Cladding sector road map for realising the CIM vision

Emeka Agbasi, Chimay Anumba and Alistair Gibb
Department of Civil and Building Engineering, Loughborough University, Loughborough, UK

Abdulla Kalian and Alastair Watson
CAE Group, School of Civil Engineering, Leeds University, Leeds, UK
**Cladding sector road map for realising the CIM vision**

**Keywords:** Cladding sector, computer-integrated manufacture (CIM), cladding product model, road map, supply chain

**Abstract**

This paper lays out a road map for computer-integrated design and manufacture of building-specific cladding systems, describing the key implementation phases and highlighting domains (supply chain organization, software vendors, suppliers, process modellers, etc) involved in each phase. It takes a holistic look at the way forward, identifying that such a long-term transformation will need to be managed strategically both at a company and sector level and that training and education within the sector will be pivotal. The development of appropriate cladding information standards is seen as an essential enabler and as a catalyst for change.

**Introduction**

The need to improve the efficiency of the construction project delivery process through closer integration and collaboration throughout the construction supply chain has been widely recognized in a number of construction industry-focused reports (Latham, 1994; Construct IT, 1995; CIB, 1997; Egan, 1998; SFC, 2002]. This is also reflected in Construction Industry Research and Information Association’s UK construction 2010 foresight report (CIRIA, 1999). This report concluded that the future of construction – the next ten years at least – will be about industrial restructuring, and re-engineering of the various processes to achieve improved quality and performance through integration of the project process and the management of supply chains. Information and communication technology (ICT) is an enabler of process improvement. Consequently, there have been a growing number of ICT initiatives and research efforts aimed at developing integration solutions throughout the supply chain in construction. A range of technologies at different levels of maturity have emerged which include data and process modelling, data management, data exchange standards, integrated project database, object oriented implementation, concurrent engineering systems, etc. Sun and Aouad (1999) have categorized integration efforts according to the breadth and depth of process and data integration. As part of the drive towards project delivery process integration, developments in the manufacturing industry are being applied to the construction industry. One such manufacturing
The concept is Computer Integrated Manufacturing (CIM) which emphasises integration and co-ordination of information and effort throughout all the functional areas of an organisation. CIM combines systems and technologies designed to integrate the data and information of a company’s business, engineering, manufacturing and management functions – a brief that spans much more than manufacturing (Hannam, 1997). In the manufacturing industry, CIM is increasingly being recognised as vital for success in today’s competitive climate. Anjard (1995) highlighted that improved product quality and cycle time, lower cost, and increased competitiveness and profitability as driving forces for CIM implementation in the manufacturing sector. However, Attaran (1997) noted that to realize these benefits requires rigorous planning at all organizational levels to develop an appropriate and long-term CIM strategy, taking into consideration the pros and cons of CIM with respect to organizational goals. Benefits associated with CIM working practice could also be achieved in small manufacturing companies (Caputo et. al, 1998). To improve productivity gains, CIM has been implemented in combination with concurrent engineering and knowledge management technologies (Prasad, 2000).

Effective and efficient information exchange and complete understanding of the processes are the foundation for a successful CIM implementation. In the construction industry (structural steelwork supply chain), the CIM concept underpinned the CIMSteel project which published product model based standards (CIMSteel integration standards) to address data exchange between applications software: CIS/1 (Watson and Crowley, 1995) and CIS/2 (Crowley and Watson, 2000). CIS/1 was quite limited in scope, and thus made little impact, but CIS/2 specifications are comprehensive and currently being implemented as data exchange translators by a group of applications software vendors working with the American Institute of Steel Construction.

This paper proposes a road map for the cladding sector as a whole to realise computer-integrated design and manufacturing for building-specific cladding systems, considering developments in industry practice and technology within the construction sector. It highlights a strategy for integrating the information requirements of a cladding project delivery process, from scheme design through to the detailed design, and the manufacturing process. The road map identifies the key implementation phases, including sectors within the supply chain, that are passed to reach the goal of computer-integrated manufacture of building-specific cladding systems. Pertinent issues relating to changes in
process and culture necessary for the realisation of CIM benefits across the cladding supply chain are also discussed.

**CIM working practice in cladding context**

Computer-integrated manufacture of cladding systems for a building project is still an aspiration in the cladding sector. The CIM vision or working practice is where the scheme design information of the cladding is transmitted digitally to the organisation responsible for the detailed design, and the subsequent fabrication of the cladding components is computer-controlled without the need for paper documents. Indeed, this digital integration needs to extend beyond manufacture through to stocking, dispatch and on-site installation. Today, different software vendors have addressed individual tasks leading to ‘islands of automation’ that are not integrated. From a software perspective, to achieve the vision of a fully integrated and largely automated cladding project process, a single software suite spanning the whole specification-design-manufacture-installation cycle is needed. However, given the wide spectrum of activities that would need to be supported (for example drafting, detailing, estimating, costing, planning, scheduling, CNC control), a more realistic approach to CIM in the cladding sector is to facilitate the effective flow of information between discrete applications.

Delivery of the cladding work package involves separate activities undertaken by different organisations. Missing information often results in assumptions being made and budget variations. Bottlenecks inherent in the current cladding procurement, primarily associated with information clarity between the scheme and detailed design stages, are addressed by CIM working practice. This would use a cladding product model to integrate the information requirements of project delivery processes across organisational boundaries, from scheme design through detailed design to the manufacturing and installation processes.

**CIM constraints and drivers**

**CIM constraints**

Currently a number of factors, particularly technological and cultural barriers, hinder integrating the cladding procurement process. These factors are drawn from current developments in the industry
practice and technology. Technical, process, and economical issues that hinder the adoption of CIM working practice in the wider construction industry include:

- Lack of effective data exchange capability between dissimilar software applications. For example, lack of integration of data between CAD and other applications. Common CAD data exchange formats, such as DXF or DWG, are limited to exchange of geometric information, and both formats are proprietary. The need to re-key any information due to data exchange problems defeats the object of CIM.

- Absence of a mature information-driven construction project delivery process based on agreed data structures and information management conventions. Also, the awareness of processes is largely implicit. It needs to be made explicit to support the development of integrated working and business process improvement across the whole construction sector.

- High costs of bandwidth for data exchange and for network maintenance within organizations (exchange of information over a still reluctant telecommunications system).

Additionally, there are also important e-commerce related contractual and legal issues. Other barriers that are specific to the cladding sector include:

- The current absence of commercially available generic software specifically to support the design and the detailing of cladding installations. Similarly, as cladding is a component-based assembly, the absence of complementary electronic libraries of cladding components.

- CIM is a relatively new concept within the cladding sector. As with the introduction of any new working method, there will be some resistance that needs to be overcome. The attitudes of the people working in organizations implementing CIM and its management need to be addressed.

- Small and medium-sized cladding fabricators would regard CIM as an expensive undertaking that can only be done by large fabrication organisations with stable flow of work. Downstream CIM infrastructure is inevitably expensive and investments are seen as ones that must be made up front. For many firms these costs represent a significant barrier.

- The implementation of CIM is a long-term undertaking and requires the involvement of other supply chain organisations to be successful. For a company that is faced with falling margins, there is little incentive in examining a system that may require some years before it yields any benefits.
CIM drivers
Future drivers of computer-integrated manufacture of cladding systems are summarized as follows:

- Likely future transformation of the construction project process by ICTs implies that electronic process and communication will be the norm. This will facilitate increasing upfront consideration and integration of the cladding work package into the building project process, including collaboration between organizations involved in the cladding supply chain. Digital transactions will drive the demand for a cladding product model as a means of exchanging and sharing cladding information between applications. This is likely to lead to a sector agreed information and data-centric cladding project delivery process.

- On-going development and implementation of Industry Foundation Classes (IFCs) and other platform-independent data exchange and sharing technologies will bring about more effective data exchange. These developments will reduce the re-keying of cladding product model data through better interoperability of software tools.

- Increasing use of building models (that incorporate a cladding product model) that grow with the project through all phases of the lifecycle means that cladding data can be easily accessed throughout design and fabrication stages. Since such a “project model” will incorporate the different disciplines and their views, it could be used to co-ordinate CIM within a wider building project. As CAD systems move towards object-oriented technology, this will enable more generic definition of information from which relevant views may be extracted. This is seen as being supported by a “project server” database to which information can be sent and from which it can be obtained on demand.

- There is the expectation that Web technologies will become even more critical for project coordination both internally and externally. As XML technology becomes prevalent as the preferred information delivery mechanism, it could be used to tag Web objects (Web-based construction and manufacturer's product information) to the relevant parts of a cladding model.

- Continued improvements in the price and performance of ICT infrastructures will facilitate its widespread diffusion to the whole of the construction sector. However, investment in CAD/CAM technologies by small and medium-sized cladding fabrication organizations would depend on the volume of business and whether the flow is sufficiently stable to justify the investment.
• There is a good potential for CIM automation, particularly for metal cladding, due to the low weight of metal cladding components (compared to structural steelwork).

**CIM road map for the cladding sector**

To achieve the vision of CIM a number of challenges must be addressed. They include: changing the current cladding procurement process to enable CIM; investing in adequate ICT infrastructure - hardware/software; and developing a robust cladding product model. Others are implementing mature data exchange and data sharing specifications (based on that cladding product model), and changing the inherent culture and attitudes associated with current practice.

The real difficulty in achieving CIM relates to culture, how to change to a new way of working. The contractual implications of CIM working practices are outside the scope of this paper. However, a study (AEC, 1999) that addresses, amongst others, legal and contractual issues surrounding digital information recognises that the risk associated with integration of information will be reduced by the development of a legal framework that recognizes the value of information and how it is used. The study also indicates that, to a large extent, this will come about through a clear definition of ownership and liability with respect to information that is stored and shared electronically. A project, eLEGAL (Hassan et al., 2001) is currently tackling these issues. The key implementation phases for CIM are illustrated in Figure 1.

**Planning for CIM**

CIM working practice requires the collaboration of cladding supply chain organisations working on a given cladding work package in the digital information exchange process. Thus this approach requires at least project collaborating partners, if not the whole of the cladding sector, to reach a consensus committing them to the concept of CIM. This then provides a rational basis for allocating resources to CIM. Since CIM is a way of doing business, there must be total commitment to CIM by management at all levels.

The sequence of activities undertaken in the current procurement of cladding systems for building projects will not change significantly as a result of CIM. The interfaces between activities will be
better integrated than in the current largely paper-based approach. However, the success of the changeover to CIM to facilitate an integrated project delivery process will depend to a large extent on the ease of moving data between applications used by different organisations. In order to effectively plan for CIM for the whole of the cladding sector, the broad outline of the would-be information-centric process has to be determined in this phase to assist with:

- The identification of constraints such as the commercial considerations, lack of appropriate applications software and data exchange incompatibilities.
- The development of a CIM-based cladding procurement process.
• Alignment of internal processes with the external project delivery process. A high level of awareness of the data needs is of high priority in planning for CIM.

• The establishment of information exchange protocols.

• Identification of skills gaps to be created by CIM working practice particularly in three key areas, process engineering, information management, and data communication.

**CIM-based cladding delivery process**

In this phase, there is a requirement for a CIM-based process model that defines good practice for working within the cladding sector and allows the identification of information needs. Explicit definition of this model will allow individual cladding supply chain organizations to streamline and align their internal business processes and methods of working to an established cladding sector process model to ensure free flow of information. This implies that organisations involved in the delivery process need to clearly understand the sequence and timing of information (what is required, and when it is required) for each key activity. This understanding will enable the definition of information supporting particular activities. Aggregation and streamlining of this information will assist in building cladding product models used for exchanging cladding data at the interface of activities undertaken by different organisations. Thus this phase involves developing and standardising the delivery process of different cladding types. The process needs to be detailed at the interfaces of activities undertaken by different supply chain organisations, to facilitate the capture of information needs.

**Cladding product model development, acceptance and testing**

For the information requirements identified in the preceding section to be meaningful and computer-processable, they need to be structured and co-ordinated in a cladding product model. Achieving CIM in the cladding sector is underpinned primarily by the development of cladding product models that capture and provide the information required at each stage of the procurement process. Compared to current practice, this represents a more structured, formal and holistic approach to exchanging cladding information between organisations.
This phase will focus on developing the required product model spanning the different cladding types that form the basis of specifications for exchanging information within the cladding supply-chain (between different applications software and between different companies). Figure 2 illustrates the two key activity interfaces in the design and manufacture of project-specific cladding (i.e. scheme to detailed design and detailed design to fabrication) and shows two distinct cladding sub-models denoted 2D PM and 2D+ PM. The first sub-model (as developed for rainscreen cladding in the CIMclad project www.cimclad.com) captures the requirements against which the cladding scheme design was developed, and the proposed scheme. It is essentially two-dimensional since its role is to capture the concept scheme as “painted” onto the elevations of the building. The second sub-model needs to define the details of the components and thus must include more geometric information. Additional sub-models, installation and testing for example, may also be required.

Figure 2 also illustrates that the concept scheme design and the detailed design have to be developed against the context of the building scheme design. The latter seems likely to be developed using 3D building modelling software prior to the cladding sector making this transition.

Take in Figure 2

Building on the CIMclad work on rainscreen cladding, and working in conjunction with the industry, this phase will identify, for all target cladding types together with the required interfaces, what information needs to be transferred. This information will then be used to develop either a unified cladding product model or a number of complementary sub-models. To gain maximum buy-in to the model across the cladding sector, the product model (or, more likely, informal abstracts of the formal model) will need to be subjected to widespread review by the industry and vendors of applications software. Early software testing is also likely. Specifications for supporting data exchange within the
cladding sector will then be developed and published for implementation. This is expected to require alignment with existing standards (IFC and/or the CIMsteel Integration Standards (CIS)) and subsequently lead to commercial software implementations. It is also anticipated that specifying complementary XML Schema for much of the model to enable lighter-weight implementations, particularly in areas such as libraries of components.

CIM infrastructure

Seamless CIM operation relies not only on a CIM-based cladding delivery process model and a structured cladding information model, but also on accessible telecommunications operating at acceptable speeds that would provide a convenient means for moving the cladding product data between applications. This phase requires an assessment of the present ICT usage by cladding supply chain organisations and requirement planning to ensure effective CIM potential. This will include:

- Use of standard local network protocols with adequate performance, robustness (particularly in factory contexts) and interoperability – including appropriate Internet access.
- Servers with appropriate performance and capacity.
- Hardware and applications software platforms that are appropriate in capacity and scope (to deal with digital data), and which will acquire compliance with the new exchange specifications.
- Necessary planning and tooling of factories.
- Trained staff.

Model deployment and data exchange

Exchange of cladding model between the different platforms used by cladding supply chain organisations marks the realisation of the CIM vision - enabling the delivery of building-specific cladding systems through computer-based integration of design and manufacturing activities using a cladding product model. This phase addresses ways of exchanging the cladding model between cladding supply chain organisations once it has been implemented as a software including issues relating to seamless data exchange. Two data exchange scenarios, illustrated in Figure 3, between applications used by cladding organisations are envisaged, namely:
Serial exchange involves the sequential transfer of cladding product model files from organisations involved in upstream project activities to those involved in downstream fabrication and installation activities. At each stage of the procurement process, the model is populated with additional data generated at that stage. In practice the actual flow may be more complex (when feedback or rework is required) which poses data management issues (these can be addressed).

Parallel data exchange requires that the model data is stored in one location, with all users having (remote) access. This seemingly simple model is superficially very attractive but becomes complex when the possibility of multiple users wishing to update the data is considered (raising issues of data ownership, change control and propagating the consequences of change). These complex data

Take in Figure 3
management issues are being addressed within the broad product model approach, but serial data exchange is more likely to be deployed first.

At the end of this phase the cladding information specifications will be implemented to provide data exchange between existing and future applications. Typically these exchanges will involve the use of traditional data exchange translators mapping data between the proprietary internal data structures of the applications and those of the product model. It is possible that some future applications may adopt an internal data structure that is derived from that of the product model to simplify the mappings necessary within the data exchange translators. The exchanges themselves are likely to be predominantly direct between two applications, but with increasing trials through a shared database.

To achieve this level of integration this phase will require:

- Commitment from a sufficient proportion of the cladding supply chain to process harmonization and to incremental process integration through deployment of the cladding information specifications (leading towards CIM).
- Leadership and support from organizations within that supply chain sufficient to give confidence to the software vendors.
- Active participation (and the investment of resources) by the software vendors.
- Support from education and training organizations.

A complete cladding sector transition to CIM envisaged at this stage involves the exchange of cladding information specifications required at upstream (front-end construction industry domain) and downstream (back-end manufacturing industry domain) of the cladding project delivery process. It should be noted that at the CIM back-end, the downstream cladding product model is bridging into the back-end detailing and manufacturing domain and should directly drive the fabricators’ CNC equipment without the need for further programming. Obviously, fabricators will need to install / update their plant to fully capitalise on the enhanced data. The downstream model also captures installation-related information, thus drives the concept of CIM through manufacture into delivery, erection, testing (and maintenance).
Conclusions

The long-term goal of CIM working practice is to improve the efficiency and competitiveness of the cladding sector through integration of the cladding procurement process, the specify-design-manufacture-install cycle. The CIM road map presented in this paper identifies key phases aimed at transforming the current fragmented design and manufacture of building-specific cladding systems into a computer integrated process. This includes:

- Streamlining the current cladding work package procurement process to enable CIM
- Investing in adequate CIM infrastructure
- Developing and testing a cladding product model
- Developing industrially deployable cladding information specifications based on that model
- Vendors of applications software implementing those information specifications (and validating those implementations)
- The supply chain deploying that software and using the cladding information specifications to support the incremental realisation of CIM.

To realise this goal will require long-term commitment and participation from sufficient of the supply chain, plus sufficient involvement of the application software developers, to provide a critical mass that can snap-through and thus carry (much) of the rest of the industry with it.

References


Egan, J. (1998), "Rethinking construction", Department of Environment, Transport and Regions (DETR), UK.


<table>
<thead>
<tr>
<th>Phases</th>
<th>Communities Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 0</td>
<td>Cladding supply chain organisations Software vendors</td>
</tr>
<tr>
<td></td>
<td>CIM planning</td>
</tr>
<tr>
<td>Phase 1</td>
<td>Cladding supply chain organisations Suppliers &amp; Process Modellers</td>
</tr>
<tr>
<td></td>
<td>CIM-based delivery process model</td>
</tr>
<tr>
<td>Phase 2</td>
<td>Product modellers End users Software vendors</td>
</tr>
<tr>
<td></td>
<td>Cladding product model development, acceptance, and testing</td>
</tr>
<tr>
<td>Phase 3</td>
<td>Cladding supply chain organisations Hardware &amp; Software vendors</td>
</tr>
<tr>
<td></td>
<td>CIM infrastructure</td>
</tr>
<tr>
<td>Phase 4</td>
<td>End users Education and training organisations Hardware &amp; Software vendors</td>
</tr>
<tr>
<td></td>
<td>Model deployment and data exchange</td>
</tr>
</tbody>
</table>

Figure 1: CIM implementation phases
Figure 2 Interfaces between cladding design and fabrication activities
Figure 3: Cladding product model central to serial or parallel data exchange between applications