Modelling the building cladding attainment processes

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Abstract

The cladding of a modern building is a critical, and expensive, specialist subsystem of the total building. This paper is concerned with modelling the supply chain processes within the building cladding sector of the UK construction industry. The modelling was conducted within the context of CIMclad, a research project involving a consortia of universities and industry that is seeking to move the cladding sector towards computer integrated design and manufacture. The goal was to better understand the existing supply chain processes. These processes are complex and span a diverse range of players, each of whom may play one or more roles. The methodology employed was a combination of informal mapping of the procurement chain and the application of formal process modelling techniques.

Introduction

The construction industry is under considerable pressure to improve its processes and to deliver better quality, cost effective, client satisfying and on-time construction projects (Construct IT, 1995; Construction Industry Board, 1997; DETR, 1998). Recent government-funded reviews (Latham, 1994; Egan, 1998) have highlighted the inadequacies of the business processes of the construction industry and outlined the considerable scope that exists for improvement. In response to this, many researchers have focused on modelling the industry’s business processes as a means of better understanding current practice and identifying specific processes that need to be re-engineered. Examples include: Froese (1996), Anumba & Evbuomwan (1996), Kamara et al (2000), and Austin et al (1999). While these efforts address aspects of the overall construction industry, there is very little work that focuses directly on the cladding sector.

The cladding industry is relatively small industry, but is rapidly growing and currently accounts for over £2 billion worth of output per year in the UK (Agabasi et al., 2001). Leading companies from the cladding sector have joined with Leeds and Loughborough Universities to form the CIMclad initiative with the goal of putting the industry on the path to processes integration and increased processes standardisation, following the general trend in the construction industry at large. The construction industry is under considerable pressure to improve its processes and to deliver better quality, cost effective, client satisfying and on-time construction projects (Construct IT, 1995; Construction Industry Board, 1997; DETR, 1998). CIMclad was conceived to investigate the feasibility of improving the efficiency and competitiveness of the cladding sector through the development of a standard framework leading, ultimately, to computer-integrated design and manufacture of cladding.

CIMclad selected as a pilot the particular class of building cladding known as “rainscreen cladding”. Also called layered cladding, rainscreen cladding comprises external decorative panels (that shed much of the rain and which can be made of a wide range of materials), an airgap, a vapour barrier and a supporting backing wall. The panels are normally supported off the backing wall by a grid of metal supports, typically the latter belong to a particular (proprietary) cladding system.

The objective of the modelling work reported on within this particular paper was to represent and to better understand the existing supply chains within the cladding sector. In this paper we introduce and
describe the UK supply chain for rainscreen cladding and present the modelling work that was conducted to gain this understanding. The understanding was subsequently used to guide and inform further research on how these supply chains could be improved, and the steps needed to create more effective business processes. This subsequent work led to the development of a roadmap to lead the cladding sector towards Computer-Integrated Manufacture; the further phases of the research will be reported on within papers that are currently under preparation.

**Modelling methodology**

The rainscreen attainment processes were modelled in two stages. The first stage was to create an informal model from design through to installation. This was intended as a concise activity sequencing map to portray the rainscreen process and thus to serve as an outline and a resource for the second stage, developing a formal information flow model. Created using the IDEF0 methodology (see later), this model spans the main aspects of design, development, marketing, manufacturing, supply, fabrication and installation of a (generic) rainscreen cladding system, modelled from the viewpoint of senior engineers within the industry supply chain.

The resulting model is applicable to all the main procurement routes and is too large to reproduce in its entirety within this paper. The complete model can be found in one of the CIMclad project reports (Kalian et al., 2001) together with further discussion of the various procurement routes.

**The rainscreen supply chain**

**Functional overview of the process**

The overall supply chain of a building project includes the client, advisors, designers, contractors and suppliers. The supply chain for the rainscreen cladding includes more specialist organisations (or more correctly “organisational roles”) such as backing-wall contractor, common materials suppliers, system owner, profile extruder, accessories manufacturers, panel material supplier, panel fabricators, cladding fabricators, specialist installers and installation gangs.

Without making reference to a particular procurement method, it can be said that the client generally employs advisors to help put ideas together and develop an overall project brief. These advisors can include quantity surveyor’s, architects, bank managers or the client’s own management team. The client advisors obtain information from (or information is supplied proactively by) designers and suppliers of cladding systems - including rainscreen cladding. In parallel with developing the design brief, the advisors are also likely to advise the client on the most appropriate procurement method. After the brief has been developed, project designers and subsequently project contractor are employed directly by the client or the advisors (depending on the type of procurement method used). Typically, rainscreen contractors are not involved in the early stages of the overall project design. The architect specifies rainscreen as a generic item and includes it in the overall project scheme-design and the general arrangement drawings. Rainscreen specific general arrangement, structural and detail/shop drawings follow later.

A backing wall typically supports the as-installed rainscreen. Construction of the backing wall may or may not be included within the rainscreen installer’s contract (it is likely to be part of a contract package undertaken by another specialist contractor). Irrespective of who does what, the rainscreen installation programme clearly needs to be co-ordinated with the construction programme for the backing wall, with a focus on the fixings.

**Table I** (see page 11) illustrates the potential complexity of the rainscreen supply chain relationships by suggesting how the previously identified organisational roles may be involved in generic tasks relating either to a design area or to a type of component.

The relationships between the parties within the rainscreen supply chain can vary widely. In the two sections that follow we look more closely at two main sub-supply chains:

- the design, manufacture and marketing of a cladding system; and
the design, fabrication and installation of a particular rainscreen.

System design, manufacture and marketing
The design, manufacture and marketing of a particular (rainscreen cladding) system can be viewed as a distinct supply chain.

The key player is the **system owner** who owns the rights to the system. Within the UK market the three strongest system owners are Cometec, Kawneer and Schuco (each of whom is a significant operator in the global marketplace). By definition, a system owner owns the patents to one or more systems together with a considerable body of knowledge and experience including specific documents such as design drawings, manuals and specifications. A system owner needs both the technical and the financial resources to warrant the performance of their system (when installed within their specified usage envelope). It is common for a system owner to have in-house capacity to manufacture the system profiles.

The second major player is the **system supplier** who sells a system into a particular market. As a minimum, this involves holding stocks of the profiles, marketing the system and providing technical support. The system supplier is typically a subsidiary of the system owner but, depending upon the market, the system supplier may simply hold some form of dealership. Depending upon the context, the system supplier may:

- buy his system profiles from the system owner or utilise local extruders;
- to a greater or lesser extent, localise the system owner's design; and
- have the capability to warrant the performance independent of the system owner.

Three characteristic variants on the system supply chain can be identified:

1. **Dominant system owner**
   Where the system owner acts as the system supplier and has the in-house capacity to manufacture (extrude) the necessary system profiles:
   - uses own manufacturing capacity for making dies and profiles;
   - produces profiles and stocks them in bulk;
   - typically out-sources accessories and stock them in bulk;
   - provides localised system design and warrants performance.

   It is typical for a dominant system supplier to seek to increase their dominance of the supply chain through the marketing strategy of supplying of bespoke system specific design software to the cladding fabricators.

2. **Dominant system owner out-sources profiles**
   As above except that the extrusion of the system profiles is out-sourced.

3. **Localisation by system supplier**
   This form of supply chain is found where the system owner does not dominate a local market and is reliant on the experience of a (local) system supplier to partly redesign the system for local conditions. In this situation the system supplier:
   - has a licence to localise the system design for a specified market;
   - may also assume responsibility for warranting system performance;
   - typically out-sources the system profiles and stocks them in bulk; and
   - typically out-sources accessories and stock them in bulk.
Rainscreen design fabrication and installation

The design, fabrication and installation of a particular rainscreen installation can also be viewed as a distinct supply chain.

This supply chain includes design, fabrication and installation activities, but the key determinate of the shape of the supply chain is who holds the cladding contract with the main contractor. Contractually, it is the organisation who holds the cladding contract that is responsible for the design and for the performance of the rainscreen, although this responsibility may be passed on to others (such as the system supplier). Two shapes of supply chain can be distinguished: one when the contract is held by a fabricator, and the other when the contract is held by an installer. It should be noted that some companies act both as fabricator and as installer.

Where the rainscreen contract is led by the cladding fabricator two, types of fabricator are recognised: a panel fabricator who typically only fabricates the cladding panels, and a rainscreen fabricator who typically fabricates and supplies the other components of the rainscreen. Many of fabricators have the capability also to act as a specialist installer of cladding, enabling them to assume full contractual responsibility for the whole of the cladding. Two characteristic variants on the rainscreen design, fabricate and install supply chain can be identified:

- A dominant rainscreen fabricator who undertakes the rainscreen (or wider) cladding subcontract from the main contractor, acting both as the panel fabricator and the specialist installer.
- A less-dominant rainscreen fabricator who undertakes the rainscreen (or wider) cladding subcontract from the main contractor, but out-sources the panel fabrication to a panel fabricator and/or the installation and commissioning to a specialist installer.

On an installer led rainscreen contract, the main contractor subcontracts the rainscreen (or wider) cladding to a specialist installer who:

- typically out-sources design responsibility and performance warranty to a rainscreen fabricator;
- out-sources detailed design and supply of components to the rainscreen fabricator;
- out-sources panel design and supply to a panel fabricator; and
- installs and commissions the rainscreen.

Process modelling

To understand and to depict the complex relationships that have been described above, and to better understand the associated flows of information, a process model need to be established. A two-stage approach was followed to deliver a well founded generic process model for rainscreen cladding.

The first stage was to create a preliminary map of the domain from design through to installation. This was intended as an activity sequencing map to portray the rainscreen process, and thus to serve as an outline and a resource when developing a more formal process information flow model.

The second stage being to create a formal process information flow model using IDEF0 process modelling techniques. This model spans the main aspects of design, development, marketing, manufacturing, supply, fabrication and installation of a (generic) rainscreen cladding system modelled from the viewpoint of senior engineers within the industry supply chain. The model is applicable to the main procurement routes design and build, traditional, management and partners approaches via a fabricator led or a specialist installer led rainscreen contract.

Preliminary mapping of the domain

During this first stage of the process modelling an informal model intended that mapped the process on a single A4 sheet was developed using a conventional block and arrows hierarchy. Mapping process activities in this way is an effective enabler for expert knowledge elicitation and discussions with industrialist (Kalian et al., 2000).
The resulting model shown in Figure 1 (see page 10) and portrays the as-is rainscreen processes from design to installation. The model represents a generic process sequence. At the fabrication and installation stages it depicts the two main rainscreen procurement methods, and at design stage the four main types of project procurement approaches. For simplicity this model ignores information feedback between the parties thus, although this way of mapping depicts activity flow in sequential patterns, this should not be taken as being the typical progression of the activities. The more formal IDEF0 model (which should not be read sequentially) is better able to represent such complexity.

The informal model was used as a discussion enabler during the first steering group meeting and subsequently during the industrial visits to illicit current industry practice. Enhancements arising from these discussions with a diverse range of industrial partners give some confidence that the map provides a good reflection of the processes.

**Formal process information flow model**

During the second stage of the process modelling a formal activity model was developed spanning the main aspects of design, development, marketing, manufacturing, supply, fabrication and installation of a (generic) rainscreen cladding system. It was modelled from the viewpoint of senior engineers within the industry supply chain, and is applicable to the main procurement routes discussed previously. The scope of the model includes:

- Cladding a new building and over-cladding of an existing building.
- External links to the overall design and construction of the building.
- The re-engineering of the cladding system to address a situation that lies outside (but close to) its normal design envelope as specified by the supplier.

Thus the model addresses a partly-engineered rainscreen installation. The more typical standard installation of a cladding system is a simplification of the model, while the less common fully-engineered installation would require an extension to the model.

![Figure 2: IDEF0 model: Inputs, controls, outputs and mechanisms](image)

This second more formal model was produced using the IDEF0 functional modelling methodology. One of IDEF (Integrated Computer Aided Manufacturing (ICAM): DEFinition) family of modelling techniques, IDEF0 (IDEF0, 1993) has been very widely used for process modelling and results in a hierarchy of related diagrams plus a supporting glossary. The basis of an IDEF0 model is that an input is consumed and transformed by an activity into an output (see Figure 2). An activity is triggered when the state of the input and the control allow it, while the mechanism identifies the primary means by which the activity is executed. Thus a control governs when an activity occurs (and is not necessarily consumed) while a mechanism is something that is used (but not consumed) during an activity. In an IDEF0 diagram the boxes represent activities and the connecting arrows represent things (e.g. raw materials, products, documents, and data). It is the location of an arrow relative to the box it connects which determines its role (input, control, output or mechanism). The connecting arrows can split or merge, and a control may also act as an input (i.e. be consumed).
Table II: IDEF0 Model: decomposition of rainscreen activities

Table II illustrates how the top-level [A0] activity “procure and install rainscreen cladding” is hierarchically decomposed into lower-level activities, initially into the first level activities [A1], [A2], [A3] and [A4]. Space does not allow the seven formal IDEF0 diagrams to be reproduced, however the [A-1] context diagram is illustrated in Figure 3 and how the activities are decomposed between the IDEF0 diagrams is illustrated in Figure 4. Readers are invited to consult the full model, both the IDEF0 diagrams and the supporting glossary, as published in a CIMclad project report (Kalian et al., 2001) that is accessible on the web.

The [A-1] context diagram of the IDEF0 model (illustrated in Figure 3) only shows the top-level [A0] “procure and install rainscreen cladding” activity, but it defines the overall scope and the external connections of the full model. The model assumes a pre-engineered cladding system is employed, but that the particular installation falls outside the normal usage envelope of that system (thus requiring some engineering beyond the standard suppliers’ performance warranty).
The model highlighted the organisational roles (as described in Table I, see page 11), types of cladding systems, cladding panels and types of rainscreen installation. Three types of installation are described below.

(1) Standard (rainscreen) installation

A pre-engineered cladding system employed within the normal design envelope specified by the supplier of that system. The engineering design responsibility lies with the system supplier.

(2) Partly-engineered (rainscreen) installation

A pre-engineered cladding system employed outside (but relatively close to) the normal design envelope specified by the system supplier. The standard engineering design must be re-appraised, and the system possibly modified, as may be necessary in the particular circumstances. The engineering design responsibility is likely to remain at least partly with the system supplier.

(3) Fully-engineered (rainscreen) installation

Cladding that must be fully engineered, even if it includes components from a pre-engineered cladding system. No engineering design responsibility will lie with the system supplier (unless explicitly accepted by a system supplier acting as a rainscreen engineer for that particular installation).

The majority of rainscreens are standard installations, some are partly-engineered installations and only a few are fully-engineered installations. A system supplier may assume full engineering responsibility of a particular partly-engineered or fully-engineered installation. This can be either as an extension of the supplier’s normal technical support of their own cladding system, or simply through them acting commercially as a rainscreen engineer. New (generic) cladding systems may evolve from particular partly-engineered or fully-engineered installations.

One of the conclusions of the first CIMclad report (Agabasi et al., 2001a) was that the use of a product model to standardise the interface between concept design and detailed design (within the second of the two sub-supply chains) would be particularly advantageous. Mapping this onto the IDEF0 model, and referring to Figure 4, the scheme design for the total building is developed in [A22] and the general arrangement drawings in [A24]. Typically rainscreen design emerges from [A24] as no more than a performance specification and an indicative layout. Detailed design and the actual layout for a specific system takes place in [A32].

![Diagram illustrating activities from the IDEF0 model](image)

**Figure 4: Illustrative activities from the IDEF0 model**

This being the case, a requirement for the product model would be to capture the design intent in [A24] and transfer this to [A32]. Thus we need to study in greater detail what information is produced in [A24] and at least investigate the feasibility of starting further upstream in [A22]. If we are also looking to future support for computer integrated manufacturing we also need to look at the downstream requirements to [A34]. In defining the requirements for the product model it is clear that this must focus on the underlying information and not make assumptions about the contractual framework or the shape of the supply chain (since these are variable and could easily change in the future).
Conclusions

A study of the current building cladding attainment processes has been reported. Specifically, the UK rainscreen cladding supply chain has been described in some detail and the modelling of that supply chain, which underpins our understanding, has been presented.

Two distinct (sub) supply chains have been identified. In the first, a limited number of system owners and their associated system suppliers make available to the sector pre-engineered rainscreen cladding systems. The systems are marketed by the system suppliers who provide technical support to users of the system in addition to supplying the bulk supply of system components. The system supplier will normally warrant the performance of the system provided it is used within the specified design envelope. The second supply chain, which results in a particular rainscreen installation, embraces design, detailing, fabrication and installation. The contractual framework can differ, but typically a rainscreen contract is let against performance specifications and an outline layout. Typically, the contract is held by a rainscreen fabricator or a specialist installer and may be wider in scope that just rainscreen cladding.

The process model was used to scope the subsequent development of a product model for rainscreen cladding (Kalian et al., 2003), by helping to identifying its roles and thus its information carrying requirements, and the subsequent industrial trials of a prototype software implementation (Kalian et al., 2001a). However, as reported in this paper, the study also gives broader insights of how the cladding sector currently operates, exploring current information and communications within the supply chains. It has thus been used as a baseline for business process improvement studies leading to the publication of a roadmap for the cladding sector as presented within the final CIMclad project report (Agbasi et al., 2002).

Acknowledgement

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References


Figure 1: Informal model of the rainscreen processes
### Table I: Involvement of organisational roles in tasks

<table>
<thead>
<tr>
<th>Organisational Roles</th>
<th>Design Scope</th>
<th>Tasks related to …</th>
<th>Component Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Cladding</td>
<td>Rainscreen</td>
</tr>
<tr>
<td>Project Client</td>
<td>◊</td>
<td>◊</td>
<td></td>
</tr>
<tr>
<td>Client Advisor</td>
<td>◊</td>
<td>◊</td>
<td></td>
</tr>
<tr>
<td>Project Designer</td>
<td>◊*+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Contractor</td>
<td>◊*+♣</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backing-wall contractor</td>
<td>*+♣</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Material Supplier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Owner</td>
<td>◊*+♣</td>
<td>*+♣</td>
<td>+♣♣</td>
</tr>
<tr>
<td>System Supplier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profile Extruder</td>
<td>♠</td>
<td>♠</td>
<td></td>
</tr>
<tr>
<td>Accessories Manufacturer</td>
<td></td>
<td></td>
<td>+♣♣</td>
</tr>
<tr>
<td>Panel material supplier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panel Fabricator</td>
<td>+♦</td>
<td>♦</td>
<td>♦</td>
</tr>
<tr>
<td>Cladding Fabricator</td>
<td>*+♣</td>
<td>*+♣</td>
<td>♦+−</td>
</tr>
<tr>
<td>Specialist Installer</td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Installation Gang</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>

Each symbol represents a task. Any occurrences of a particular symbol in a:

- **column** indicates which organisational roles are involved in that task (relating to either a design areas or a type of component).
- **row** indicates which tasks (relating to design area and/or a type of component) an organisational role is involved in.

**Table I: Involvement of organisational roles in tasks**