

2007

## CITAX: Defining XML Standards for Data Exchange in the Construction Industry Supply Chain

Alan V. Hore

*Technological University Dublin, alan.hore@tudublin.ie*

Roger West

*Trinity College, rwest@tcd.ie*

Follow this and additional works at: <https://arrow.tudublin.ie/beschrecon>



Part of the [Construction Engineering and Management Commons](#)

---

### Recommended Citation

Hore, A.V. and West, R.P. (2007), CITAX: Defining XML Standards for data exchange in the construction industry supply chain, 24th W78 Conference, Maribor, Slovenia, 26th-29th June 2007. doi:10.21427/ahrm-rs88

This Conference Paper is brought to you for free and open access by the School of Surveying and Construction Management (Former DIT) at ARROW@TU Dublin. It has been accepted for inclusion in Conference papers by an authorized administrator of ARROW@TU Dublin. For more information, please contact [arrow.admin@tudublin.ie](mailto:arrow.admin@tudublin.ie), [aisling.coyne@tudublin.ie](mailto:aisling.coyne@tudublin.ie), [vera.kilshaw@tudublin.ie](mailto:vera.kilshaw@tudublin.ie).

# **CITAX: Defining XML Standards for data exchange in the construction industry supply chain**

Dr. R.P. West<sup>1</sup> and Dr. A.V. Hore<sup>2</sup>

1. Department of Civil, Structural and Environmental Engineering, Trinity College Dublin.  
rwest@tcd.ie

2. School of Real Estate and Construction Economics, Dublin Institute of Technology.  
alan.hore@dit.ie

## **Abstract**

The current methods of ordering, delivering and invoicing of products in the construction industry is enormously inefficient, with vast quantities of paperwork, duplication of effort, scanning, re-keying and resolving mismatches between invoices, delivery dockets and purchase orders. The purpose of this paper is to introduce the Construction IT Alliance eXchange (CITAX) project and, in particular, to outline the work carried out-to-date by a special interest group within the project. They are seeking to define a universal set of eXtensible Mark-Up Language (XML) message standards that will allow suppliers and contractors to exchange information with each other in supply chain activity. While the group cannot ensure that suppliers and contractors use the standard, the ultimate goal of the project is not only to have the standard in place, but also to provide the impetus to ensure that as many stakeholders as possible use them. How this might be achieved is also part of the project and its success will be judged by the extent of the adoption of the standard by the industry.

## **Key Words**

e-procurement, Standards, Trading, XML

## **1.0 INTRODUCTION**

Information and Communications Technology (ICT) tools are used today to support Architecture, Engineering, Construction and Facilities Management (AEC/FM) business processes. The information entered into these ICT tools, however, is almost invariably passed from one ICT system to another by producing paper-based electronic documents, which in turn are re-entered into the various other ICT systems along the AEC/FM life cycle (Froese, 2003). Ma et al., (2004) spoke of the old fashioned techniques of exchanging information on paper, re-entering this data on a multiplicity of occasions and the extensive printing of such data. It has been extensively reported by many authorities that collaboration of project teams and the exchange of data between project teams in the construction industry is not efficient (Thomas, 1999 and Gunnigan et al., 2004) but that undoubtedly, the sensible use of ICT enhances productivity.

Research into effective collaboration in the AEC/FM industry has been carried out over many years. Teicholz and Fisher (1994) developed the concept of Computer Integrated Construction (CIC) to integrate design and construction based on object-orientated models. Anumba (1997) developed an internet system for multiple parties on a construction project to exchange project information and called for the need for project information exchange protocols to be developed for the construction industry.

There are many dedicated organisations globally seeking to redress the over reliance on paper-based business processes in construction, such as the Construction Industry Institute (USA); VTT (Finland); Construct IT (UK), Construction Excellence in the Built Environment (UK) and Construction IT Alliance (Ireland) among many others. The

International Alliance for Interoperability (IAI) is a global coalition of industry practitioners, software vendors and researchers who collectively promote the need for information to flow from one computer to the next throughout the life cycle of a construction project. The IAI have developed Industry Foundation Classes (IFCs) for both product and non-product data exchange standards to enable them to be adopted in the industry (Froese, 2003).

There is also an array of collaborative initiatives globally seeking to introduce interoperable data exchange standards within the AEC/FM sector. Examples in the United Kingdom include the Network of Construction Collaboration Technology Providers (NCCTP), Open Design Alliance (ODA), HUB Alliance, Avanti, Asite, Planning and Implementation of Effective Collaboration in Construction (PIECC) and Project Information eXchange Protocol (PIX), among others (Goodwin, 2004).

This paper will outline the progress of a particular project managed by the Construction IT Alliance (CITA). The project, known as the CITAX project, is a two-year collaborative project involving twenty five CITA member organisations who are seeking to demonstrate that significant measurable economic improvements can be achieved by using readily available ICT tools to radically improve business processes in the Irish construction industry. This paper will specifically focus on just one of the five collaborative module teams which has a specific role to develop and implement an industry-wide standard version of the eXtensible Mark-up Language (XML) that will allow both suppliers and contractors in the Irish construction industry to trade electronically.

## **2.0 CONSTRUCTION IT ALLIANCE**

CITA originated as a research project in the Dublin Institute of Technology in 2002. The organisation's goal is to encourage participants in the Irish construction industry to take greater advantage of current and emerging ICT (Thomas and Hore, 2003). The members comprise in excess of 135 corporations drawn from a broad cross-section of the Irish construction industry, including architects, engineers, contractors, suppliers, clients, ICT companies, government departments, state agencies and third level institutions. The main source of funding originates from membership subscriptions with other income sourced from training courses and sponsorship of events. The main activities involve organising bi-annual member meetings, training courses, information dissemination through the organisations website and online newsletters and promoting the work of its Special Interest Group (SIG) network.

## **3.0 CONSTRUCTION IT ALLIANCE EXCHANGE PROJECT**

CITA obtained funding for their project known as the Construction IT Alliance eXchange (CITAX) project under an Industry Led Network Scheme (DETE, 2006). The overall aim of the project is to facilitate more efficient business transactions between companies in the Irish construction sector by the deployment of readily available ICT tools, in particular construction business processes tools, and to radically improve the productivity of these business processes. However, the use of ICT in a formal way may also improve the quality of available project data, thereby allowing more in-depth analysis.

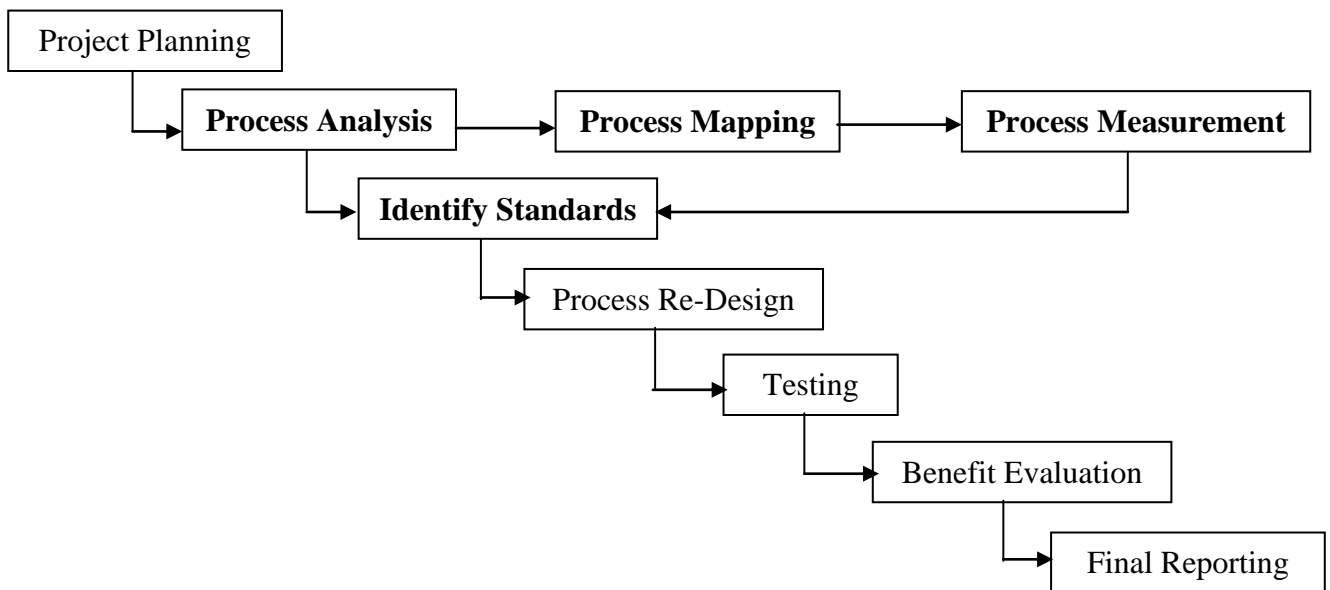
Early consultation of the CITA membership in 2005 identified five core areas that required particular attention. The five core modules identified were: -

- Module 1 - Production and exchange of CAD drawings.
- Module 2 - Production and exchange of trading documentation, such as purchase orders, goods received notes and invoices.
- Module 3 - The pricing of tender documentation electronically and recommendation of a preferred tender for selection.

- Module 4 - The storage, retrieval and general dissemination of project information on construction projects.
- Module 5 - The use of building information model data in the production of bills of quantities.

The longer term objective of the network is to develop a platform for the design and development of open standards that would be promoted within the Irish construction supply chain. Each module has a Project Leader drawn from industry with a good cross section of companies from different disciplines participating in the each group, including the support of a main building contractor and an academic institution.

Figure 1 illustrates, at a high level, the methodology adopted in the project. The steps in bold text refers to the stages of the project which this paper will particularly focus.



*Figure 1* CITAX Methodology

At the time of writing this paper, all of the module plans have been completed and signed-off by the module participants and work is in progress in regard to the analysis of the existing business processes. The remainder of this paper will focus on the work of the group in the process mapping and analysis phase and, in particular, to understand the problems and inefficiencies that exist in the production and exchange of trading documentation, such as Purchase Orders (POs), Goods Received Notes (GRNs) and invoices.

## 4.0 CITAX MODULE 2 - TRADING

### 4.1 BACKGROUND

In 2002 an SIG was set up to evaluate specifically the administration of ordering, delivering and invoicing of building materials. The purpose of the group was to review the procure-to-pay process within the Irish construction industry in order to establish, primarily, if there were ways in which the process could be re-engineered to make it more efficient. From the outset it was clear that ICT could make a major impact in streamlining the construction supply chain, just as it had done in other industries, such as automotive and retailing. The members of the SIG agreed to undertake a number of pilot projects to assess the technology

available and to provide hard evidence of the benefits that it could bring. In this way, it was possible to provide evidence of how ICT formed an integral part of the re-engineered solution, thereby achieving efficiencies which would otherwise be impossible to deliver.

The authors also carried out observation studies and surveys which demonstrated the need for the current purchasing processes adopted in the Irish construction industry to be re-engineered (Hore and West, 2004 and Hore et al., 2004). A pilot project commenced in early summer 2004 where in-situ concrete deliveries were electronically captured on a Personal Digital Assistant (PDA) hand held computer on a local construction project. Both trading partners reported significant cost and productivity savings. An independent review and evaluation of the pilot performance, carried out by a management consultant, verified these findings (Hore and West, 2005c).

A further pilot was successfully completed in 2005, where trading partners achieved a successful three-way electronic match of the purchase order, delivery note and supplier invoice on a live construction project. Significant measurable economic benefits were reported by the trading partners (Hore, 2007). An attitude survey was carried out by the authors in 2004 (Hore and West, 2005a) and in 2005 (Hore and West, 2005b), which indicated the perceived opportunities arising from and barriers to the introduction of paperless e-procurement.

The pilot project carried out in 2005 proved that ICT can make significant efficiencies in the supply chain process. The technology was effective without reducing any of the controls within the overall process. In fact, the pilot identified that there were significant increases in control that could be achieved. In addition, much of the labour intensive work included keying-in, checking of data and resolving mismatches, was eliminated (Hore and West, 2005c).

There were a number of key findings from the 2005 pilot project (Hore, 2007):

1. XML standards needed to be agreed for all message types required in the supply chain process to allow suppliers and contractors to electronically exchange information more easily between trading partners.
2. Building contractors need to deploy a handheld solution on their sites to record the receipt of deliveries in order for them to gain the maximum benefit from an electronic supply chain process.
3. Electronic catalogues need to be kept up-to-date to ensure that pricing information is accurate.
4. The deployment of any solution such as this requires commitment and support from senior management in order to fully optimise efficiencies within their businesses.

## 4.2 MODULE AIM

The CITAX module on e-procurement seeks to verify that significant measurable economic benefits can be achieved by collaborating trading network members on a live project by the adoption of an XML standard. The project deliverables include:

1. Develop a universally acceptable XML standard for electronic exchange of purchase orders, delivery notes and supplier invoices.
2. Demonstrate, by participation in a live pilot project, that purchasing data transactions can be more efficiently exchanged between trading network members by the adoption of the XML standard.

One of the most significant challenges for the CITAX module 2 team was how to tailor-make a suitable XML standard that would be acceptable to the vast majority of players in the Irish construction sector, especially as many traders are small enterprises. For the adoption of a common XML to be widespread, it is important that the companies participating in the project would define and agree sets of message sets for each of the stages of the trading process.

#### 4.3 PROCUREMENT PROCESS MAPPING

Following an agreement on the module plan, an analysis was conducted on the existing business processes. The methodology adopted by the project team involved:-

1. The identification of the activities to be included or excluded as decided in the planning phase
2. The process was formalised into flow-chart form, including the activities of all likely participants.
3. A top-down approach was adopted in analysing the process, breaking the process down, from higher to lower levels.
4. In general terms, to avoid unmanageable detail, the analysis did not go below activity level, that is, a job which can be carried out by one person in one phase of work (see Figure 2)

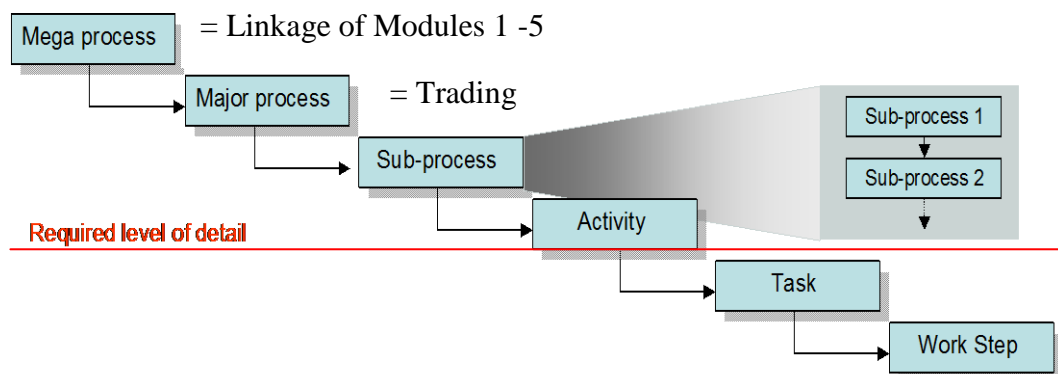


Figure 2. Process Mapping Level of Detail

The scope of the process under review started with the PO process and ended with invoice generation. Prior to the PO process, there is a negotiation process which is outside the scope of this document. Similarly after the invoice processing there is a payment process which is also outside the scope of this project. This scope can be seen in Figure 3.

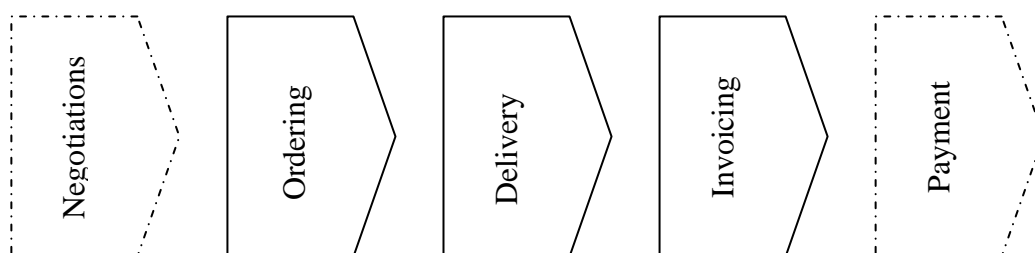
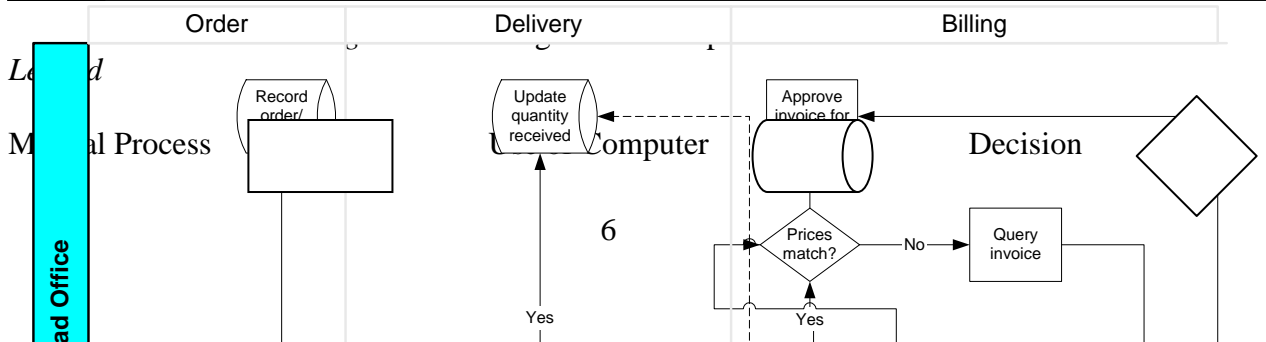
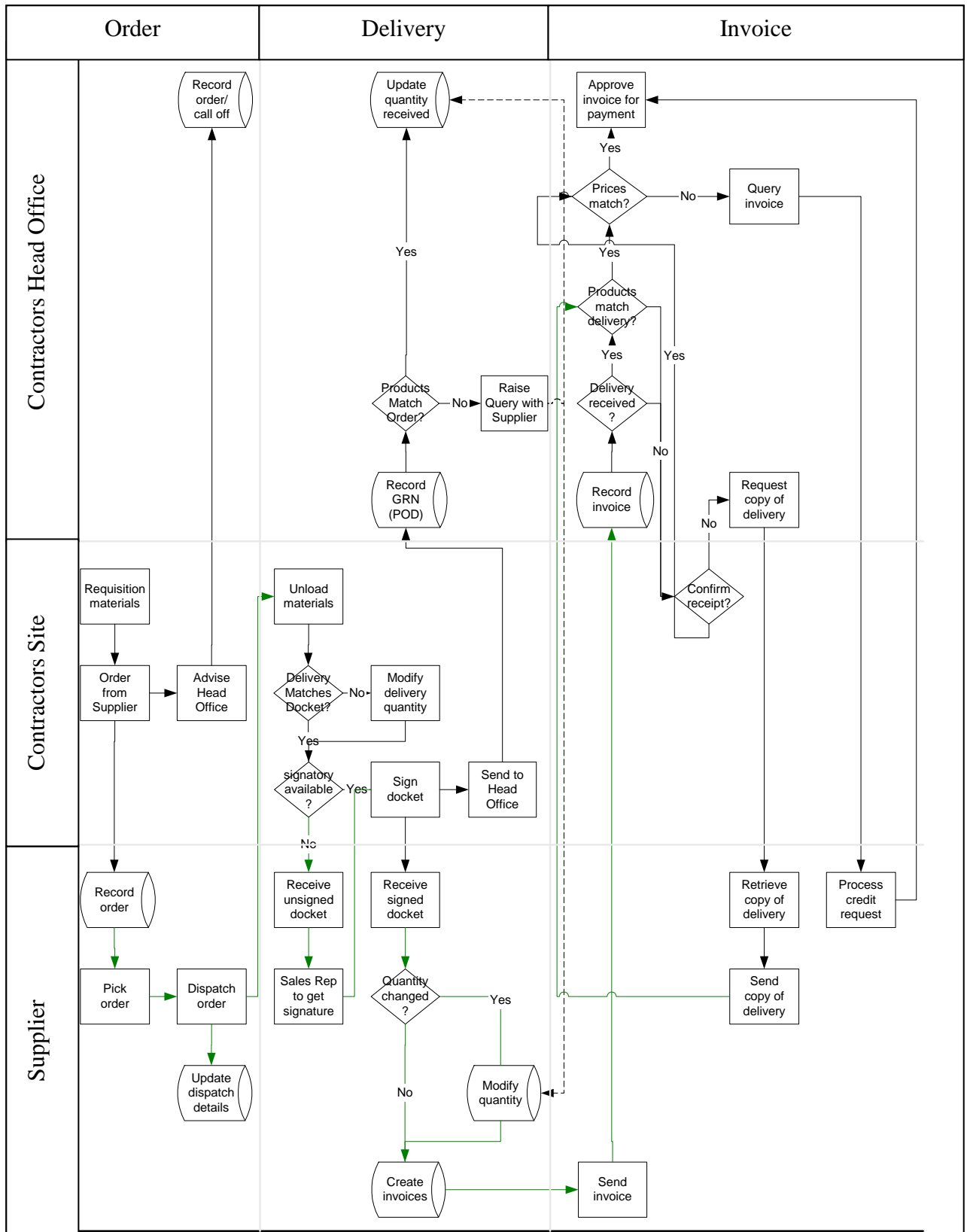


Figure 3. Scope of Trading Module

Following consultation with the module participants an existing process map was agreed upon which is shown in Figure 4.



In reviewing the order process, the negotiation between supplier and contractor has been excluded from the scope of the work being undertaken. This can involve a formal tender process, or can simply involve buying from a preferred supplier. The contractor and supplier may each create a ‘master order’ on their systems, although this does not always happen. A ‘master order’ is like an approved product list, where products to be purchased and their pricing have been agreed. Where a ‘master order’ is used, a site simply has to create a ‘call off’ order, where they draw down quantities from the ‘master order’.

There are several ways in which the process can break down, all of which must be accommodated in the XML message set:

1. *Misinterpretation of requirements.* Even with faxed orders, there is room for misinterpretation of what is required. This can arise from orders which simply give a description of what is required, or by specifying an incorrect product code. With phone orders, this issue is more acute.
2. *Insufficient stock.* If the supplier is out of stock on a specific item but does not realise it until picking time, the site may not receive all of the items ordered. Similarly, the supplier may substitute one product for another, if the one ordered is out of stock.
3. *Picking discrepancies.* Errors in picking/batching products will only be caught when the items are delivered to the site.
4. *Site not advising head office.* It is very common for sites to forget to advise head office of orders placed. This means that head office has no visibility of its exposure to costs on a project until invoices arrive in from suppliers making tight cost control difficult.
5. *Incorrect details recorded on head office system.* The order (if recorded on the head office system) can be incorrect due to the same issues faced by suppliers when dealing with site orders, i.e. misinterpretation of site’s requirements. This compounds the issue of suppliers misinterpreting requirements.

The XML message sets being proposed for the order phase are identified in Table 1.

<b>Message Type</b>	<b>Description</b>
Order	Order messages are created by the contractor and sent to the supplier.
Order Confirmation	On receipt of an order from a contractor, it is created/saved on the supplier’s system. Confirmation of the details recorded/received is transmitted back to the supplier. This can include out-of-stock notifications. This message can also be used to create an order on the contractor’s system if it has not been recorded there previously.
Order Cancellation	Used to cancel an order that had previously been sent through from the contractor.
Shipping Notice	This lists the items that are going to be delivered to the site.

*Table 1. XML message sets proposed for order phase*

The delivery process involved an excessive degree of administration work for both the contractor and the supplier. This is due to the necessity of the supplier requiring a signature on a delivery docket, in order to demonstrate Proof of Delivery (POD) and the contractor’s necessity to prepare GRNs on their ICT system, to enable the approval of supplier invoices.

There are several ways in which the process can break down:

1. *Handwritten adjustments on delivery dockets.* Every docket has to be examined by the supplier for handwritten changes. This is prone to error, both in terms of missing changes that were made and in interpreting the handwritten changes on a docket.



2. *Unsigned dockets.* The difficulty in locating an authorised signatory often means that deliveries remain unsigned. In addition, some items, such as trowel-ready mortar, are delivered to sites when there is nobody present. These unauthorised delivery dockets often have to be signed at a later time by a site foreman/site manager.
3. *Unauthorised people signing dockets.* It is often a problem for a driver to locate an authorised signatory. Drivers can occasionally obtain a signature believing that the person is authorised to do so, only for the supplier to discover later that the signature is from a sub-contractor not authorised to sign for the delivery.
4. *Delivery dockets not being sent to head office.* Missing delivery dockets is a very significant issue for most sites. On average, almost 25% of dockets on construction sites go missing (Gunnigan et al., 2004)
5. *Interpretation of items on delivery docket.* Quite often, the staff inputting delivery dockets are not familiar with the details of the products delivered. Therefore, it is a difficult task for them to correctly select the appropriate cost codes for the items delivered.
6. *Administration effort.* Contractor's have administrative, resources occupied with inputting supplier delivery information, while supplier's have administrative staff checking dockets for manual adjustments, and in some cases, involved in scanning the original delivery dockets.

The XML message sets being proposed for the delivery phase are identified in Table 2.

Message Type	Description
POD	Signed delivery docket delivered back to the supplier.
GRN	Goods Received Note used to list items received on the delivery.

Table 2. XML message sets proposed for delivery phase

The module participants concurred that supplier invoices were largely sent by post in the construction industry. However, it was acknowledged that some companies send invoices by email, but it was noted that there was some dissatisfaction from the Irish Revenue Commissioner requirements, as there may be VAT implications for companies sending and accepting invoices sent by email.

There are several ways in which the process can break down:

1. *Missing delivery dockets.* Many of the issues raised earlier in the supply chain come to a head when an invoice is received. A key issue is missing delivery dockets against which to reconcile the invoice. This involves administrative, effort requesting copies of delivery dockets and then matching them to invoices.
2. *Discrepancies with purchase order.* A common problem is the mismatching between the material rates on the invoice and on the original PO.
3. *Cost overruns.* Site may have ordered products which are more expensive than planned, with a knock-on impact on the cost of the project.

The XML message sets being proposed for the invoicing phase are identified in Table 3.

Message Type	Description
Invoice	Invoice from contractor to supplier.
Credit Note	This is just the reverse of an invoice.

Table 3. XML message sets proposed for invoice phase

Figure 5 depicts how some of these message types would flow in any proposed redesigned process.

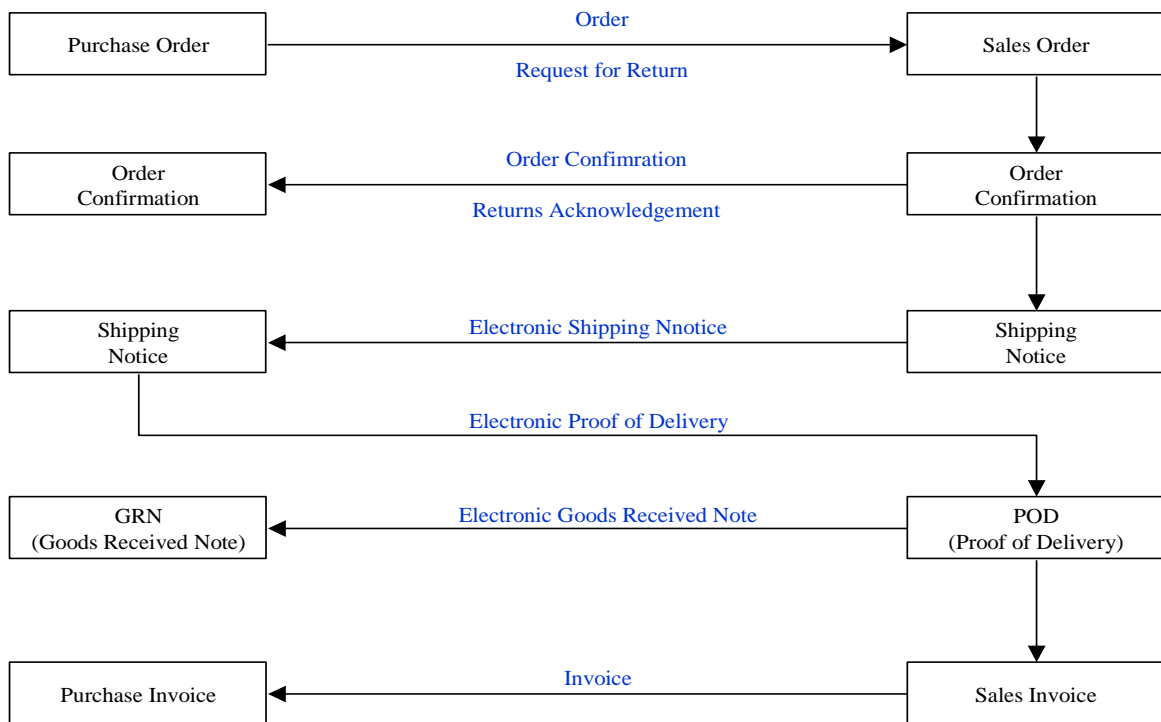


Figure 5. Flow of message types to be defined on the CITAX project

## 5.0 REVIEW OF XML STANDARDS ADOPTED IN THE CONSTRUCTION INDUSTRY

XML allows users to define different tags, in order to convey the meaning of business data. XML is a mark-up language for documents containing structured information. Structured information contains both content (words, pictures, etc.) and some indication of what role that content plays. It uses identifying tags that allow information exchange without having to reformat the data for retrieval and viewing. XML makes it possible to tag information with labels that make its purpose both amenable to processing by computers and comprehensible to humans. The tags describe the data and the structural relationship between the tags. Since XML data is completely independent of presentation and can be read by any XML enabled system, it means that any data from any source can be processed, exchanged and delivered to any type of XML enabled application and hardware. The output of data into different formats takes place using style sheets to any XML enabled appliance. For example, an invoice in a supplier's business application could be sent to a customer and viewed on a personal computer using no more than a web browser (Leenders et al., 2001).

XML standards have been developed in several industries, such as business, retail and also the building and construction industry. These standards are essentially shared vocabularies and rules for defining the structure, content and meaning of similar XML documents. XML is extensible because each element of data is separately identified, all of the elements do not have to be present in the message, only the elements that are required by the message definition, the XML schema.

In the building and construction sector a number of projects have developed XML based standards, which are at various levels of maturity and adoption.

- Building and Construction XML (bcXML) was developed under the European funded Fifth Framework eConstruct project. The eConstruct project sought to develop,

implement, demonstrate and disseminate a new ICT standard for the European building construction industry (Toleman et al., 2001).

- Electronic Business XML (ebXML) was developed in parallel to the eConstruct project. This standard focused on industries more advanced than construction. It is used mainly by large companies across dedicated networks or value-added network services. For example, ebXML is adopted by the United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) in partnership with the Organisation for the Advancement of Structured Information Standards (OASIS) and numerous industrial bodies (Lima et al., 2003).
- Architecture, Engineering and Construction XML (aecXML) is an XML standard developed by Bentley Systems for the project and business-to-business communication for architecture, engineering, construction and facilities management transactions.
- Construction Industry Trading Electronically (CITE) has a standard based on the international Electronic Data Interchange for Administration, Commerce and Transport (EDIFACT) standards. The standard covers trading documents such as enquiries, quotations, orders, dispatch advice and invoice formats.
- The Business Application Software Developer's Association (BASDA) has developed their eBIS-XML standard. The standard was first developed in 1999 and has been widely implemented since. The standard messages are designed in the form of "schemas" which allow large corporate accounting systems to communicate with small business applications. This means that a company does not need to know if its supplier or customer is eBIS-XML enabled before it sends an eBIS-XML order or invoice. BASDA is currently being adopted on the UK Office of Government Commerce (OGC) Conduct eProcurement Assessment Trials.
- The International Alliance for Interoperability (IAI) is facilitating exchange of information between software applications using Industry Foundation Classes XML (ifcXML). IFC provides a means to encode and store information for the entire project in a model that can be shared among diverse project participants. The technology of exchanging information using the IFC is established but many areas require additional development before comprehensive interoperability solutions are reached (Froese, 2003).

Other initiatives include the Global Procurement Standards Organisation (GPSO) and OASIS who have initiated a cooperative effort to begin development of global electronic procurement standardisation under the auspices of a proposed Electronic Procurement Standardisation Technical Committee (EPS TC).

In this context, a new XML standard for e-procurement of construction materials appropriate to the Irish construction industry, with its wide base of small contractors and suppliers, is to be developed.

## **6.0 CONCLUSIONS**

Currently there are millions of documents exchanged on paper in the construction industry, each having to be re-keyed as they pass between different locations and computer applications (Cole, 2004). Coupled with this the world of XML comprises a vast array of standards and technologies that interact in complex ways. According to Whittle (2002), there are over 2000 XML standards for an invoice alone.

There is broad agreement within the Irish construction industry of the need to agree standards for data exchange, such as through the use of XML. The key to unlocking the greater potential of ICT in construction purchasing is to demonstrate that significant business benefits can accrue to the wider industry by investing in appropriate XML standards in the

trading process. In this way, through the re-engineering of the process, ICT can deliver what would otherwise be impossible to achieve in a paper-based system (NRC, 2003).

There is a general awareness in the construction industry of the benefit of deploying readily available ICTs in improving purchasing process in construction. The lack of a common data exchange standard in the construction industry increases implementation costs (Cole, 2004). The reality, however, is that in order to achieve these business benefits, the larger construction companies need to invest in ICT. Future research will need to show how the Irish construction supply chain can benefit overall from an industry-wide solution, given the large number of small players in the marketplace. In order to achieve this, closer collaboration is needed between the major players in the industry and longer term relationships are needed between supply chain organisations.

The technologies deployed in the pilot projects carried out by the authors in 2004 and 2005 are mature and appropriate ingredients to be deployed in the CITAX project. However, there needs to be a level of awareness among the larger contractors and suppliers in the Irish construction industry that traditional paper-based dependent processes should not be maintained in modern construction businesses into the future. It has been shown that ICT significantly enhances productivity and provides ready access to electronic data which is easier to manipulate and analyse.

The construction industry approaches any change in business processes, whether it involves technology or not, with some trepidation (Rankin et al., 2006). For more widespread electronic trading, businesses must not only use a common language, they must also standardise the data sets and interfaces to provide interoperability. In an ideal system, each piece of data would be entered only once and be available to any ICT system in the trading network that needs it. High frequency flows should be fully automated and transmitted in standard formats with common protocols and standards (Cutting-Decelle, 2006).

This paper has set out a framework in which the Irish construction industry can move towards the definition and adoption of a common XML for information exchange in e-procurement. Its success will inevitably be judged by the extent of its adoption, a problem exacerbated by the diverse nature of the industry's players.

#### *Acknowledgements*

The authors wish to thank Pat Talbot and Aidan Fitzmaurice of Talbot Associates, and Finbarr McCarthy of Sentrico Technologies for their input into this paper. The authors would also like to thank Enterprise Ireland for their financial assistance of the CITAX project.

#### **REFERENCES**

- Anumbia, C.J., (1997), "Collaborative working in construction – the need for effective communication protocols", Computing in Civil Engineering, Proceedings for the 4<sup>th</sup> Congress, ASCE, Boston, 89-96.
- Cole, T.C., (2004), "The effective implementation of E-Business", Incite 2004 Conference, Designing, Managing and Supporting Construction Projects Through Innovation an IT Solutions, Langkawi, Malaysia, 253-258.
- Cutting-Decelle, A-F, Young, B., Das, B., Case, K., Rahimifard, S., Anumba, C. and Bouchlaghem, D., (2007), "A review of approaches to supply chain communications: from manufacturing to construction", Electronic Journal of Information Technology in Construction, 12, 73-102.
- Department of Enterprise, Trade and Employment (DETE), (2006), "Implementing the National eBusiness Strategy of the Department of Enterprise Trade and Employment", Government Publication, Ireland.
- Froese, T., (2003), "Future directions for IFC-based interoperability", Electronic Journal of Information Technology in Construction, 8, 231-246.

- Goodwin, P., (2004), "The PIX Protocol – A risk reduction tool for construction projects", Society of Construction Law Conference, London, 45-58.
- Gunnigan L., Orr T.L.L. and Hore A.V., (2004), "Rationalising the construction materials purchasing process", The International Salford Centre for Research and Innovation (SCRI) Research Symposium and International Built and Human Research Week, Salford University, Manchester, 376-385.
- Hore, A.V., (2007), "The use of ICT to re-engineer purchasing in the Irish construction industry", PhD thesis, Trinity College, University of Dublin,.
- Hore, A.V. and West R.P., (2004), "A Proposal for re-engineering the procurement of building materials by effective use of ICT", Incite 2004 Conference, Designing, Managing and Supporting Construction Projects Through Innovation an IT Solutions, Langkawi, Malaysia, 375-380.
- Hore, A.V. and West R.P., (2005a), "Attitudes towards electronic purchasing in the Irish construction industry", 2005 CIB W92/T23/W107 International Symposium on Procurement Systems, Las Vegas, USA, 289-296.
- Hore, A.V., and West R.P., (2005b), "A survey of electronic purchasing practice in Ireland: a perspective for the Irish construction industry", The 2<sup>nd</sup> International Salford Centre for Research and Innovation (SCRI) Research Symposium and International Built and Human Research Week, Salford University, Manchester, 98-108.
- Hore, A.V. and West R.P., (2005c), "Realising electronic purchasing in the Irish Construction Industry", Combining Forces – Advanced Facilities Management & Construction Through Innovation Conference, Helsinki, June 2005, 154 - 166.
- Hore, A.V., West R.P. and Gunnigan L., (2004), "Enabling the re-engineering of material purchasing in the construction industry by the effective use of information technology", The International Salford Centre for Research and Innovation (SCRI) Research Symposium and International Built and Human Research Week, Salford University, Manchester, 386-395.
- Leenders, M.R., Fearon, H.E., Flynn, A.E. and Johnson, P.F., (2002), "Purchasing and Supply Management", McGraw Hill, New York.
- Lima, C., Stephens, J. and Bohms, M., (2003), "The BCXML: supporting e-commerce and knowledge management in the construction industry", Electronic Journal of Information Technology in Construction, 8, 293-308.
- Ma, Z., Li, H., Shen, Q. And Yang, J., (2004), "Using XML to support information exchange in construction projects", Automation in Construction, 13(5), 629-637.
- National Research Council (NRC), (2003), "Beyond productivity, information technology, innovation, and creativity", edited by Mitchell, W.J., Inouye, A.S., Blumenthal, M.S., The National Academic Press, Washington. D.C.
- Rankin, J., Chen, Y. and Christian, J., (2006), "E-procurement in the Atlantic Canadian AEC industry", Electronic Journal of Information Technology in Construction, 11, 75-87.
- Teicholz, P. and Fischer, M. (1994), "Strategy for computer integrated construction technology", Journal of Construction Engineering and Management, 20(1), ASCE, Boston, 117-131.
- Thomas K. and Hore A.V., (2003), "A reflection on the development, activities and deliverables of the Construction IT Alliance (CITA) in Ireland", CIB W89, International Conference on Building Education and Research, 9-11 April, 381-895.
- Thomas K., (1999), "A study of the use of information technology in the Republic of Ireland construction sector", The International Journal for Construction Information Technology, 7 (1), 21-34.
- Tolman, F., Bohms, M., Lima, C., Van Rees, R., Fleur, J. and Stephens, J., (2001), "E-construct: expectations, solutions and results", Electronic Journal of Information Technology in Construction, 6, 175-197.
- Whittle, J., (2002), eCentre UK, Presentation to CITE Annual Conference, Birmingham, UK.