ENABLING LEAN SUPPLY WITH A CLOUD COMPUTING PLATFORM – AN EXPLORATORY CASE STUDY

Marcelo Azambuja[1], Thomas Schnitzer[2], Meral Sahin[3] and Felix Lee[4]

ABSTRACT

Traditional supply practices usually generate waste such as lack of materials and/or accumulation of large inventories on construction job sites. Lean supply systems require the integration of suppliers in the production process as a means to minimize waste. Such integration allows better synchronization of supply and demand and pulling of materials to the job site. Supply chain visibility and real time information are a must in this environment. Manufacturing and retailing have widely used information technology (IT) solutions, such as enterprise resource planning systems, for managing their supply chains. In the construction industry, only a few large construction firms can afford to deploy sophisticated IT tools. The majority of firms are small to medium-sized companies that do not have the resources and/or the manpower to use and maintain proprietary supply chain management solutions. This research explored freely available Google cloud computing tools, focusing on the Google Fusion Table (GFT) as a cloud-based platform to enable real time information on the supply process and site demand. This paper describes the development and testing of the platform that was used by a mechanical contractor to implement a pull fabrication, delivery, and installation system for pipe spools. The results suggest that the proposed platform provides the basic functionalities for developing a cost-effective tool for small and medium-sized construction firms to manage supply chain data and implement lean supply systems.

KEYWORDS

Lean Supply, Cloud Computing, Pull, Pipe Spools.

INTRODUCTION

Construction clients are demanding faster, cheaper, and higher-quality facilities. These demands generally involve responsive production chains and closer coordination and collaboration between the construction project team (O'Brien et al. 2009). Appropriate management of information (e.g. orders, schedules) and material flows is required in order to respond to clients' expectations and keep supply chain costs at an adequate level (Azambuja and O'Brien 2009). Project delays, disruption of

1 Assistant Professor, Department of Construction, Southern Illinois University Edwardsville, Edwardsville, IL, 62026, USA, mazambu@siue.edu
2 Estimator, Rock Hill Mechanical Corporation, Saint Louis, MO, 63122 USA, tschnitzer@rhmcorp.com
3 Masters Student, Department of Mechanical and Industrial Engineering, Southern Illinois University Edwardsville, Edwardsville, IL, 62026, USA, msahin@siue.edu
4 Professor, Department of Mechanical and Industrial Engineering, Southern Illinois University Edwardsville, Edwardsville, IL, 62026, USA, hflee@siue.edu

site work flows, and elevated carbon footprint are common consequences of poor supply chain management (Alarcon et al. 2005, Tommelein et al. 2003, Memarzadeh and Golparvar-Fard 2012).

Supply chain visibility measures the amount of communication and control a company has over its supply chain network. That network can include suppliers, logistics providers, and pretty much anyone else who is involved with the movement of materials (Simch-Levi 2010). As construction projects grow in size and complexity, the materials management process will naturally become more complex. Because supply chains are increasingly powered by information technology, flexible IT-based solutions are an increasingly important part of a supply chain design (Shramm et al. 2011). Arbulu and Ballard (2004) proposed strategies to implement lean supply systems in construction. They suggested the use of web-based tools based on the Last Planner System (LPS) for production control linked with the material management process. Arbulu et al. (2005) used Strategic Project Solutions' (SPS) lean tools for production control, synchronization, and monitoring of concrete and expanded polystyrene panels supply and demand. Better reliability of supply and demand was achieved in both cases due to a greater visibility across the value stream. More recently, Cho and Fischer (2010) implemented an integrated system of Virtual Design and Construction (VDC), lean, and real-time data capturing tools for the supply chain management of doors, frames, and hardware. The system improved the alignment between supply and demand and reduced distortion of demand information.

According to the Construction Industry Institute (2011), the implementation of materials management information systems must facilitate the dissemination of current data to a wide range of system users and be applicable to a wide range of project conditions.

Against this background, it is no surprise that cloud computing is generating intense interest. A Cloud-based platform enables instant, real-time visibility across all supply chain participants and saves companies from having to purchase, maintain, and train IT staff on expensive hardware and proprietary software code (Schramm et al. 2011). This subject is especially appealing to the construction industry since most of the firms are small to medium size companies which usually do not have resources and manpower to develop, use, and maintain proprietary supply chain management solutions. According to Kumar et al. (2010), consulting firms have been offering cloud-based services for construction companies, however, more than 90% of the companies cannot afford them.

This paper describes the development and testing of a free cloud-based platform. A mechanical contractor used the system to visualize supply and demand information and to pull production and documents from upstream processes.

OVERVIEW OF GOOGLE FUSION TABLE

Google fusion table (GFT) is a cloud-based data management and integration service. The development of this service aims to address growing challenges facing the legacy single enterprise database framework in an increasingly connected world. These challenges include, but are not limited to, the support of collaboration among multiple users and multiple organizations, the consideration of users with less technical skills, and the seamless integration of data collection, presentation, and visualization in a web environment (Gonzalez et al. 2010). These challenges are also present in the management of construction supply chains.

At present, GFT provides users with a variety of data management, integration, and visualization functionalities without any software installation. These functionalities include: 1) upload tabular data files of up to 100MB – the data can contain geographical objects such as points, lines, and polygons; 2) the table can be exported to KML for viewing on Google Earth; 3) querying data through filters and aggregates; 4) integrating data from multiple sources through joins across tables that may belong to different users; 5) sharing data with a selected set of users; 6) commenting on data at the level of individual rows, columns, or cells; and 7) visualizing data in web-based charts, maps, and time lines.

Companies can save any file type to this cloud-based service and make it accessible anywhere there is internet. These files, from excel spreadsheets to PDFs, can be accessed and edited by anyone the creator of the file deems fit. They can be viewed, uploaded, and edited from any computer, smartphone, or tablet by anyone with a Google account. For example, a jobsite foreman can send in time sheets from his or her phone with a document record for the company. Another appealing aspect of Google Drive is that the first five gigabytes of memory are free. This enables any company to have a network that can be accessed anywhere and by anyone without utilizing company capital.

In this research, we propose to use GFT as a cloud-based supply data management and visualization platform to enable rapid supply and demand information exchange. A key feature of this platform is that data from multiple sources can be merged to allow multiple parties to query and visualize supply chain status, therefore increasing supply chain visibility. The researchers worked with a mechanical contractor to explore whether GFT could be used to implement a pull fabrication, delivery, and installation system for pipe spools. The platform should provide the capability for integrating data between the construction job site, fabrication shop, and main office.

THE GFT PLATFORM

MOTIVATION

The platform was developed in collaboration with a mechanical contractor. The firm specializes in commercial HVAC, process piping, and pipe model fabrication. Its main products are ductwork and pipe spools for customers ranging from healthcare to energy industry. The mechanical contractor has been doing an excellent job removing waste in the design and fabrication processes by using building information models (BIM) and computer-aided manufacturing. However, the company is aware of its inefficient and wasteful supply process and is looking for economical and creative ways to streamline this process. For example, the information exchange between shop fabricators and field installation personnel is extremely limited during project execution. Since the shop fabricators produce piping sections to meet the demand of the field installers on multiple jobs, it is imperative that the information passed on between the two entities be communicated effectively and accurately. The shop fabricators are key in the supply process because they prioritize production and delivery of materials. Currently, they make production sequence decisions based on the drawings they receive from the CAD operator, ignoring field demand. The field installers cannot visualize the status of the fabrication process and as a consequence their plans are usually based on outdated schedules.

The result of this mismatch between demand and supply, which is a prevailing characteristic of traditional supply practices, is lack of materials and/or accumulation of large inventories on construction job sites. Lean supply systems require the integration of suppliers in the production process as a means to minimize waste. Such integration allows better synchronization of supply and demand and pulling of materials to the job site. Supply chain visibility and real time information are a must in this environment. The GFT platform was created to make an environment where this information could be exchanged.

GOOGLE FUSION TABLES

The research team visited the mechanical contractor’s office and fabrication shop and interviewed experienced project managers, field installers, and shop fabricators to understand manufacturing, shipment, and installation processes. This data guided the development of useful fusion tables.

This contractor uses Building Information Models (BIM) for all projects. All piping components from pipe size to valve quantity can be represented accurately. From these models, CAD operators create pipe spool drawings and send them out to the fabrication shop in large batches on a daily basis. Shop fabricators receive this information, typically a diagram, from which they can make the corresponding section of pipe for the field installers. The spool drawings include the spool tracking number, which is also applied to the pipe with a barcode in the form of a spool tag. This is done so that every pipe spool can be tracked throughout the fabrication stages (Figure 1). The spool number is also connected to the bill of materials and weld numbers. The tag also displays the planned shipment date. Even though this information is readily available, the company has not being collecting and using it to track their pipe spools within the shop floor. There is no tracking system in place to control which, when, and where pipe spools are delivered on job sites. The contractor intends to track installation dates in the near future. The purpose of the GFTs is to relay information from the time the spool drawing was created to when the final installation occurs. The contractor understood that cloud-based computing could be a powerful tool to improve the current supply process.

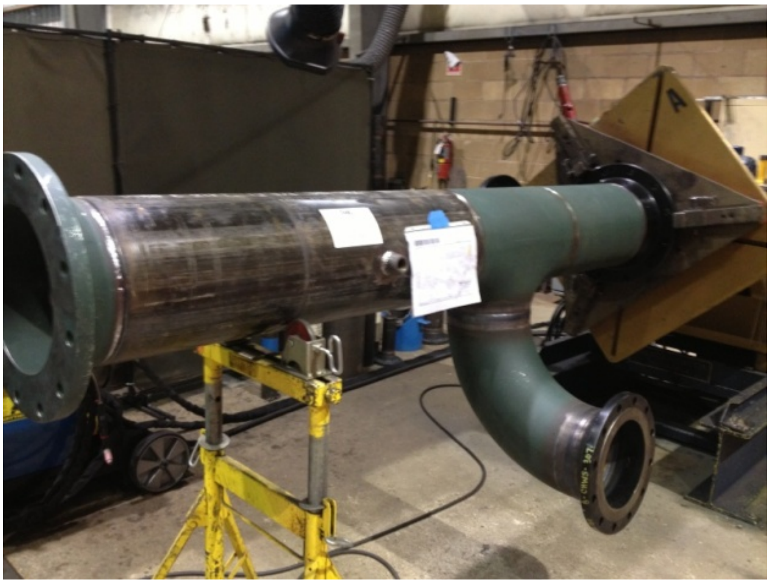
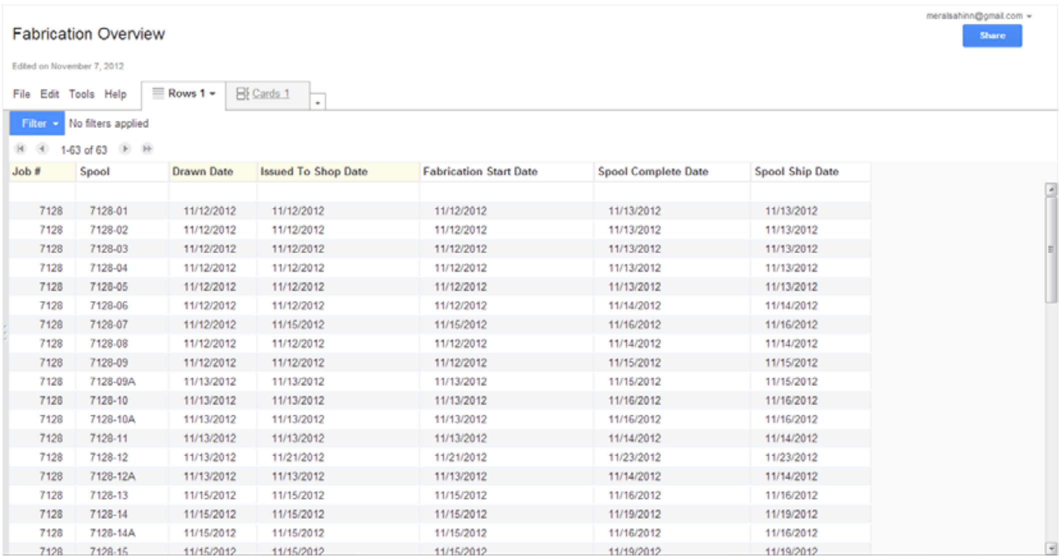


Figure 1: Pipe Spool

The researchers then sought direct input from potential users to develop the platform. Several meetings were needed to create the fusion tables. The first table was built for the CAD operator who is in charge of the spool drawing process. This table was created to show when each spool was drawn and when it was issued to the shop. Another table was created for the shop fabricator to depict when the fabrication was started, completed, and the spool was shipped to the jobsite. By fusing the elements of these two tables, a third table named Fabrication Overview was created. Figure 2 shows the Fabrication Overview table. One can instantly identify the fabrication status of any spool.



Fabrication Overview

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Job #	Spool	Drawn Date	Issued To Shop Date	Fabrication Start Date	Spool Complete Date	Spool Ship Date
7128	7128-01	11/12/2012	11/12/2012	11/12/2012	11/13/2012	11/13/2012
7128	7128-02	11/12/2012	11/12/2012	11/12/2012	11/13/2012	11/13/2012
7128	7128-03	11/12/2012	11/12/2012	11/12/2012	11/13/2012	11/13/2012
7128	7128-04	11/12/2012	11/12/2012	11/12/2012	11/13/2012	11/13/2012
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7128	7128-06	11/12/2012	11/12/2012	11/12/2012	11/14/2012	11/14/2012
7128	7128-07	11/12/2012	11/15/2012	11/15/2012	11/16/2012	11/16/2012
7128	7128-08	11/12/2012	11/12/2012	11/12/2012	11/14/2012	11/14/2012
7128	7128-09	11/12/2012	11/12/2012	11/12/2012	11/15/2012	11/15/2012
7128	7128-09A	11/13/2012	11/13/2012	11/13/2012	11/15/2012	11/15/2012
7128	7128-10	11/13/2012	11/13/2012	11/13/2012	11/16/2012	11/16/2012
7128	7128-10A	11/13/2012	11/13/2012	11/13/2012	11/16/2012	11/16/2012
7128	7128-11	11/13/2012	11/13/2012	11/13/2012	11/14/2012	11/14/2012
7128	7128-12	11/13/2012	11/21/2012	11/21/2012	11/23/2012	11/23/2012
7128	7128-12A	11/13/2012	11/13/2012	11/13/2012	11/14/2012	11/14/2012
7128	7128-13	11/15/2012	11/15/2012	11/15/2012	11/16/2012	11/16/2012
7128	7128-14	11/15/2012	11/15/2012	11/15/2012	11/19/2012	11/19/2012
7128	7128-14A	11/15/2012	11/15/2012	11/15/2012	11/16/2012	11/16/2012
7128	7128-15	11/15/2012	11/15/2012	11/15/2012	11/19/2012	11/19/2012

Figure 2: Fabrication Overview

For the field installer, a table was created to show what date the field installer would need the individual spools and also what date they were installed. This table also included a map displaying the job site location and a link to a PDF file including the spool drawing. Finally, this Jobsite table was fused with the Fabrication Overview table to create the Job Overview table. This fused table could depict everything from conception to installation. Figure 3 illustrates the structure of tables built in the GFT platform.

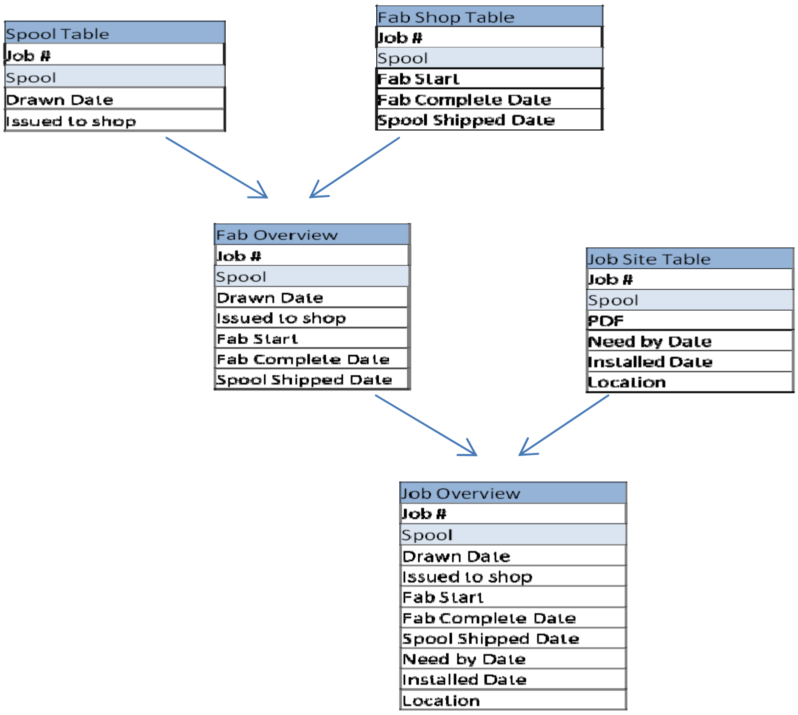

Figure 3: Platform Structure

When these tables are fused together, the information entered in one table is automatically updated in the others. The information from the field installers can be rapidly communicated to the fabricators on what spool they need and when so that the fabricator can set priorities on what spools need to be manufactured first. The shop foreman can now visualize in real time the demand from several job sites and quickly adjust to the ever-changing installation needs. The shop foreman liked the ability to convey fabrication status in the cloud. According to the foreman, this platform will greatly reduce the time he spends on the phone discussing fabrication issues with field installers and project managers. The foreman should also see a reduction of space used for storage of finished spools. From the installation foremen's viewpoint, the ability to see what spools are being shipped from the fabrication shop helps him managing everything from manpower to small tools and consumables for the installation. This tool could help relieve downtime and also implement just in time deliveries, since the field would be ready to install each spool being shipped. These tables were created to invoke situational awareness for every person involved in the supply process. Next section describes the findings of an exploratory case study used to test the platform.

EXPERIMENT AND RESULTS

The GFT platform was tested using an actual fast track process piping job. The mechanical contractor had to install fifty pipe spools within two weeks. The main goals of the experiment were as follows: 1) Implement a lean supply system for the installation of pipe spools. The Jobsite Foreman would then be capable of pulling the drawing and fabrication of spools from his computer, smartphone or tablet at the job site. 2) Identify the benefits and limitations of the platform.

One experienced employee who understands the supply process helped the researchers setting up the experiment and played one of the three roles in the exploratory study. He provided the drawings (extracted from the BIM model) and a range of typical durations to be used to create spool drawings, fabricate, ship, and install several types of spools. He only provided the installation schedule to the person who played the role of Jobsite Foreman. The Jobsite Foreman was encouraged to change the sequence or delay the request of selected spools in order to test how other players would behave in the pull system. The three roles (users) of the platform were: the CAD Operator, the Shop Foreman, and the Jobsite Foreman. The experiment was straightforward. The Jobsite Foreman would add site need dates for each spool, the CAD Operator could not issue the drawings to the fabrication shop until they were requested by the Jobsite Foreman, and the Shop Foreman would only work on the spool after receiving the information from the CAD Operator. The Shop Foreman would then ship the spools to the job site. Finally, the Jobsite Foreman would verify the delivery date and add the final installation date in the system. The users should only use the system to visualize site demand and pipe spool status to implement the pull system. No other type of communication was allowed between the players during the two-week period.

The experiment produced a large amount of data. Figure 4 summarizes the overall delivery performance for fifty pipe spools.

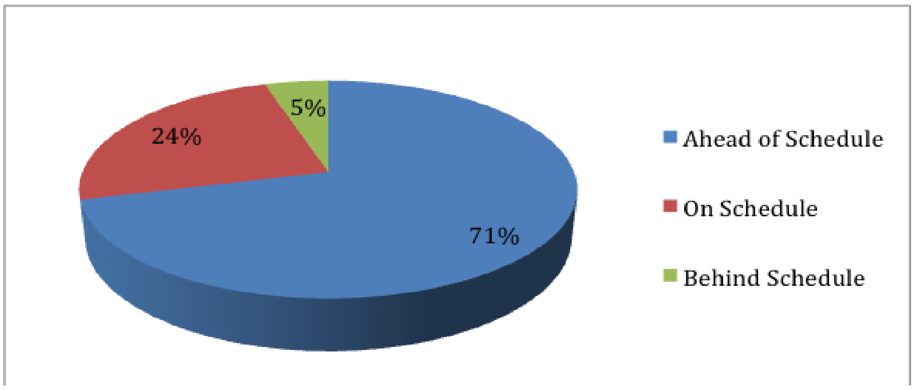

Figure 4: Delivery performance using GFT

Seventy one percent of the pipe spools were delivered slightly ahead of schedule, twenty four percent on schedule (just-in-time), and only five percent behind the original schedule. Early deliveries are usually not desired in a pull system. In this case, the Shop Foreman ignored the site need date displayed in the system and authorized early shipments of spools to the job site. This issue was further discussed with the mechanical contractor.

The platform can also be used to store supply and installation performance metrics. The mechanical contractor can easily retrieve historical information of several jobs. For example, actual durations for drawing, fabrication, shipment, and installation of pipe spools can be obtained. Currently, the company does not document installation time. The platform seemed to be a first step towards this direction. Metrics such as on-time fabrication, shipment, and installation will be available in the database as well.

The analysis of milestones can point out opportunities for improvement at interfaces between processes. For example, the observation of early shipments triggered the discussion on push and pull disciplines with the Shop Foreman. Only three spools were delivered later than the expected date. The Jobsite Foreman realized that his requests were unrealistic given the average lead time to draw and fabricate those spools. Figure 5 displays the number of days that each spool spent on the job site before final installation. The contractor can rapidly calculate average inventory sizes for multiple jobs and make assessments of daily and weekly plans. Reasons for planned or unplanned deviations from the plan can be recorded in the fused table. Therefore, the platform not only enables supply chain visibility but also stores lessons learned and supply knowledge information.

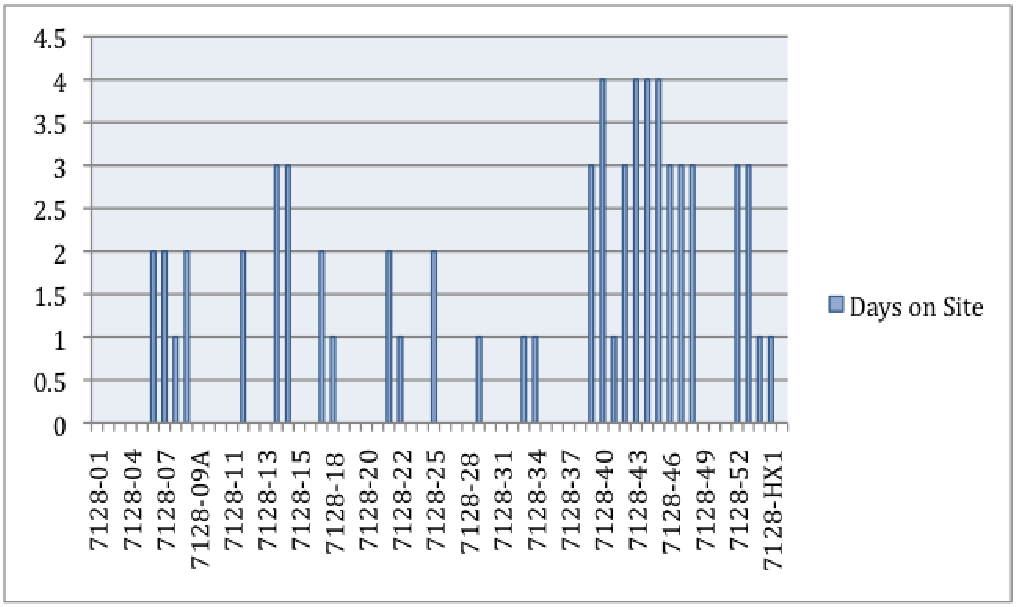

Figure 5: Pipe spools inventory

The cloud-based system provided the expected supply chain visibility. Demand and supply information was readily available. According to the mechanical contractor, the ability to see in one glance the progress of the job and each player's needs is the great advantage of the system. The users exchanged information using GFTs to implement a pull system. The jobsite fusion table worked as an electronic kanban, pulling the pipe spools to the job site.

The tables were relatively easy to use but data entering was time consuming. The research team identified other limitations during the experiment. The fusion tables do not allow rewriting multiple columns/rows of information at once. Also, users experience would have been better if the system could have given an alert to the network users when changes were made on their tables. Users decided to log in once or twice a day to check site demand and spool status during the experiment. Finally, wireless connection is highly desirable to run the platform from smartphones and tablets.

CONCLUSIONS AND FUTURE RESEARCH

The proposed Google cloud-based platform supports rapid visualization of demand and supply data and instant tracking of the status of construction materials in the supply chain. A mechanical contractor tested the platform's capabilities to implement a lean supply system for pipe spool installation. The results of this exploratory study were very positive. The research team is currently working with the mechanical contractor to automate data entry in the GFT platform. Information from RFID tags attached to pipe spools will be automatically loaded in the fusion tables. In the near future, the system will also include data from suppliers of critical components (e.g. valves). Building information models will be uploaded in the platform as well.

Additional pilot tests are necessary to validate the capabilities described in this research. However, a readily available and low cost alternative has been investigated and may be an interesting solution for small and medium size companies that cannot afford the expensive software packages used for similar purposes.

The platform can serve as a starting point for the development of a supply market intelligence database. Further research will explore the platform's capability to guide supplier selection decisions, to perform environmental performance assessment of supply chains, and to improve supply chain risk analysis in the early stages of capital projects.

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