Solution framework proposal: taking effective control over the project delivery chain with automatic identification and agent-based solutions

E. Ilie Zudor
Computer and Automation Research Institute (SZTAKI), Hungarian Academy of Sciences, Budapest, Hungary, and
J. Holmstrom
Department of Industrial Engineering and Management, Helsinki University of Technology (HUT), Helsinki, Finland

Abstract
Purpose – The objective of this paper is to propose a solution framework for better project delivery control.
Design/methodology/approach – Three emerging technologies that may offer practical solutions are reviewed. These are: automatic product identification, merge-in-transit (MIT), and agent based control systems.
Findings – Combining project site level and shipment specific control makes it possible to implement MIT in the project delivery chain. This basic functionality of merging deliveries is needed to react to project delays, and improve rescheduling project resources.
Research limitations/implications – Systems design and trials are needed for further development of the proposed solution framework.
Practical implications – Organizations responsible for coordinating project deliveries need to think about the incentives and costs for logistics service providers, and other business partners to participate in MIT solutions.
Originality/value – The proposed framework is based on an open identification scheme. This makes it possible for new project delivery partners and service providers to locate and start using the controlling software applications without prior notification and arrangement.

Keywords Identification, Project management, Computer applications, Logistics

Paper type Conceptual paper

Introduction
A project delivery chain comprises the suppliers and logistics service providers that are needed to deliver a certain unique investment project (Kärkkäinen et al., 2003). Examples of project delivery chains are the chains needed to deliver the materials and components for building a house or to install a new elevator in a house.

Project delivery chains have to fulfill many stringent logistics requirements to perform well. For example, in commodity delivery, where there are substitutes, a delivery service of 96 percent may be very good. But in a project delivery chain, where perhaps a 100 different materials are needed, such a level of delivery service for individual materials leads to project delays, cost increases, and customer dissatisfaction. Also, individual deliveries are usually not earmarked for a specific purpose or customer in commodity and consumer goods supply chains. But in a project delivery chain many items are especially designed for a specific project site, which complicates the task of managing the project delivery supply chain.

The delivery in the commodity and consumer goods supply chain is generally made through established distribution channels to established retail outlets. In project delivery, the delivery is to project locations that are project specific. The logistics service is provided by different logistics service companies depending on where the project site is located. The delivery of sub-orders often should be done in a very narrow time window. To reduce the risk of damage and loss, the delivery should not be early. At the same time the project is delayed if the delivery is late. This way penalty costs are incurred in both cases.

The special requirements listed above makes managing project delivery supply chains a most challenging logistics tasks. It is also a task which lacks effective information management tools and solutions. The objective of this paper is to present a solution proposal for solving some of the most critical management and control challenges in the project delivery chain. First, the relevance of better management and
Processes model for the project delivery chain: a mobile telecom example

In this section the complex processes of the project delivery chain are described by using an example. The example is the delivery of equipment for building cellular mobile telephone networks. The description is based on an action research study by Collin (2003).

The network of base stations is the backbone of a cellular telephone system. The other components are the end-user mobile terminals (i.e. the mobile phones), network switching and support systems. From a logistical point of view the delivery of the base station equipment is the most challenging. It is very challenging because the base stations have to be built in a large number of individual sites and many times in difficult locations. Additionally, the base station equipment is high-value and sometimes customized or configured for an individual network location.

The project delivery chain is driven by the site implementation process of the operators building the cellular network. To operate efficiently it is important to understand the operator customer’s process and to adjust the project delivery process to the customer process. The main phases of the operator’s process are network planning, site acquisition, construction work, equipment delivery, installation and commissioning, and integration of the base stations into the network. The phases of the customer’s process are shown in Figure 1.

In principle, if the customer’s project plan could be completely relied upon, it would be possible to plan and schedule the production and delivery of equipment with high efficiency and accuracy. However, all phases of the implementation process can change unexpectedly before the telecom installation is started. The cellular network plan may be updated to increase capacity, there may be problems with getting all permissions for locating a base station in a specific location, construction work may be delayed, the delivery of critical components and materials may be late, or key personnel may not be available for the installation work.

The conventional way to respond to this uncertainty is to collect base station equipment in nearby warehouse locations well ahead of time. However, this is very inefficient and also expensive when there are a large number of site-specific configurations. The configurations may change many times before the planned installation date. This way, despite buffering equipment nearby the site, there are critical components that are missing and delay installation on the planned date. Sometimes a needed component may even be physically present in the same warehouse, but it is difficult to identify it and reassign it. The problem is greater still if the equipment is in transit when the need for identification, reassignment, and rerouting occurs.

The root problems are in linking changes in the site implementation plans to equipment delivery, and in tracking and tracing project delivery components after the equipment has left the base station manufacturer’s premises. Most logistics service providers today provide tracking solutions for the shipments that they handle. But for controlling and managing the base station delivery chain this is not enough. The project may for different suborders use different logistics service providers, each with their own proprietary tracking solution. In the same way an equipment manufacturer may for different projects use different logistics service providers, each with different tracking solutions. This makes it difficult both for the operator customer and the manufacturer to get an overview of the project delivery chain, and to efficiently issue instructions for rerouting and reallocation when project requirements change.

Emergent technologies in supply chain management

The base station example illustrates some of the practical complexity involved in increasing the dynamic control and management of material flows. In this section three emerging technologies that may offer practical solutions are reviewed. These are: automatic product identification, MIT, and agent based control systems.

Automatic identification

The introduction of automatic identification (Auto ID) technologies is seen as a new way of controlling material flow, especially suitable for large supply networks (Kärkkäinen and Holmström, 2002). The aim of most Auto-ID systems is...
to increase efficiency, reduce data entry errors, and free up staff to perform more value-added functions.

Automatic identification is the broad term given to a host of technologies that are used to help machines identify objects. Auto identification is often coupled with automatic data capture. That is, companies want to identify items, capture information about them and somehow get the data into a computer without having employees type it in (e.g. www.autidlabs.org). Automatic identification’s main principle consists of the application of a tag containing information about and on products (parts and/or finished assemblies), which will be later read by a device called “reader” or “interrogator”.

Automatic identification encompasses various technologies such as: bar code technologies, radio frequency identification (RFID) tags, smart cards, magnetic inks, biometrics, optical character reading, voice recognition, touch memory and many more.

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There are several methods of identifying objects using RFID, but the most common is to store a serial number that identifies a product, and perhaps other information, on a microchip that is attached to an antenna and together form the RFID tag. The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves returned from the RFID tag into a form that can then be passed on to computers that can make use of it (Auto-ID Center, 2004). When an interrogator reads an RFID tag the unique identification code of the tag can be used as a reference to a database on a local network or the internet that contains the information related to the individual product or references to where information on the product is stored.

The information contained on different types of identifiers is not standardized at the moment, and different developers encompass different quantities of information. In present applications, few product-related data are incorporated on RFID tags, as increasing the quantity of information also drastically increases the costs of the tag. Examples of additional information to store on a tag can be found in the approaches discussed in the work of Kärkkäinen et al. (2003) and Wong et al. (2002).

The primary shortcoming of bar code tags as an identifier is that it is a line-of-site technology. If a label is ripped, soiled or falls off, the item cannot be identified by scanning anymore. Another issue is that identification standards for one-dimensional bar codes typically only specify the manufacturer and product, not the unique item or delivery unit. For example the European article numbering (EAN) bar code on each consumer package is the same as every other, making it impossible to identify which one might pass its expiration date first. In the grocery industry standards for identifying delivery units by bar code scanning has therefore, been developed in the last 10 years for distribution centers, where products can be easily identified by attributes such as sell-by-date.

The primary shortcoming of RFID is standardization and the high cost of readers and tags. Gate readers typically cost thousands of Euro, and tags still cost 50 cents or more. A problem is that readers typically operate at only one radio frequency, while there is a range of different frequencies used in tags. If the tags used in different projects use three different frequencies, a logistics service provider might have to have three different readers in a freight terminal to identify the deliveries from different customers. With the high cost of readers this undermines the business case for investing in RFID in the project delivery chain.

If widely adopted, automatic identification technology potentially makes it possible to know exactly where every item in the supply chain is at any moment in time. Automatic identification also reduces or even eliminates human error from data collection. More reliable inventory records would reduce the need to keep safety inventories, reduce loss and waste by pilfering and aging. Better information makes it potentially easier to track safety and security problems and improve the customer service level.

Merge-in-transit

For the successful completion of an individual project – be that maintenance, installation or construction – all materials and personnel resources have to be available in time, in the right location, and in the right quantities. Missing just one critical low value item out of a hundred could delay the whole project, and delay the return on investment.

To ensure availability and a short delivery lead-time a common practice is to consolidate all the required materials at an inventory location close to the project site. However, as there may be 100s or 1000s of project sites there is also a need for a large number of inventory locations. Maintaining availability of all materials in each location is both expensive and difficult. The result is that companies active in project businesses typically are burdened with high inventory levels without having achieved the required service levels to complete projects effectively and in time.

A solution option is represented by the MIT technique (Ala-Risku et al., 2004). MIT is an alternative approach to ensure availability of materials on a project site, not by relying on inventory close to the project site, but on managing the deliveries in time to the right location from different sources across the supporting supply and service network. In MIT the composite deliveries from different sources are not delivered individually to the project site, but held up and combined into one delivery while in transit between the supplier and the final destination.

Methods to identify the cost reductions that the introduction of MIT would make possible, have been elaborated (Ala-Risku et al., 2004) and the results were very encouraging. Naturally, there are many situations when MIT is not economical and local inventory is necessary, such as:

- delivery of standard items when there are no suppliers able to deliver economically to a consolidation center within the time window of requirements planning to starting installation work;
- when the project requires bulky commodity supplies such as cement that are most economically delivered in dedicated vehicles directly from the suppliers to the project site.
However, the co-ordination of many different supplier and logistics companies is a complex task. As a consequence, examples of this type of operation are difficult to find one of the few reported examples from practice is Dell’s MIT of monitors and PCs (Richardson, 1994). MIT is a task that needs new business processes to be developed and innovative technical solutions supporting the new processes. The primary obstacle is in developing advanced business processes that can be quickly implemented in a standard way with a new partner, perhaps for completing just a single transaction.

### Agent-based systems

An agent is a real or virtual entity able to act on itself and on the surrounding world, generally populated by other agents. Its behavior is based on its observations, knowledge and interactions with the world of other agents. An agent has capabilities of perception and a partial representation of the environment. An agent can communicate with other agents, reproduce child agents, and has its own objectives and an autonomous behavior (Koussis et al., 1997).

As an intelligent entity, an agent operates flexibly and rationally in a variety of environmental circumstances given its perceptual and effectual equipment. As an interacting entity, an agent can be affected in its activities by other agents and perhaps by humans (Weiss, 1999; Kádár et al., 1998).

In multi-agent systems (MAS), heterogeneous distributed services are represented as autonomous software agents, which interact using an agent communication language (ACL) based on speech. A close analogy between the departments and actors in the production networks such as supply chains of large projects, and agents in a shared software environment can be seen. The analogy consists in the departments within an enterprise working towards both global and local goals with shared, finite resources. Furthermore, departments often must work together to achieve these goals. The production network (Ilie Zudor and Monostori, 2001) is a complex interaction of a number of functional entities in order to achieve some level of performance in the delivery of products to customers.

Efforts have been made to utilize automatic identification technologies in developing so-called “intelligent products” and an “Internet of things”. The creation of an “Internet of things” (Autoidlabs, 2004) approach refers to the development of a network that connects computers to objects, including affordable hardware, network software and protocols, and languages for describing objects in ways computers can understand.

The “intelligent product” is a product whose information content is permanently bound to its material content, and which can influence decisions made concerning its destiny. Establishing connections between manufactured products and the internet using automatic identification technologies will enable accurate, timely information about a specific item to be stored, retrieved, communicated and even used in automated decision making or control functions relevant to that item (Wong et al., 2002).

### Solution proposal for project delivery control

Our solution proposal to improve control of project delivery chains is based on the combination of automatic identification and MIT techniques in an agent-based environment. Figure 2 shows the proposed approach for managing project deliveries in process.

The basis for the proposed solution is that each delivery has a dedicated software application that is uniquely responsible for the information collection and control of the individual delivery, and that each project site has a software application that is uniquely responsible for the information collection and control of the individual deliveries to that project site. In other words, each shipment and each project site is represented by an individual software application, or software agent.

The proposed concept requires that the deliveries and perhaps some of their components, are equipped with identification tags (note that both RFID and barcodes can be used), which links the delivery or component to the internet location where the relevant data about them are stored, and to the software application responsible for controlling the delivery.

The individual software application or agent that controls the delivery can be found based on the ID@URI (Dialog, 2004) that is written on the identification tag physically applied to the delivery or component. This solution makes it possible for new partners and service providers to locate the controlling software application without prior notification.

When the identity of a delivery is recorded using automatic identification, the identification of the delivery activates the appropriate software application. Activating the application enables the delivery agent to communicate over the internet with the logistics service provider, supplier, or customer that read the identity. The communication can, for example, be a request from the controlling delivery agent for registering the time and location of the identification event in its database. The communication can also be command and control instructions to the logistics service provider, such as delaying the shipment until a later time when other shipments also have arrived at the location.

The types of agents in the proposed model are the project, the network builder, the delivery, the merge agent for the project site and the supply agent.

The project agent (PA) represents the contracting organization, responsible for the whole project delivery. The PA establishes all the rules for the chain and the information is always passing through its own network. The project will be divided by the PA in activities. Here the activity can be defined as a part of the project (often called sub-project), seen as a job order or order line by the supply agents.

Delivery agents belong to the project; there is one DA for each project activity. The merge agent belongs as well to the PA and there is one for each project site.

Supply agents represent suppliers and logistic service provider companies.

In this paper not all the agents involved in the supply chain, nor their functionality, will be comprehensively discussed. Focus is on the agents and functionality most critical for the introduction of the approach.

A schematic representation of the PA is shown in Figure 3. The figure shows the structure of the agent architecture when executing, i.e. it shows how one project, one project site and the delivery agents for the materials needed on the site are related.

In a traditional approach, among the first tasks of a project manager is to identify all the activities in the project, together
with their independence and the order in which they must be done. Following, estimates regarding times and costs are made, and the network of activities is built. In the proposed approach, the PA, through its network builder agent, behaves in a similar way, but having a supply point of view, instead of building the network of activities based on their timings, a network based on the location where each activity is to be performed will be built. Figure 4 shows a simplified location-based network.

$S_1, S_2, \ldots, S_n$ represent the locations of the different supplier sites, where the activities are to take place.

$L_1, L_2, \ldots, L_n$ symbolize the location of the logistic service provider companies.

$P$ represents the project site.

$\text{sub}[1] \ldots [n] = \text{suborders}$. 

$\text{sub}[i \ldots j] = \text{merged suborders}$.

The arrows do not represent the distance, just the direction of the material flow (suppliers $\rightarrow$ consolidation point $\rightarrow$ project site).

For each shipment a delivery agent is assigned and it will be the agent’s responsibility to interact with suppliers and service providers. Part of the DA is the AutoID module that, based on the identifications tags applied on the ordered shipments, will monitor and update the state of the activity. In case any deviation from the planned due date should occur, the DA will contact the project merge agent (PMA), which will take the necessary measures (e.g. An activity is sensed to be late, the DA of this activity announces the PMA, which will announce the DA or DAs of the activities that are related to the activity being late. The related activities, if possible, will be also delayed, in order that the MIT can take place at the established consolidation point.).

The tracking of a shipment should ideally start inside the supplier company. However, tracking must, at the latest, start at the time when the delivery leaves the supplier. The minimum requirement for data collection by the DA is the time and place for when tracking is started, the destination and due date, and the time and place of delivery. Information exchange (tags reading) should happen at least at tracking starting time, activity agreed due-date and activity actual finishing time (for the case when the due-date and finishing date do not coincide).
**Systems designs in progress**

The first steps towards realizing solutions following the outlined framework are in progress. At Helsinki University of Technology, a solution for designing delivery agents is underway. The focus has been on finding a solution that makes it possible to deploy DAs in a changing multi-company network without a centralized authority responsible for delivery identifiers. The team adopted the ID@URI approach, combining a local identifier that the dispatcher is responsible for, with the globally unique URI identifier defined by internet. The solution design for the DAs was developed and tested in the Dialog project, and is now further developed in an open source community (http://dialog.hut.fi). The design will also be further developed and evaluated within the PROMISE project in the European Union’s sixth framework programme.

The software application (part of PMA) responsible for coordinating the DAs of shipments to a project site is yet to be developed. However, when scheduling and rescheduling of activities is necessary, the PMA function required is analogous to an order management application for controlling orders in a manufacturing environment. Such an application (Ilie Zudor et al., 2003) has recently been developed by SZTAKI and the intention is to develop an initial PMA solution design based on it. Another avenue to be explored is the suitability of commercially available supply chain event management (SCEM) applications for coordinating project deliveries.

**Discussion**

The development of interacting sub-order specific control and project site specific control applications is the basis for solving a great number of the problems faced in the project delivery chain. The combination opens up new solution opportunities to a set of complex project delivery chain issues. Product specific control is the foundation for solving issues such as track and trace, inventory management, point of use visibility, asset management, activity based costing, lead time visibility, end-of-life processing, individualized maintenance, and real-time installation instructions in a dynamic environment.

The solution outlined in this paper shows how project site level and shipment specific control together enables MIT. This basic functionality of merging deliveries can be enhanced to react better to project delays, and improve rescheduling project resources.

Although the joint implementation of the concepts presented in the paper has many advantages, there are also many problems to overcome. Foremost among the anticipated problems are convincing logistics service providers and other business partners to invest in automatic identification technology and to provide accurate information on delivery status and prioritization. However, a good reason for a business partner to adopt the outlined solution framework is that improved tracking and tracing makes it possible to reduce costs associated with delays. If the true priority of each delivery is known, efforts to expedite and reschedule can be focused on the critical few.

In addition to research related to the development and deployment of the outlined solution framework in practice, an important theoretical issue is determining the appropriate level of intelligence. One important characteristic of agents is their ability to learn (Kádár et al., 2003; Csáji et al., 2003). This is an advantage, but also a challenging subject for research (Csáji et al., 2004; Monostori et al., 2004). What technique to use, when to learn, what to learn are questions that need answers when adaptive features are added to the simple agents discussed in this paper. In particular, the merge agent for the project site is interesting from an automated learning point of view. What specifically should the PMA learn to “worry” about and when to start “worry” about a delivery not respecting the established due-dates?

**References**


Auto-ID Center (2004), available at: www.autoidcenter.org


