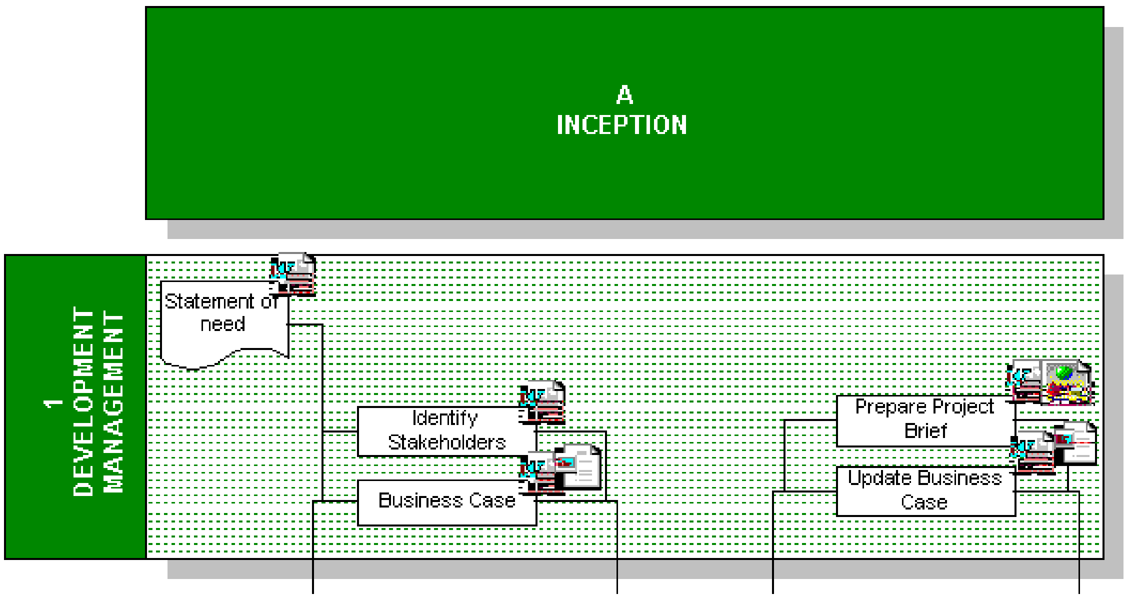

Figure 4.1 A process map specialised for a project with relevant documents (BAA 1996)

Figure 4.1 can be used to demonstrate how such a process map can be used either for current working, for checking on past work, or for a look-ahead to future work requirements. Figure 4.1 shows part of the detailed process for a construction project with processes to be completed and the flow of control between the processes. In this view it also shows the documents which feed into each process and those which are created during the process. In this view the user can inspect all of the documents which fed into the process and which came out, for example, a series of Word documents, CAD detail drawings, and a VR mock-up of views when passing through the building.

With an active process map the user is informed of the running processes and can see the status of documents and models (completed, being worked upon, and not started) which are being created or modified during the process. In the future view the user can identify all documents which must feed into a process and determine from which processes these documents will be created, and hence what still needs to be completed before the examined process could be activated.

These process maps allow top level general information to be viewed and also provide the ability to drill down to very detailed process specifications. At the top levels the system shows the documents which feed into any of the processes encapsulated by a top level general process, and any outputs from the lower level processes which feed into other processes further down the line. That is, these process maps show the document interfaces between processes, either aggregated at higher levels, or in great detail at the more detailed process level.

The final part of the product, process, and document triangle is the possible linkages from product models, and the tools which manipulate product models as part of the design and construction process, to the related documents and processes. To this extent all product information should allow a user to navigate through to the related documents and processes. Current work on standards, especially the IAI-IFCs version 2.x (IAI 2001), provide the representational capability to manage the connections between products and related documents and processes.

For example, in a CAD system it should be possible to select a single element (or a whole sub-assembly) and determine which documents refer to, or impact on, the selected element. These documents would provide information on constraints on the element, e.g., signed off specifications, as well as preferences for its design. At a later stage in the building's life, for example during facility management and maintenance, the documents would provide information on the original specification, tenders, and as-built drawings. This access to the document trail helps to identify who has been (or is currently) working on the element selected and what decisions have been made which may impact on the work that is currently being performed.

In terms of enhanced co-operation and collaboration these linkages provide users at all stages of a project with directed access to all information which relates to various portions of the building, no matter where this information might be stored. This can help ensure that all participants in a project are aware of the decisions which affect their work and are aware of the current set of constraints which limit what they are able to do in their work. In terms of managing liability in a project it ensures that all participants are aware of the constraints on their work and at what stage of finality the portion of the project they are working upon is currently at.

4.4.2 Dispute reduction

Document management in CLDC has the potential to reduce disputes on projects through guaranteed supply of up-to-date information to all project participants. It also introduces new methods to ameliorate legal admissibility considerations for previous problem areas. The major ones are considered below.

Verbal instructions issued on site have always been a breeding ground for legal and contractual wrangles. Contracts usually have a clause providing for a maximum time by when a verbal instruction must be confirmed in writing, often by the receiver of the instruction back to the instructor, who of course can query it. As often as not the work will have been started before the written confirmation has been generated. This gives the person carrying out the work the opportunity of matching or revising the original instruction to the actual work carried out. This, not surprisingly, leads to dispute.

There is emerging technology that should now resolve this in the form of hand- and palm-held computers (or even wearable computers) that can communicate not only with each other via infrared but with head and site office PCs via modem. This means that the whole team can be immediately appraised of the instruction and provide the necessary support, or countermand it if there are wider implications not appreciated on site.

Telephone conversations pose similar problems and require confirmation if a contractual event, such as a request or instruction is included. Actual recordings are not considered viable, they are time consuming to review and are treated with suspicion. However, the fact that a phone-to-phone connection was made, when and for how long is commonplace for billing purposes. Obviously the nature of the conversation is not recorded or even if anything pertinent was said at all.

E-mail and messaging has the advantage of being relatively easy to operate and the system can record that it has been received. It should not be difficult to note that it has at least been read by requiring an acknowledgement.

Site diaries are kept by the client's site representative and are often submitted as supporting evidence in case of disputes. These have traditionally been in hard copy format (like a ship's log) to be inspected by the client's contract supervisor during site visits. Items recorded will include delivery of materials, labour on site, inspections, visitors, site activity, weather conditions, stoppages, etc. Diaries are often backed up with site progress photographs normally taken from fixed locations and on a regular basis e.g. weekly or monthly unless specifically requested. A digital camera or video used by an inspector (e.g., mounted in a hardhat) could provide a useful and accessible view for the off-site team and provide supporting evidence for contractual debates.

4.4.3 Supporting Health and Safety and Building Handover

In many countries, regulations (e.g., the Construction (Design and Management) Regulations (CDMR 1994) in the UK) have created new legal responsibilities for clients and their consultants and contractors when undertaking most forms of construction. The construction industry has an unenviable track record when it comes to health and safety and regulations like CDMR aim to improve this, not only during construction, but also when carrying out the maintenance, alteration, refurbishment and ultimate demolition of the building. A Health and Safety file is prepared during the design and construction of the building containing information for safe occupation and is handed over with the building to the owner. This becomes a legal requirement and is accompanied by a considerable amount of drawn and manufacturers' information which is rarely structured in a form that is useful for the facilities manager. Providing mechanisms to allow the appropriate extraction of views of the DMS repository suitable for this purpose then becomes an interesting issue. Clayton et al. (1999) examine how to provide facility information automatically structured into documents appropriate to support facility management.

Regular daily photographs linked to activities will also provide a useful record of how the building was put together, where services are buried and how to access or dismantle parts of the building for future maintenance, replacement and refurbishment.

CAD drawings often lose attribute data if they are transferred to other applications such as those operated by the facilities manager. The facilities management application will only use the final versions of design drawings and rarely needs access to earlier versions. Layering the information for facilities management use will ensure the right level of data is transferred at hand-over and hopefully cut out the huge mass of superfluous information.

4.5 ToCEE: an example of advanced document management

As an example of the potential of document management as part of a concurrent engineering environment we discuss the European Union funded project ToCEE (Towards a Concurrent Engineering Environment) which was completed in 1998 (ESPRIT 1995 and Amor et al. 1997). The primary objective of the ToCEE project was the development of an overall conceptual framework, along with specific software tools, for concurrent engineering support.

Key issues for a successful concurrent engineering approach that were addressed are:

- distributed process, product, document and regulation requirements modelling with special focus on intra- and inter-model operability
- inter-discipline conflict management
- legal aspects related to the product data and the electronic documentation
- information logistics and communication management
- monitoring and forecasting
- cost control

Models were developed by the project under separate work packages to cover process, product, logistics and documents, with cross-cutting themes of legal issues, conflict (clash) management and standards and regulations.

One of the major measures of the benefit of a concurrent engineering environment is its level of support for co-operation and collaboration between all participants in the project. The ToCEE project delivered an infrastructure which aimed to engender better co-operation and collaboration with a project through the provision of open interfaces to all participants' organisations and also through an open interface to all services provided to the project. This allowed controlled access by any participant to all levels of information in the system, whether that be the evolving product model, the state of the process management system, or the documents held in the project. Figure 4.2 shows the general framework of the ToCEE system in relationship to the clients and services involved. The server end of ToCEE ties together the full set of product, process, document, regulations, and conflict management systems from the involved participants to be visible through a single interface. Then from the client's end it is possible to access this unified set of services without regard to the location of any of the services or their information. Figure 4.2 shows the interfaces currently supported in ToCEE, which are via e-mail requests, through an Internet browser, or through tailored wrappers around existing design tools.

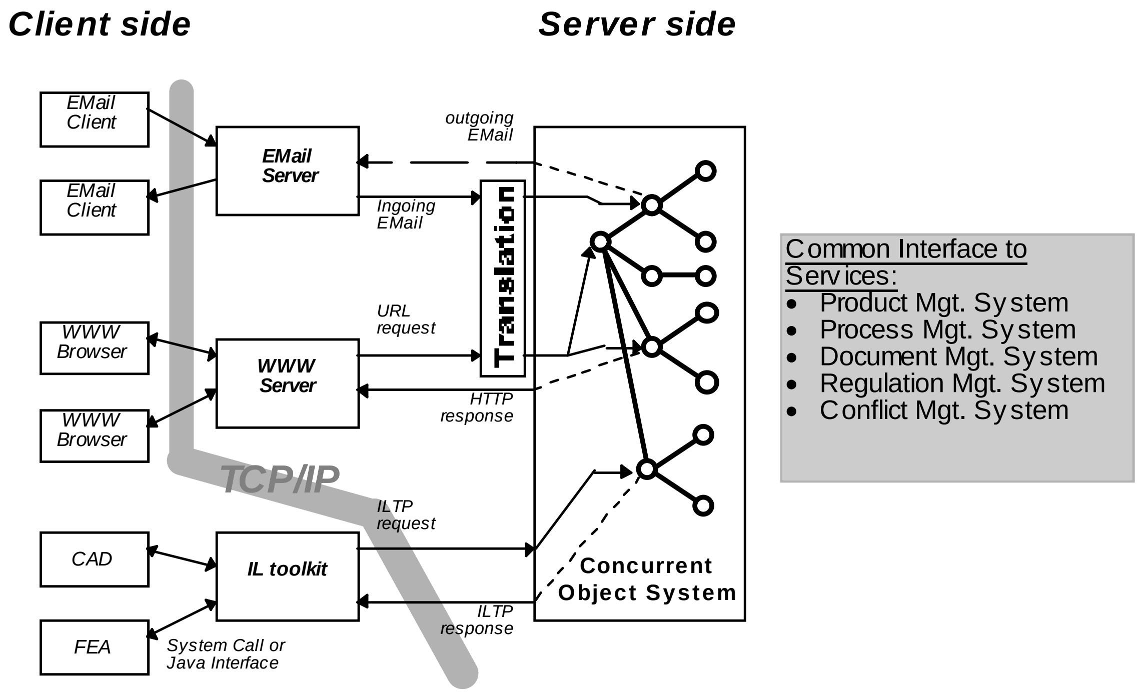

Figure 4.2 The ToCEE system framework

One of the servers implemented in ToCEE was a DMS managing all project documentation and communications. In this DMS particular emphasis was paid to how such a system can keep track of document version numbers, the interrelationships between documents, and how they could be audited (initial data models and functionality specifications of the DMS can be found in Amor and Clift 1996 and 1997). This was managed whilst retaining the document character of electronically stored data. The model had to have an open architecture which could be easily adapted by users to meet requirements particular to them. It had to address current and emerging standards for project information, making use of existing systems where appropriate and seeking to influence their future development so that they facilitate the future requirements of electronic concurrent (collaborative) engineering. Although the document model developed was specified independently from the product and process models there were close links between the models to help maintain the legal and auditing requirements of the emerging concurrent engineering environment.

4.6 Conclusions

It is clear that documents and their management remains a vital role in a successful project. The move towards IT-based document management, and especially Internet-based systems, is proving effective in supporting concurrent engineering principals, especially enhanced collaboration and cooperation across organisational boundaries for team members in a project. Though the use of DMS creates some legal issues in terms of processes and admissibility in a legal system based around paper processes there are best practice guides which ameliorate this issue. It is also clear that best-practice usage, and future developments, of DMS will provide for greater life-cycle support especially for facility management. The impact of interoperable systems, based around standard data models, is going to require integration across the product, process and document views which are currently treated separately in system developments in this industry. This remains one of the biggest research issues in effective management of information on a project.

4.7 References

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