CONSTRUCTION SUPPLY CHAIN IMPROVEMENTS THROUGH INTERNET POOLED PROCUREMENT

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ABSTRACT

Construction material supply chains have evolved over time to base production and materials management decision-making on demand information from the immediate downstream node in the supply chain. This myopic view leads to demand signal amplification as individual upstream nodes attempt to forecast and fulfill orders. Further compounding this demand distortion is the fact that a great amount of demand uncertainty exists between the supply houses and contractors. Supply houses are challenged to base production and materials management decision-making on orders received from a large number of disparate contractors from diverse trades. The aforementioned demand distortion and uncertainty causes construction supply chain distribution channels to be crowded with unnecessary inventory. This paper investigates a new business model for Internet-enabled pooled procurement in construction supply chains based on research currently in-progress. Through global integration of procurement information over multiple projects, pooled procurement leads to efficiency in material manufacturing and distribution, decreased material costs to contractors and owners, and reduced transaction costs.

KEY WORDS

Supply chain management, pooled procurement, Internet-enabling technologies.

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INTRODUCTION

With the widespread use of information technologies in construction, contractors are racing to keep up with the pace of technological change while learning to apply those technologies in their enterprises. More than ever, business processes that were collected together within a construction firm are subject to competition from outside forces. Davidow and Malone (1992) in their visionary book, "The Virtual Corporation," predicted that information processing capabilities would result in a business revolution. They believed that firms that could meaningfully restructure themselves to focus on core activities and outsource other processes could achieve "cost-effective, instantaneous production of mass-customized goods and services."

Davidow and Malone specifically addressed the manufacturing industry that was characterized by fixed and long-term agreements to mass produce goods. However, the "temporary networks" proposed by Davidow and Malone are a paradigm that has long existed in construction where contractors form and reform cooperating groups for each project (Kornelius and Wamelink 1998). Inroads have been made in high technology manufacturing industries to take advantage of this flexible business model. A decade ago, manufacturers attempted to vertically integrate all business activities. Today, highly competitive high tech supply chains, such as for personal computers, stay competitive through dynamic sourcing from a competitive marketplace of vendors for many or all constituent components (Bartholomew 1999).

Emerging virtual communities of commerce on the World Wide Web will allow the formation of temporary business networks in many industries. As the economy changes, as competition becomes more global, it is no longer company vs. company, but supply chain vs. supply chain (Henkoff 1994). How will construction supply chains be effected by this trend? It will be necessary to reconsider construction supply chains by measuring the value-added at each node and looking for ways to decrease waste and latency. The efforts of the Lean Construction Institute are an indication of the trend in this direction in construction (Melles 1994, Alarcón 1993).

Incorporating the concept of the "virtual corporation," this paper investigates a new business model for Internet-enabled pooled procurement in construction supply chains. First, causes of demand distortion in construction supply chains are identified and discussed. Second, the concept of pooled procurement from other industries is identified and discussed. Finally, a framework for applying pooled procurement over the Internet for multiple projects is investigated as a method of integrating disparate information. This will contribute to efficiency in material manufacturing and distribution, decreased material costs to contractors and owners, and reduced transaction costs in construction supply chains.

CONSTRUCTION SUPPLY CHAINS

SUPPLY CHAIN COMPLEXITY

Previous research investigates lean production models for application in construction supply chains (Tommelein 1998, O'Brien 1995). There is little doubt that improvements are needed in the handling and distribution of materials to the construction site. However, a myopic view of supply chains leads to sub-optimization. A holistic view of supply chain interactions allows for the evaluation of overall performance of material handling, distribution, and information flow through every link of the chain, beginning with initial raw materials (Figure 1).

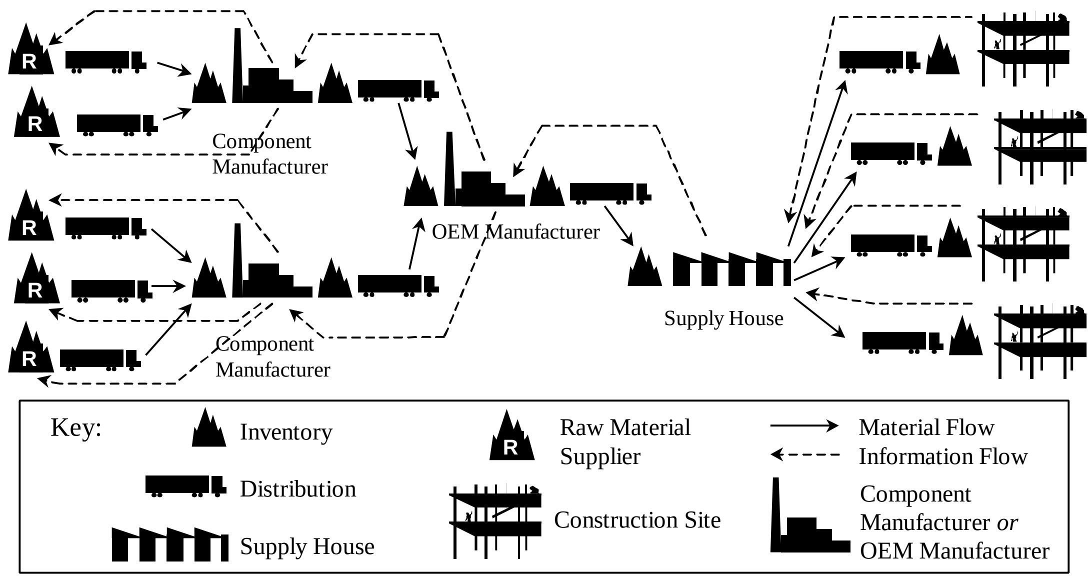

Figure 1: Example of a Construction Supply Chain for a Building Material

When considering all nodes of a building material supply chain, the number of and complexity of interfaces becomes evident. In Figure 1, there are twelve interfaces between supply chain nodes (one for each black material flow arrow). This figure assumes that all distribution services are executed in-house by each supply chain node. Each of these nodes is charged with making forecasting and production and ordering decisions based on the downstream demands, internal capacity and upstream constraints of nodes in the chain with which it interfaces. This situation is less than ideal.

By limiting coordination to node-to-node communication, the supply chain is unable to flexibly meet the demands of the end customer. An example of this would be if one of the raw material suppliers in Figure 1 stocks out of the material required by the downstream component manufacturer. Because the material supplier is not able to communicate this to the entire chain, all other nodes fulfill their orders causing unnecessary inventory at the component manufacturer and the original equipment manufacturer (OEM manufacturer). The OEM inventory would be impacted since the component produced by the non-impacted component manufacturer would be fulfilled.

This example leads to the conclusion that even a supply chain with only a few nodes can lead to problems if communication is limited. Supply chain complexity becomes even more daunting when it is considered that the chain diagrammed in Figure 1 is less complex than an average building material chain. However, a more detailed investigation into the mechanics of even this simple construction supply chain will indicate the need for a new, simpler information and material transaction business model.

DEMAND DISTORTION

Effective operational control of a supply chain requires centralized coordination of key data (Lee and Billington 1992). For industrial manufacturing, this typically has meant forecasts, inventory status at all sites, backlogs, production plans, supplier delivery schedules and pipeline inventory. In other words, supply chain integration requires all nodes in the network to communicate and share detailed, current information. The inability or unwillingness to share this detailed information leads to distorted demand information and a phenomenon known as the “bullwhip effect” (Lee et al. 1997).

The bullwhip effect was first coined by Procter & Gamble during a replenishment pattern study for disposable diapers (Nahmias 1997). Procter & Gamble noticed that even though diaper demand was relatively stable, the upstream orders were amplified. Figure 2 demonstrates the bullwhip effect as it might occur for the building material supply chain previously described in this paper. In the example, contractors working on several separate projects begin to order more of a building material during week five. The supply house increases orders to the OEM manufacturer, however, there is a time lag between the demand and the time the order is received. Having received the supply house orders in the fifth week, the OEM manufacturer ramps up its forecast in response to increased demand and increases its orders to component manufacturers, again with a lag. Finally, the component manufacturers behave in the same way with their raw material suppliers.

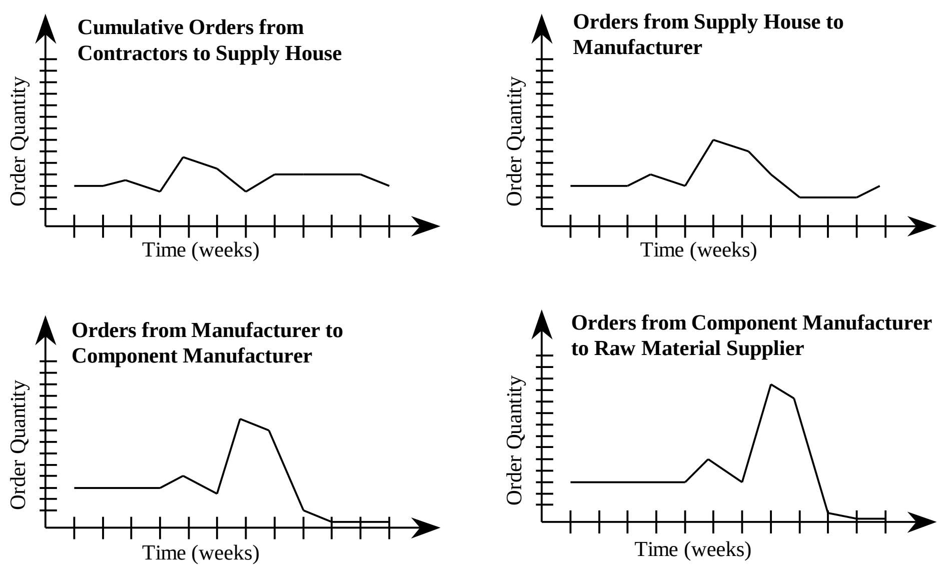

Figure 2: “Bullwhip Effect” for a Construction Building Material Supply Chain

The graph of the cumulative order quantity from contractors to the supply house indicates that the upsurge in demand for the building material in the fifth week was only for a two-week period. However, the increased demand for the material amplified at each upstream node. Lee et al. (1997) identified the recurring theme in supply chains that variability of an upstream node is always greater than at a downstream node. This increasing variability up the supply chain is primarily due to the fact that each and every company in the supply chain does its own forecasting, scheduling, inventory control and material requirements planning. This effect is compounded by the fact that ordering is typically based on the immediate needs of the downstream customer.

EFFECTS OF DEMAND DISTORTION

The uncertainty and variability in perceived demand in a supply chain causes each node in the chain to stockpile inventory. A study of various industries indicates that an average of more than 100 days of inventory supply exists in the total supply chain from the manufacturer to the retailer (Lee et al. 1997). The costs of carrying this inventory are tremendous. The breakdown of the incremental costs of carrying inventory is as follows:

- Cost of Capital,
- Cost of Storage,
- Taxes and Insurance, and
- Breakage.

The cost of capital has the largest impact on the per unit cost of carrying inventory. From an accounting standpoint, inventory and cash are for practical purposes equivalent. Thus, unnecessarily held inventory represents capital that could be otherwise invested. The costs of capital are based on an amalgam of accounting measures such as internal rate of return, return on assets and the hurdle rate. Costs of storage, taxes and insurance, and breakage have a comparatively lesser effect on inventory carrying cost in industrial manufacturing, however, are of particular interest in construction since they have the potential to vary significantly from one building material to another. For example, gypsum board would have a higher likelihood of breakage than structural steel.

CONTRACTOR DEMAND MANAGEMENT

POOLED PROCUREMENT

A multiple-industry study conducted by the Center for Advanced Purchasing Studies reports that purchasing through pooled procurement groups results in average savings of 13.43 percent (Hendrick 1997). When compared against the average annual cost of operating these groups, it was indicated that, on average, returns on investment of 767% were achieved. Typically, these group purchasing arrangements are implemented in fragmented industries where the end-customer does not have much buying power and demand is uncertain and/or variable. As was previously discussed, uncertainties and variability are amplified as demand information propagates upstream in the supply chain. Therefore, a procurement solution that decreases this variability would effectively reduce the amount of inventory carried in the supply chain.

One industry in which group purchasing has had a major impact is healthcare. There are over 550 group purchasing organizations in healthcare (Medical Economics 1998). These group purchasing arrangements now account for 80% of the current $179 billion in annual spending by hospitals and nursing homes in the United States (HICPA 1998). Pooled procurement in healthcare is a relatively new phenomenon. Yet, because of the positive impact it has had in hospital material management, it has rapidly become prevalent in the industry.

Hospitals have come to rely on the system for the reduced pricing gained by volume discounting. However, the upstream supply chain network impact is also profound. The group purchasing organizations have reduced uncertainty and variability of end-customer demand through pooling and subsequently reduced the bullwhip effect.

It is difficult to predict the precise effect that pooling procurement will have in the construction industry. Any impact on the bullwhip effect in construction supply chains will help to reduce inventory carried and therefore overall costs. However, construction is a fragmented industry composed of many different trades using diverse project delivery systems. This makes coordination of a pooling effort difficult. Because construction is project-based, or composed of “temporary networks,” pooling procurement is at the same time a challenge and potentially very rewarding. A pooled procurement system in the construction industry would require much coordination and trust. It is unlikely that contractors would pool together and build enough trust to form large-scale procurement coalitions. However, in industrial engineering and other fields, it is trusted third parties that are emerging to provide this pooling service and the requisite environment for trust.

ECONOMIC ORDER QUANTITY ANALYSIS

Among other things, pooled procurement reduces demand distortion thereby reducing inventory carrying costs in supply chains. For construction supply chains, pooling procurement would group material purchasing for multiple projects and multiple construction firms. Contractors could then achieve economies of scale on the purchase of building materials. Larger scale purchasing would allow supply houses to perform more accurate ordering and forecasting. Development of a consistent economic order quantity for construction building materials would allow for improved overall supply chain efficiency.

There exists a trade-off between the inventory carrying costs previously discussed and the fixed costs associated with ordering. The economic order quantity (EOQ) model is a method developed in the manufacturing industry to analyze this trade-off and arrive at an optimum order quantity (Nahmias 1997). Because industrial supply chains are typically structured with fixed chain networks, it is assumed that once an EOQ has been determined it can be implemented. However, in construction supply chains, contractor ordering is done on a project basis. Thus, the existence of temporary project networks for construction supply chains and industry fragmentation makes implementation of an EOQ impractical without implementation of pooled procurement.

The objective of EOQ analysis is to minimize the average cost per unit of time by selecting the optimum order quantity (Q). The function for average cost per period F(Q) is the sum of the setup cost per period and the inventory carrying cost per period. Graphing the setup cost and the inventory carrying cost per period and summing them yields the average cost per period function. Figure 3 contains this graphical representation. Note that the trade-off between annual setup cost and the annual cost of carrying inventory reveals a minimum value for the average annual cost function.

In the figure, a shaded area represents the range in which orders are typically placed by contractors. Fulfillment of these single project orders leads to excessive supply chain inventory and higher costs of meeting demand. The incremental increase in average annual cost is greatest when low quantity orders are made. Therefore, a contractor who decreases their order by one unit for a building material will have a comparatively higher impact on orders much lower than the EOQ. By pooling procurement over multiple projects, contractor demand signal to supply houses and to the entire building material supply chain can be managed more efficiently.

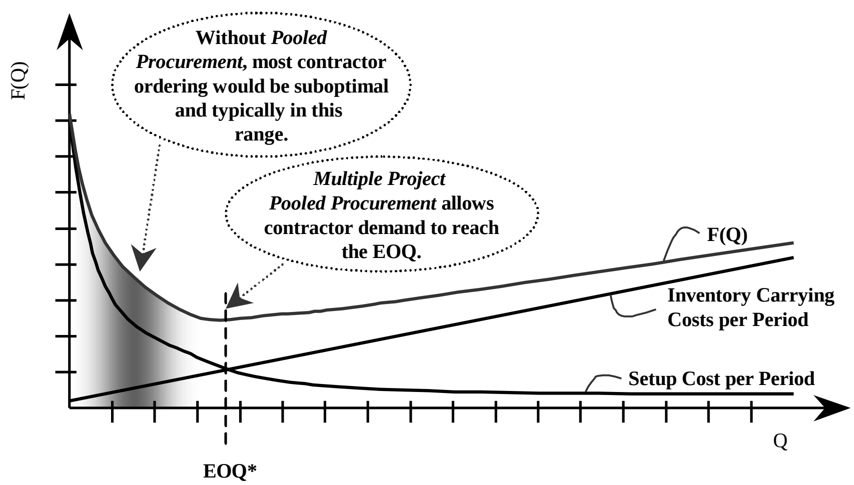

Figure 3: Qualitative Variable Average Annual Cost Function

FRAMEWORK FOR INTERNET-ENABLED POOLED PROCUREMENT

STATE OF THE ART OF PROCUREMENT OVER THE INTERNET

If a supply chain is considered as a distinct entity, all links in the chain would perceive the end customer as the contractor (or, perhaps, the facility owner) in terms of demand planning. Pooled procurement is a method to tie the overall performance of the supply chain to aggregated contractor demand. However, implementation of this new procurement framework requires that information and planning be coordinated along the entire supply chain. The Internet provides a platform for the coordination of this type of information.

In recent years, the Internet has evolved as a tool for electronic commerce. Available services have increased that provide a platform for transactions and trading communities. Formation of virtual marketplaces has been sparked by the current trending increase in business to business transactions. With the infrastructure for pooled procurement over the Internet in place, the challenge for the construction industry is to build a pooled construction procurement World Wide Web communities and communicate information to all members of the construction supply chain network.

World Wide Web sites exist today that provide similar services in other industries. For example, the Chemdex (http://www.chemdex.com) site aggregates order information for biological and chemical reagents. Users browse through electronic catalogs to order products and the Chemdex group aggregates those orders for supply chain optimization. Through pooled procurement, Chemdex offers advantages to customers and manufacturers/distributors by facilitating information exchange and aggregating economies of scale.

Other examples exist that apply more readily to the construction industry. For example, MetalSite (www.metalsite.com) and eSteel (www.esteel.com) are two new sites dedicated to providing a platform for the electronic exchange of materials that relate to the construction process. The eSteel site, for example, plans to "level the playing field" by providing a marketplace for the exchange of steel using the Internet as the transaction platform. Both rely heavily on the idea of pooling procurement services using the Internet to offer price advantages to customers and economic ordering practices for the supply chain network.

INTERNET-ENABLED POOLED PROCUREMENT MODEL

In order to illustrate pooled procurement transacted over the Internet, we return to the building material supply chain described earlier in this paper. Each of the links in this building material supply chain must make decisions regarding materials management, capacity allocation, and forecasting. Pooling procurement information into a global repository allows each of the network nodes to access the information required for their decision analysis. However, representing this information in a way that can be shared between companies and applications requires shared information models for complex transactions. Figure 4 illustrates the architecture for Internet-enabled pooled procurement as proposed in the context of this paper. The on-line hosted application services are assumed to contain the brokering services for sharing content over the Internet. Additionally, the hosted applications would provide functionality to manage and monitor procurement activities. In this system, information exchange is now centralized and visible to all supply chain nodes. Workflow management systems can also be implemented to control the flow of information and tasks.

Integrating the global information for multiple projects, pooled procurement requires a highly capable information system. Each supply chain actor publishes electronic catalogs which are accessed via the pooled procurement server. The contractors who use the system will interface through a web browser and make orders based on project material demands. The pooled procurement system then aggregates orders by building material and publishes demand requirements to all supply chain nodes. Each node then makes production decisions based on the demand and publishes these to the on-line services directory. Resource leveling for the entire supply chain is then calculated based on production capacity and material requirements for decision optimization.

EFFECT OF POOLED PROCUREMENT MODEL ON DEMAND DISTORTION

When supply chain networks collaborate and share information as described in the Internet-enabled pooled procurement model, the causes of demand distortion are likely to reduce. First of all, because demand information is available to all nodes in the supply chain, there is no lag in the communication of order information. Because this demand information is based on aggregated contractor orders, forecasts are less uncertain and can be made in economic order quantities. Therefore, the effects of demand distortion that lead to the bullwhip effect would reduce. Because of the demand distortion reduction, the amount of inventory safety stocks that needs to be carried in the supply chain would be reduced leading to decreased overall costs and increased efficiency.

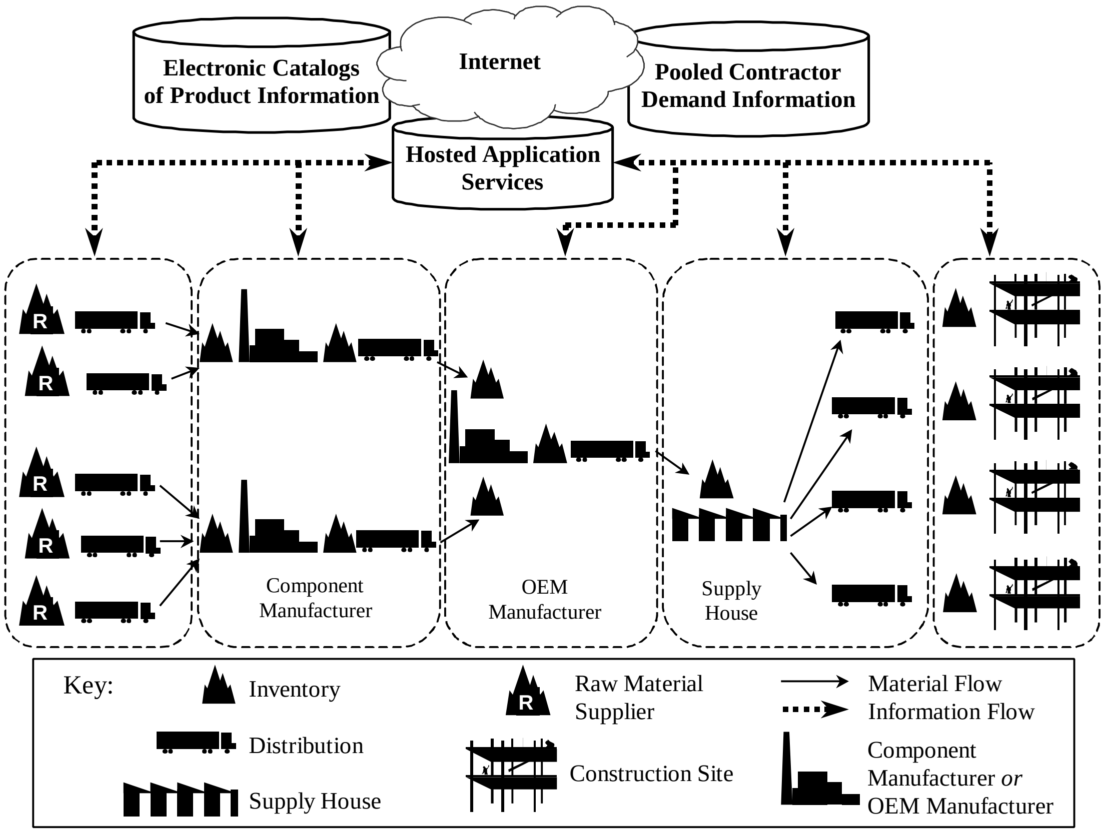

Figure 4: Internet-enabled Pooled Procurement Model for Construction Supply Chains

CHALLENGES FOR IMPLEMENTATION IN THE CONSTRUCTION INDUSTRY

The Internet-enabled pooled procurement system as proposed does require some organizational and technical consideration before it can be implemented in the construction industry. Based on research completed to date, certain challenges remain to be addressed before the industry could launch such an initiative. Organizational challenges are identified and discussed in Table 1. Technical challenges are identified and discussed in Table 2.

CONCLUSIONS

Supply chain networks that collaborate and share information using the proposed Internet pooled procurement model would perceive benefits in terms of efficiency in material manufacturing and distribution, decreased material costs to contractors and owners, and reduced transaction costs. Due to tighter integration of information and decision-making, construction supply chains would be capable of holding less inventory and realizing a more accurate demand signal. However, for transactions of this nature to take place over the Internet, the industry must address some key issues with respect to technology and organizational behavior. Further research investigation is underway to extend the Internet pooled procurement model and to address the aforementioned challenges. Once the industry moves to adopt an Internet-enabled pooled procurement system, the cost of infrastructure development would decrease and the construction industry would move toward more lean practices.

Table 1: Organizational Challenges to Implementation of Internet Pooled Procurement

Organizational Challenge	Discussion
Contractors might perceive Internet pooled procurement as a threat.	Pooling procurement of building materials will provide small to medium sized contractors with previously unachievable economies of scale. Larger contractors may see this "leveling of the playing field" as the threat of increased price competition.
Contractors might be unwilling to share information.	For a pooled procurement system to have the greatest impact on the entire building material supply chain, information must be shared. Some contractors may feel that sharing certain procurement information represents strategic knowledge for their company. As such, they may be unwilling to share all the information needed to optimize the supply chain.
Legal issues might hinder procurement pools formation.	The U.S. government places certain rules and restrictions on pooled procurement practices in the form of antitrust laws.

Table 2: Technical Challenges to Implementation of Internet Pooled Procurement

Technical Challenge	Discussion
Publishing content over the Internet requires a sharable format.	The current standard for World Wide Web content is HTML, however this is insufficient for the transactions in the Internet-enabled pooled procurement model. A new standard is evolving called XML (eXtensible Markup Language) which will allow for sharing of content for complex information such as will be required for this system.
Standardization of shared information.	There is not a currently agreed-to standard for sharing models of information content. The International Alliance for Interoperability is in the process of defining Industry Foundation Classes for this purpose.
Level of Internet technology and usage by contractors.	For the information and business transactions to be performed using the Internet, all participants must reach a minimum level of technology and understanding. Issues such as Internet connection speed, project web sites, Internet and computing infrastructure at project sites, etc. need to be addressed.

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