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DEVELOPMENT OF AN E-BUSINESS SOLUTION FOR THE INTEGRATION OF STEEL REINFORCEMENT SUPPLY CHAIN IN CONSTRUCTION PROJECTS

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ABSTRACT
Although it is currently possible to read structural drawings and prepare concrete reinforcement schedules automatically, improvements in scheduling, cost and project delivery will not be significant if the complexities in the interactions of parties involved are not addressed. Reinforcement steel is a critical material for construction success in terms of cost, schedule and ultimate integrity of the structure. It is still common practice for rebar fabricators to accept structural design information in CAD drawing formats and then generate new drawings for the shop floor, which ultimately are presented to the contractor as blueprints. Collaborative supply chain solutions provide support for the capture and communication of customer demands, and enable these demands to automatically trigger business events and initiate process workflow. This paper presents a system that will allow the rebar industry to collaborate with construction and design firms, thus implementing a robust supply chain with dynamic marketplaces enabled by electronic business technologies.

KEYWORDS
Steel Reinforcement, Supply Chain Management, E-business, Extensive Markup Language (XML)

1. INTRODUCTION

The current practice of integrating quantity take-off and procurement of reinforced steel offers a huge area for improvement, thus representing an adequate scenario for the implementation of new ideas of e-business, electronic marketplaces, collaboration and integration of the supply chain. Rebar fabricators accept hardcopies of blueprints and return CAD files featuring different layers and elements. Similarly, these early stages in materials delivery are subject to many interactions that ultimately affect the duration and cost of the construction project. Any discrepancy in the quantity take-off will translate into delays for the parties involved in the design team.

The fragmented nature of the construction industry, with its lack of coordination and integration between the different disciplines involved in various stages of the project procurement process, creates a huge opportunity for improvement. These opportunities must be targeted for the implementation of strategies that facilitate the integration of the different project disciplines.

1.1 Specific Problem Statement

As pointed out by numerous experts from industry, many problems in the execution of construction projects arise from miscommunication. The reasons for these problems include incomplete, erroneous, out-of-date or late information, resulting in extra cost and time to complete a project. Problems are followed by discontent and mistrust among project participants often leading to expensive corrective actions or litigation.

At the present time, meaningful electronic communication in the construction industry is still difficult, at least in general (Tolman and Böhms, 2000). Several initiatives have partially addressed certain isolated tasks in project management (e.g. EDI, aecXML, STEP, etc.), but only in limited cases are there standards for communication available, such as those for the exchange of electronic technical drawings, or for procurement of construction products. An integrated, vendor independent support for the complete supply chain, or even of a realistic part of the chain is not yet available. Manual methods of estimating quantities of materials and site work for construction projects are laborious and error-prone.

The adoption of the Internet by the construction industry, while maintaining existing approaches to construction process management, came with advantages and disadvantages. The fact that the Internet did not bring significant changes to current processes, facilitated its adoption. On the other hand, this adoption has presented information related problems and limited the potential of this technology at present. This is possibly why most companies and institutions contacted for information on e-business developments in the the rebar procurement process stated that this application was not feasible due to the inherent fragmented nature of the construction industry.

1.2 Context of the Problem

The early stages of the materials delivery are subject to many interactions that ultimately affect the duration and cost of the construction project. For instance, any discrepancy in the quantity take-off will translate into delays for the parties involved in the design team. Similarly, the lack of information stated on a bill of quantity or a drawing will lead to the need of issuing one or consecutive requests for information (RFI), with the obvious consequence of additional repetitive shipments between the design team, the contractor, supplier, client, and others.

These interactions are bound to set a standard for subsequent stages in the construction process, therefore hindering the flow of information between different stages of project development. The supply chain of materials can be analyzed from different perspectives in order to obtain a holistic concept of the situation. This concept will result in the formulation of a model that will improve the flow of information along the supply chain. It is very difficult to reach significant increases in construction work productivity when the basic and elementary idea of information exchange between stakeholders is left unattended. Figure 1 shows a diagram of the flow of information during rebar estimation and the revision of quantities for a traditional delivery system.

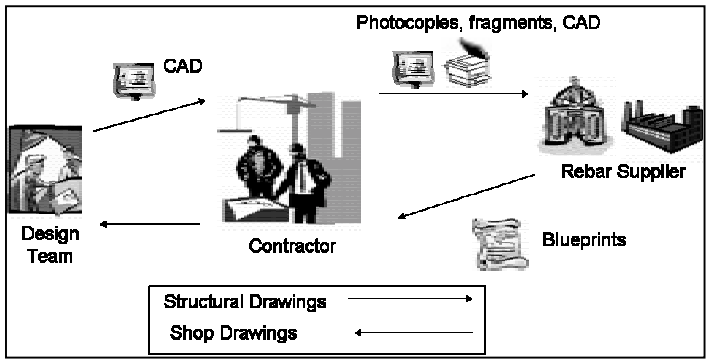

Figure 1: Traditional Rebar Delivery System

Steel reinforcement exemplifies one of the most complicated materials in any construction project. Its importance does not lie only in its repercussions for the overall strength and endurance of the structure, but in its direct implication to the schedule of subsequent activities, which are critical for the final duration of the project. Even though the rebar suppliers often present a well-executed blueprint of the shop drawing, most of the time this shop

drawing is not converted into a CAD file before submittal to the contractor. Therefore, the contractor is forced to make copies of the blueprints prior sending them to the design team. Normally, the contractor makes the corrections in green ink, letting the design team to use red. It is when a red circle is placed in the shop drawing when the contractor calls for the immediate attention of the rebar distributor. Normally, the contractor writes the requests for information (RFI's) on paper which are sent by fax to the supplier. In other circumstances the contractor will wait until the total review is completed.

2. CHARACTERISTICS OF COLLABORATIVE SYSTEMS

The process of quantity take-off and procurement of rebar can be clearly determined as an organizational function. The e-business collaborative supply chain solution must provide support for the capture and communication of customer demand, as well as enable this demand to automatically trigger business events and initiate process workflow. Some features included in the supply chain are: information sharing, collaborative planning processes and exchange of responsibilities. In other words, they key to supply chain management is to optimize parallel, rather than serial processes.

Extensive Markup Language (XML) is a conceptually common "language" that can be used to communicate over the Internet. It allows project teams to share or exchange data without requiring the use of the same software applications. The construction industry, with its complexities in project documentation, can benefit from this fact since it will not need to conform to the limitations of a strictly enforced standard. Instead, parties will be able to exchange data merely by changing the XML description of their documents (O'Brien et al., 2000). With the use of these tools, it is expected to develop an effective system that will allow the rebar industry to collaborate with construction and design firms, thus implementing a robust supply chain and a dynamic marketplace enabled by electronic business technologies.

2.1 B2B Electronic Markets and E-procurement

As defined by Dai and Kauffman (2001), B2B electronic markets function as digital intermediaries that focus on industry verticals or specific business functions. They set up virtual marketplaces where firms participate in buying and selling activities after they obtain membership. Furthermore, the marketplace creates value by bringing buyers and sellers together to create transactional immediacy and supply liquidity, and by supporting the exchange of demand and supply information. Burger (2001) defines e-procurement as utilizing electronic media, including the Internet, to streamline as many steps in the procurement process as possible. The major benefits of adopting e-procurement systems are reduced operating costs and searching costs, which lead to high returns on investments (Dai and Kauffman, 2001).

As stated previously, the preliminary stages for rebar procurement feature long periods of quantity takeoff revisions, cost estimation, quality assurance and procurement. All this is translated into expensive activities for the construction companies and the rebar suppliers, and into time overspent for activities that could be automated. E-procurement should reduce uncertainties by enabling the ordering, at a convenient price, of the precise types and quantities of materials needed to install on the subsequent workday, resulting in higher quality of the implementation of the just-in-time concept. Moreover, contractors may find the way of tracking the status of critical orders, thus knowing instantly when a supplier has run out of an already ordered item. As indicated by Kraker (2000), contractors want the purchase-related information to be entered just once, flowing easily throughout the life cycle of their projects, from the estimate and bid to the purchase order, and then into home-office systems such as job costing and accounting.

2.2 Automation of Rebar Take-off Procedures

Project document preparation is a critical issue facing professionals, developers and contractors working in the building industry. For this purpose, document preparation is presently utilizing manual, simply automated or coordinated automated techniques. An automated technique means that a computer program performs each stage of the design activity without reference to other tasks. A coordinated automated technique means that all design activities are performed with the use of a relational database that takes advantage of additional complex engineering data.

In the design and procurement stages of construction projects in general, there is a lack of a fully automated CAD-based system allowing for the creation of a bill of quantities through the interface with data from both the designers and contractors, and from manufacturers and commercial libraries. The preparation of complex project documents and adjustments of slight variations in design can be facilitated through automation. For the quantity take-off of steel reinforcement bars from structural drawings, commercial software products exist that interface with CAD drawings. These products, however, must be utilized from the early stages of design so the drawing elements can be described in the software as depicted in the CAD application. This represents a good option for new practitioners or reengineered firms, though the majority of contractors and design teams are using conventional practices (McDowell, 2001). New initiatives in the US construction market may help automate the quantity take-off of steel reinforcement bars from structural drawings. FrameWorks Plus, Geopak Rebar and Eagle Point Quantity Takeoff are examples of design packages that fit this purpose (Intergraph 2000; Geopak 2000; Eagle Point Software Corporation 2001). Moreover, software capable of recognizing, with the use of artificial intelligence techniques, rebar and other elements from structural drawings, has been developed by VHSoft Software, Inc. of Hong Kong (Castro-Lacouture et al., 2001).

In an effort to automatically diagnose potential rebar-related constructability problems, as well as to offer and implement solutions, an automated rebar constructability diagnosis model was developed by Navon et al (2000). These needs arose from an early research, where it was determined that a rebar constructability system should provide two important functions of constructability analysis, namely, to detect potential constructability problems in the early phases of a project life cycle and then to find solutions for them (Yu and Skibniewski, 1999). Nevertheless, presently there is no means for efficiently influence the fabrication delivery process from the construction site (Stone et al, 2000).

As affirmed by Dunston and Bernold (2000), it has been possible for some time now for 3D CAD modeling or walk-through data to be shared and submitted electronically for client approval. According to this study, the design, fabrications, delivery and placement of steel reinforcing bars present ample opportunities for computer integration. Previous work in this area has provided conceptual schemes for integration of the stages of design, delivery, and placement of reinforcing steel, and has shown proofs of some benefits of computer integration and automation (Bernold and Salim 1993; Miyatake and Kangari 1993; Salim and Bernold 1994).

However, these affirmations follow a wider opinion regarding communication and collaboration in the construction team, where the latest opportunity and challenge is the effective use of Web-based systems for information sharing among project partners (Rojas et al, 1999). The estimation and revision of steel reinforcing rebars is a multi-resource process, thus being performed by several individuals or resources. These individuals interact directly with the process and also interact directly among themselves. The procurement process, on the other hand, depends solely on the contractor and the rebar supplier. Their interactions are direct, though there is the possibility of indirect interactions with third parties such as the designer or the rebar detailer.

3. DEVELOPMENT OF THE PROTOTYPE E-BUSINESS SOLUTION

Figure 2 shows the flow chart representing the methodology for the development of the collaborative system.

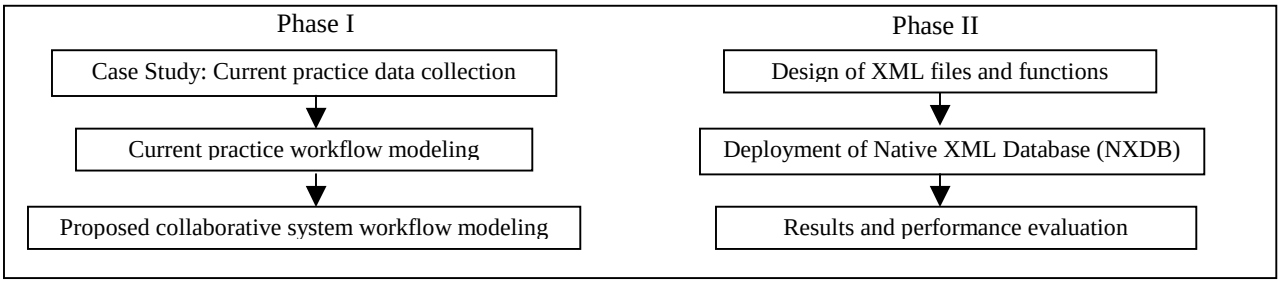

Figure 2: Methodology for the Development of the Collaborative System

3.1 Case Study: Current Practice Data Collection

A case study focused on a construction firm featuring a typical rebar delivery system will convey important information for the development of the prototype collaborative model. The firm design team and chief estimator will answer questions related to the durations of basic activities such as revisions of steel reinforcement data from structural drawings, preparation of shop drawings, modifications sent to rebar detailer, etc. In addition, several questions related to the durations of tasks by the reabar supplier, such as the preparation of structural drawings alongside designer for bidding, revision of steel reinforcement from structural drawings and shop drawings, correction of shop drawings and preparation of rebar schedules, will provide information for the construction process and the evaluation of the workflow. This case study will also assess other variables such as use of resources, costs involved and frequency of delays.

3.2 Current Practice Workflow Modeling

The current practices of steel reinforcement estimation, revision and procurement, are expected to find a linear sequence of tasks, processed by resources such as the contractor, designer, rebar supplier and detailer. Under this serial arrangement, communication between participants is fragmented, and depends solely on the presence of the participants of a specific task. Consequently, conflict resolution is not produced in a timely manner since the participants involved in a determined task are not in the position of taking any decisions without going back to a previous task. The fact that different formats are utilized for the presentation of information on reinforciement steel for estimation and procurement makes the situation even more complicated. Figure 3 illustrates the layout of the model of existing traditional practices of steel reinforcement estimation, revision and procurement.

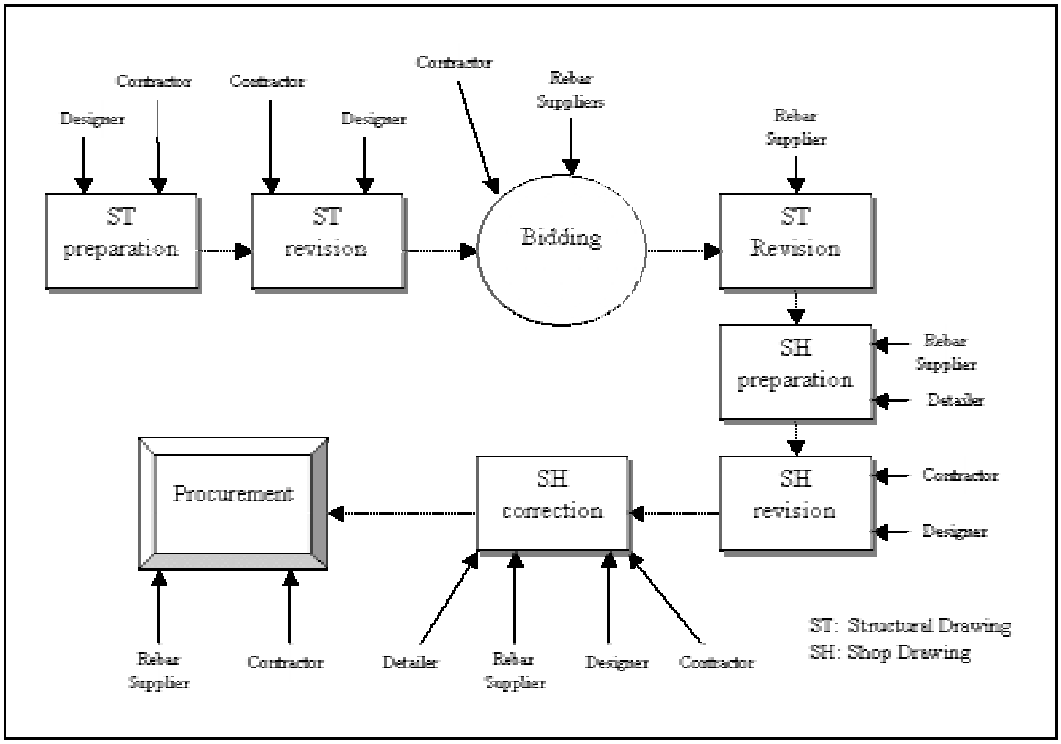

Figure 3: Workflow for Existing Practices of Steel Reinforcement Estimation, Revision and Procurement

3.3 Proposed Collaborative System Workflow Modeling

The proposed model offers a dynamic approach to the flow of information along the model network, as seen in Figure 4.

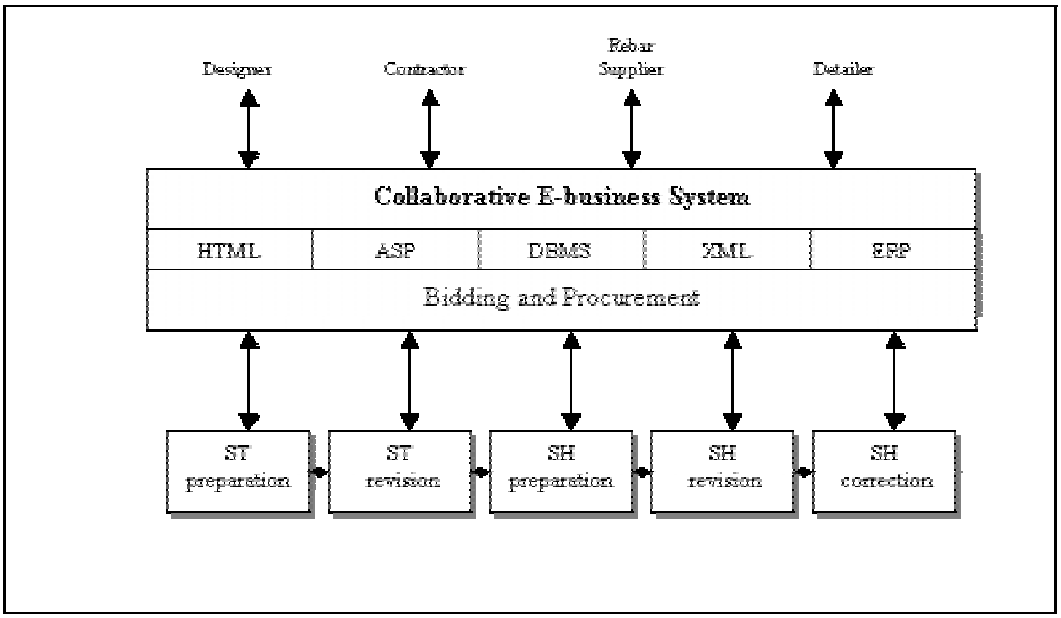

Figure 4: Methodology for the Development of the Collaborative System

The Internet serves as the environment where the e-business system will provide an efficient coordination and communication of tasks and resources. By facilitating communication as a basis for information exchange and conflict resolution, the proposed e-business model is capable of providing the overall process of estimation, revision and procurement with tools for integration and cooperation along the supply chain of steel reinforcement. The tools that constitute the architecture of the collaborative e-business system, i.e. HTML (Hyper Text Markup Language), ASP (Active Server Pages), and XML, will allow substantial communication among participants through the Internet.

3.4 Design of XML Files and Functions

The model will consist of several XML files containing information of rebars, jobs or referencing files required. The functions required for the calculation of quantities, scheduling or procurement tasks will also be designed at this stage. Figure 5 illustrates the architecture of the XML files and functions in the context of the collaborative system.

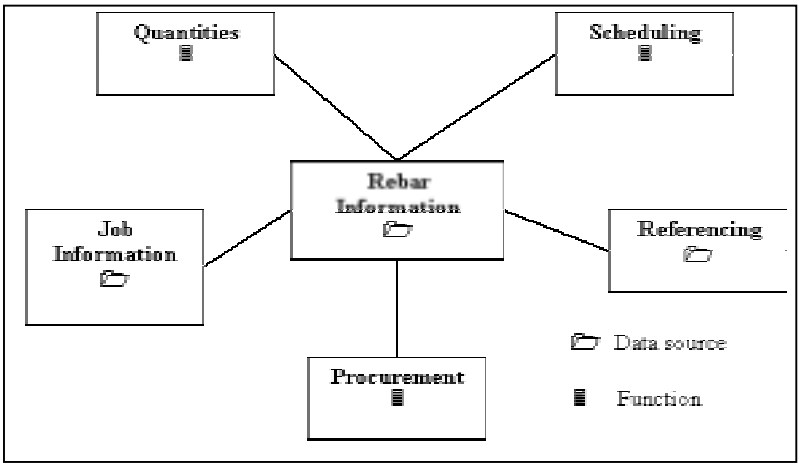

Figure 5: XML Files and Functions

Rebar information
This category includes the core data of the collaborative system. Physical characteristics of the rebar, as well as bent shapes, laps, covers and respective member will be included. The elements for this category are: reference indicator, member name, mark number, size, length, total number of bars, spacing, lap length, bar shape code, bent bar details (A, B, C, D, …, etc).

Quantities
This function will calculate the quantities of rebar required for a specified job. Also it contains several additional features such as scheduling check, structural check and delivery priority.

Scheduling
Based on the productivity of rebar procurement, delivery, bending and installation, this function calculates the projected completion times for each specific job.

Job information
This category identifies the particular job where the rebar is going to be installed. It may contain several suppliers, structural members or references, but only one job id, location and date.

Referencing
Auxiliary files that illustrate additional information of rebars are contained in this category: text, filenames, images, and hyperlinks.

Procurement
This function addresses transactions with the supplier, as well as follows up on existing orders. Includes a reference indicator, quantities, delivery time, transaction details (unit and total price) and status.

3.5 Deployment of Native XML Database (NXDB)

In order to ease the exchanges among stakeholders, the XML documents will be stored natively. NXDBs are capable of managing XML documents through their querying and updating capabilities. A commercial NXDB solution will be implemented in order to supply the programmatic interfaces and data access methods necessary to support multiple applications and data sources.

3.6 Results and Performance Evaluation

The validation of data for the workflow of existing practices under traditional delivery systems will be accomplished using a commercial simulation package. Simulation tools will provide means of determing expected duration times, critical resources, operational costs and delays, based on data gathered at the focus groups. Since there will not be an equivalent linear workflow for comparison, individual processes will be compared in order to assess improvements with the implementation of the proposed collaborative system for the integration of the supply chain of rebars.

4. CONCLUSIONS

This research is expected to provide the construction, design and steel industries with a collaborative system that will enhance the supply chain of steel reinforcing bars. The effort associated with this development may translate in large improvements for the integration of rebar quantity take-off and procurement in a construction project. The fact that rebar distributors prepare a drawing of the structure utilizing a different format makes it time consuming for the contractor to revise and correct discrepancies. Besides, delays in the bidding process due to the inefficient use of information resources by both the contractor and the rebar supplier, and the use of incomplete information by the rebar supplier, will have some effect when designing the collaborative e-business model.

The procurement process is expected to experience significant improvement, mainly because it now remains isolated from the estimation process. As a consequence, interactions that occur during the estimation process may not be considered when resolving posterior issues in the procurement process. These expected observations in durations and the use of resources are aggravated by the lack of communication among project participants during the

estimation and procurement processes. Therefore communication will be a primary target to be addressed in the design of the collaborative e-business model. Collaboration is closely related to communication in the sense that every participant in the estimation and procurement processes is going to interact with each other, share resources and convey information

E-business technologies will serve as an enabler to allow the seamless communication among project stakeholders. XML and NXDB tools will provide the means to achieve collaboration, thus obtaining significant benefits in project duration, cost and conflict resolution.

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