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Approved: Mary R. Bartling Date: 5/20/21
Project Advisor

Professor Mary R. Bartling

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I. INTRODUCTION

o Statement of the Problem

The commercial construction industry lags behind the manufacturing industry in realizing the productivity gains that can be achieved by fully implementing modern supply chain strategies. The project-based nature of the construction industry impedes the development of a coherent strategy as materials, personnel, timelines, locations and suppliers vary from site to site. The purchasing function is often fractured due to conflict of interest and duplication of effort as it is carried out by purchasing agents, project managers, superintendents, foreman and yard managers often simultaneously. Suppliers are pitted against contractors in an adversarial relationship where price is often prioritized over value.

While construction companies maintain physical offices to carry out many standard business functions the actual production is carried out on construction sites. The location of these sites can vary from a few blocks to thousands of miles away from the home office. The construction site doubles as a storage location for building materials and a production plant while gradually evolving into a finished building. The site may begin as a hole in the ground with limited lighting, power and water while temporary elevators and cranes move workers and material. As the building progresses towards a finished product accessibility and storage space is often in a constant state of flux. Access points and window of time for deliveries can be greatly impacted by the phase of construction or even the weather.

The dynamic nature of the construction industry creates numerous challenges for contractors and suppliers that may not be experienced in traditional manufacturing. Due to varying designers, specifications, locations, building types and projects a contractor's supply needs will also vary accordingly along with a supplier's ability to fill those needs. Aside from many of the

logistical challenges of delivering material to construction sites, suppliers may face logistical challenges in forecasting due to low information flow from suppliers which can result in a bullwhip effect up and down the supply chain. The bullwhip effect can also impact contractors in the form of material shortages due to errors in forecasting.

- **Purpose of the Study**

The purpose of this study is to understand if vendor managed inventory is a solution that could be more widely utilized in commercial construction. In order to answer that question this paper will attempt to understand why the commercial construction industry has struggled to implement modern supply chain strategies to achieve productivity gains at the level of the manufacturing industry. This paper will look at the relationship between contractors and suppliers in the commercial construction and identify the characteristics of a collaborative relationship as opposed to an adversarial relationship. By understanding the contractor-supplier relationship this paper can understand the barriers to supply chain innovations in general and vendor managed inventory specifically while also highlighting the potential benefits to be gained by both parties.

- **Significance of the Study**

This paper is significant because most of the published research in the commercial construction industry focuses on customer-contractor relationship rather than contractor-supplier relationship. Suppliers in the construction industry that fail to innovate and adapt will likely see declining revenues and market share because,

“water runs downhill. If someone else makes it easier to buy a bell, book, or candle than you do online, that is where the transaction will happen. Amazon is best in class at this.

Many business-to-business enterprises have a long way to go to get this right” (Jackson 2010)

By adopting supply chain innovations more common in the manufacturing industry, contractors and suppliers may be able see gains in productivity, efficiency and cost reduction. This paper can serve to highlight characteristics that contractors should use when seeking to partner with suppliers (and vice versa) to collaborate on vendor managed inventory initiatives.

- **Assumptions**

This paper assumes that there are contractors and suppliers that would like to engage in more collaborative partnerships even though there is a lack of literature. There is limited research into supplier-contractor relationship. There is even less research into vendor managed inventory relationships as both parties are hesitant to quantify the value of such a partnership. For example, according to the article Vendor-managed-inventory (VMI) in construction; “suppliers were very cautious about their statements regarding the cost and profitability” (Tanskanen 2009). This is understandable due to the adversarial nature of contractor-supplier relationships.

- **Delimitation of the Study**

This paper does not limit itself to traditional supply chain processes and definitions as understood in the manufacturing industry. The commercial construction industry faces unique challenges due to its project-based nature, and even those challenges can vary from project to project.

- **Methodology**

The method of approach for this paper will be to utilize academic journals and peer-reviewed articles. These sources will provide insights into the unique challenges faced by the construction industry. This paper will also rely on research to identify the common characteristics that make up contractor-supplier relationships and the specific characteristics that should be a prerequisite for attempts at developing an innovative supply chain strategy like vendor managed inventory. This will require looking at the conditions make vendor managed inventory successful in the manufacturing sector and how that translates to construction.

II. REVIEW OF LITERATURE

Considered a watershed document for the construction industry, Constructing the Team, also known as the Latham report, was commissioned by the government of the United Kingdom and published in 1994. Cahill and Puyburaud summarize the report in 2003's *Construction Reports:1944-98*. Sir Michael Latham made 30 recommendations intended to improve the industry and encourage cooperation. It was Latham's view that as a result of recession and economic troubles the industry had become increasingly adversarial and conflict driven. This was due to a bid low, claim high strategy to win contracts at any cost in hopes that a profit could eventually be generated through extras and claims (change orders). While the observations and recommendations were not novel, they did for the first-time gain support from within the industry as well as from the government.

Latham's report was followed four years later by Rethinking Construction, commonly known as the Egan Report (1998). Murrey writes about this highly regarded report in 2003's *Construction Reports:1944-98* as well. The report named for Sir John Egan was also funded at

the direction of the government of the United Kingdom. Egan was well known for his previous success as CEO of Jaguar Cars and implementation of modern supply chain strategies at other companies.

Egan built upon the reception of the Latham report's call for increased cooperation to propose a 'rethinking' of the construction by adopting lean manufacturing concepts and techniques. Egan advocated for the use of key performance indicators (KPI's), just-in-time delivery, zero defect and partnering in the supply chain in order to remove waste and focus more on the customer than on the next contract. The Latham and Egan reports are both widely cited sources by researchers of the construction supply chain.

A 2012 article by Bemelmans, Voordijk and Vos takes a taxonomic approach to evaluating the state of published research regarding supplier-contractor relationships. The articles that were evaluated were selected from the top five construction industry journals as well as the top five journals relating to buyer-supplier relationships. 106 articles were then selected based on their relevance to supplier-contractor relationships and their vertical integration. This was then further narrowed down to 51 articles agreed to by authors after evaluating each article's abstract. Of these articles only 25 focused specifically on the subject of supplier-contractor relationships. Roughly half focused on barriers and obstacles to collaboration while the others looked at selection criteria.

The authors found that though it had certainly increased since the year 2000, there is still a scarcity of research on supplier-contractor relationships. Empirical research is especially lacking, with most articles providing frameworks for collaboration, but not evaluating that collaboration in real world practice. Also lacking is research from the supplier's perspective

which would also be required in order foster further development of supplier-contractor collaboration within the industry.

In a 2017 journal article published in *Construction Innovation*, Thunberg, Runberg and Karrbom Gustavsson identify and categorize on-site supply chain problems on construction projects. This is done through a combination of literature reviews and informal interviews. They found that the problems could be put into four categories; material flow, internal communication, external communication, or complexity. These problems were attributed to a lack of supply chain orientation which is a prerequisite to supply chain management which can be achieved through supply chain planning.

A Blayse and Manley article from 2004 identifies the key factors that influence construction innovation whether as a hinderance or a driving force. The methodology utilized is a review of literature. There is a near universal perception that the construction industry is not particularly innovative. The article identifies six factors of influence on innovation 1) clients & manufacturers 2) structure of production 3) relationships between firms both within the industry and externally 4) procurement systems 5) regulations/standards, and 6) nature and quality of organizational resources. This article builds on previous work from Sarah Slaughter.

In her 1989 article, *Models of Construction Innovation*, Slaughter defines innovation as “*the actual use of a non-trivial change and improvement change in a process, product or system that is novel to the institution developing the change*”. This definition is also used by Blayse and Manley in there previously referenced 2004 article. They also reference Slaughter’s scale of innovation models, 1) incremental, 2) modular, 3) architectural, 4) system, and 5) radical. Slaughter concludes that there are significant benefits from the implementation of innovation in

the construction industry that goes beyond merely the contractor, but extends to the client, industry and society. She suggests that her model can be used as basis for to plan and carryout the implementation of innovation.

Briscoe and Dainty's 2005 article, Construction supply chain integration: an elusive goal? is an empirical study of the construction supply chain. The article is a case study of three clients and the construction supply chains of their respective projects. The authors focus on three relationship tiers; client, main contractor, and sub-contractor (supplier). This article is indicative of much of the writing about the construction supply chain by focusing on client-contractor relationships rather than on contractor-supplier relationships. Many of the same issues are reflected in this article as others, such as information flow, communication (lack of), supply chain alignment, and quality. These issues extend up and down the supply chain. The authors concluded that there was a preference for informal structures and little relationship between client and sub-contractor. It was found that there were insufficient levels of trust to achieve any meaningful partnerships and lasting integration.

In a 2019 article, key drivers of effective collaboration working in construction supply chain in South Africa, the authors compare key drivers of collaboration with those in construction. This was done through interviews and archival documents due to a lack of research on the subject. The article makes the same points that many other articles do, that there are distinct differences between manufacturing and construction with the latter lagging behind the former. They find that communication, trust and effective leadership are key drivers. They find the study is limited in the ability to measure to what degree these drivers can be successful in bringing about collaboration.

Arbulu, Ballard and Harper (2003) describe how the Kanban process can be used for material management in the construction industry. Kanban is a popular replenishment strategy in manufacturing, particularly the automotive industry where it originated. The authors convincingly describe how this just-in-time process can translate to a construction site and alleviate many of the material management challenges facing construction supply chains.

According to the authors, one of the most often cited causes of delays on a jobsite is lack of material. By vetting and selecting qualified supplier(s), both parties can collaborate on a replenishment system designed to reduce waste via a low-cost movement of goods. Both parties can benefit from capital preservation, reduced paperwork, increased information sharing in order to obtain the best value while achieving greater efficiencies.

Agapiou, Clausen, Flanagan, Norman and Notman (1997) write about the benefits of implementing a logistics model to manage the material flow control process on a construction project. The authors studied a specific project in Denmark, where involved parties worked together to develop a logistics plan for the site. The article describes waste and expense often related to the delivery, movement and storage on similar projects. By making small investments towards developing a control plan and hiring a designated materials coordinator the project was able to realize savings of 5% despite the extra expenditures.

The 2009 journal article, Vendor-managed-inventory (VMI) in construction, explores the logistical challenges faced in the construction industry and the use of vendor-managed-inventory as a possible strategy. The authors, Tanskanen, Holmström, Elfving and Talvitie utilize a design science approach to setup three test sites for a VMI program designed in collaboration with the contractor. At the end of the pilot, they found that VMI is an efficient way to manage the

replenishment of small items, reducing invoicing costs in addition to as time spent on doing inventory counts and unplanned trips to the hardware store. The suppliers also found that the benefits of the program outweighed a need to charge a premium for the service. This article is significant because it is one of very few that goes beyond a theory to real world implementation.

In 2002, Ibn-Homaid's article, A comparative evaluation of construction and manufacturing materials management was published by *The International Journal of Project Management*. The author's goal was to evaluate how materials management techniques from manufacturing could be applied to the construction industry. Ibn-Homaid compared inventory management, materials resource planning (MRP) and just-in-time (JIT) approaches through a process of interviews and literature studies. The author found that at the conceptual level manufacturing and construction have more similarities than differences. Ibn-Homaid concluded that MRP was a more appropriate fit for construction than JIT though it would be difficult or even impossible to fully implement the underlying principles would be applicable.

Ellegaard and Koch explore the conflict between purchasing and production in a construction company by using a single case methodology in their 2014 journal article. By conducting interviews with six purchasers and six project managers they were able to develop competing purchasing models based on how the purchasing department operated versus project managers on the jobsite. Each group had different priorities and thought that they were better equipped to carry out the purchasing function. The purchasing department preferred to consolidate spend with suppliers with whom there was a purchasing agreement, while the project managers preferred to haggle with supplier and pit them against each other and for the lowest offer. The perception of the project manager was that the purchasers overspent and did not make

the best deals. Meanwhile the purchasers thought that while the project manager may realize savings on specific products they were probably being over charged over all when negotiating with suppliers onsite. The authors concluded that company executives should be aware of conflict and work to prevent competing purchasing models from developing and encourage collaboration and integration before it is too late to reverse course.

Maqsood, Helo, and Kristianto wrote a 2013 article about how the bullwhip effect influences total supply chain cost in the steel industry. The authors reviewed available literature on the subject and created a simulation model based on the results. The authors found that the bullwhip effect caused “cycles of excess inventory, severe backlogs, inadequate product forecasts, unbalanced capacities, poor customer service, uncertain production plans, high backlog costs and lost sales” (p. 46) They concluded that information sharing up and down the supply chain could better match supply with demand and reduce cost while improving responsiveness.

Disney and Towill look at how VMI can reduce or even eliminate the Bullwhip effect in a two-level supply chain in their 2003 article. While this article looks at manufacturer-retailer relationships, it is easy to see how this could translate to supplier-contractor relationships as well. The article describes the Houlihan Effect as retailers responding to a shortage by overordering due to the perception of unreliable delivery of goods and increasing safety stock which causes a demand distortion and capacity overload which plays out in a continuous cycle (p. 632). To combat this, retailers can give manufacturers or vendors the responsibility of managing the retailers inventory levels. This involves the retailer sharing point of sale information with the manufacturer in order to gauge true demand. The Houlihan effect is also evident in the construction industry, and if suppliers were able to gauge actual demand then they could better

match supply with demand and as a result prevent the customer (contractor) from also suffering from the ill effects of the Bullwhip effect.

Authors, Fearn and Fowler look at 'lean' processes in application on two case studies conducted on construction sites in their 2006 article. They hypothesize that lean practices should be implemented with caution on construction sites as they are face more uncertainty and complexity than manufacturing operations in a controlled warehouse. The authors equate efficiency with logistics and effectiveness with project management. They found that there are many lean techniques that can easily translate to the construction site, but others do not make sense and while efficient perhaps, they are not effective and lead to a different set of problems. The authors make a compelling case that sometimes a seemingly inefficient process is more beneficial due to its effectiveness than its efficiency.

Thunberg and Fredriksson (2018) make a case to "bring planning back into the picture" in their article regarding supply chain problems in construction. The authors reviewed three cases in order to develop a conceptual model to illustrate the linkages between common problems. They identify the problems as being linked to material flows, internal communication, external communication and complexity and then whether the problem originates in preconstruction planning, onsite planning or onsite execution. They found that effective planning can mitigate issues stemming from "lack of trust, communication and standardization" (p. 440). The authors do recommend additional case studies in order to validate their findings.

Rami Sariola wrote a 2018 article titled, utilizing the innovation of potential suppliers in construction projects, because he believes that the knowledge of the manufacturers that supply the construction industry "is not used sufficiently when it comes to construction innovation" (p.

167). Sariola interviewed 18 contractors to understand their past supplier-contractor experiences related to construction innovation. By taking a low cost and low risk approach to supplier relationships, contractors waste access to a potential source of innovation by taking an adversarial stance. He found that suppliers are a potential source of innovation and uncovered ways to remove organizational and project barriers to utilizing that innovation. He believes that suppliers need to invest more in marketing their innovation and to take the time to understand the customer's perspective and why they are so risk averse. He sees trust as a significant barrier to developing the supplier-contractor relationship, but also sees limited research devoted to the topic. For suppliers to develop their relationships they must offer consistently good service, quality products, and reliable operations. Suppliers should value feedback in order to enhance products and services and resolve recurring issues. The interviewed contractors recommend going beyond flyers and emails and having in person meetings to recommend projects for 'piloting' on relevant projects. Sariola's research is limited to the selected contractors located in one country, so additional research should be conducted to confirm his findings, however he offers reasonable evidence and a convincing framework for his ideas.

Riley and Brown (2001), compare the cultures of the construction and manufacturing industries. The research was done through the use of questionnaires and interviews using a questionnaire form sponsored by the U.K. government. The comparisons were made between a construction company and two manufacturing companies for the purpose of seeing if culture could affect how the adoption of manufacturing practices in construction. They found that construction had a 'project culture' and manufacturing had a 'company culture' (p. 149). They found that the proliferation of sub-contractors which vary from site to site make it difficult to develop a company culture in construction which explains its project orientation. Like many

other articles, the authors place significant importance on communication. This article serves to reinforce the conclusions of reached by many of the other reviewed articles regarding challenges that are unique in the construction sector that are not found in manufacturing.

Dubois and Gadde came to similar conclusions as Riley and Brown in their 2002 article about productivity and innovation in the construction industry. They argue that construction is a series of loosely coupled systems while manufacturing is more tightly coupled systems. Construction relies on the success of past practices. There is a short-term, project-based outlook and the way bids are tendered are barriers to productivity and innovation. This article makes good points about unique features of construction that serve as barriers which will be difficult to overcome.

Cooperative evolutionary game and applications in construction supplier tendency written in 2018 looks at the cooperation tendencies among suppliers specifically in prefabrication construction. The authors developed a model of cooperative relationships of suppliers on major construction projects. The game model had one supplier that was cooperative and one supplier that was uncooperative. They found that cooperation would better impact a construction company's profit. The larger the order the more likely the supplier would cooperate and if there were built in incentives it would be even better. The authors recommend implementing supplier development programs and cooperation amongst projects to pool demand. This model is very abstract, but it supports the findings among other offers that the construction industry needs more cooperation amongst suppliers and contractors.

Phong Thanh Nguyen wrote the 2018 article, Determination of construction supplier evaluation criteria using word tags. The article established supplier evaluation criteria by using

tag words by using research data coming from interviews conducted with 22 subject experts. Nguyen found that “price, quality, number of projects involvement, ability to deliver on time, and supplier relationship” (p. 75). Nguyen found that price and quality are often in conflict with one another. Timely delivery is also crucial and made challenging by the non-linear demand as a project progresses through various stages. Cooperation was also found to be of significant value as it could lead to a carryover of the relationship to future projects. This article supports commonly held views of the construction industry, but it is rather simplistic in its research and conclusions.

Yao, Dong and Dresner wrote a 2012 article titled supply chain learning and spillovers in vendor managed inventory. This article is not related to the construction industry, but rather VMI in the retail industry. However, one might expect that the concepts could easily translate to construction. The authors found that there was not a lot of research into the effect of VMI on organizational learning. They researched a company that supplied electrical components to distributors and used the data to develop two econometric models. Model 1 was based on linear effects of learning based on three variables and Model 2 was based on non-linear effects on performance from self-learning. They found that the manufacturer could use experience gained to not only improve their own processes, but also to more easily implement VMI with other customers by developing templates and tools. By conducting research with only one manufacturer there are obvious limitations on the study. They recommend patience when implementing VMI as the initial payoffs may not be substantial, but by using the same personnel on multiple implementations knowledge can be retained and developed. They also found that in order to prevent performance plateau or regression both parties should agree on continuous improvement targets.

Cox and Ireland's 2002 article about common sense approaches to construction supply chain looks at contractor-supplier relationships. They provide a similar background of problems facing the construction industry as many other articles do to its low cost and adversarial nature. They propose developing non-adversarial collaborative or 'partner' relationships. They advocate for contractors to use the Kraljic method to evaluate their current supplier base. The authors categorize supplier based on the relationship, independent, buyer dominant, supplier dominant or interdependent. While both the supplier and contractor are both likely to seek a position of dominance, over the long term a collaborative relationship would be most beneficial. This article adheres to well accepted supply chain concepts.

Mikael Frödell's 2011 article outlines criteria for achieving efficient contractor-supplier relations as titled. He finds that the construction industry is reluctant to focus on developing contractor-supplier relationships despite increasing research detailing the benefits. Frödell reviews a two-year case study with Swedish contractor, Skanska, which had been conducted through a series of interviews. The essential factors identified for a relationship are trust, communication and interdependence. Performance is a key facilitator of trust. Reputation is also crucial as a low reputation impedes trust and a strong reputation may lead to a fear of the supplier controlling the relationship. There must be a mutual attraction between the parties. Communication and conflict resolution are key drivers. Skanska's number one criteria for a supplier is quality. This was followed by long-term orientation and total cost focus resulting from lead-time reduction, cost-cutting and value-creation.

David Gann's 2001 article discusses how to translate new ideas from the academic field to the construction sector and the constraints that impede that knowledge flow. He suggests that

in the U.K. there are relatively few construction firms capable of receiving and implementing ideas from academic researchers. Gann's research draws on two previous concepts, 'absorptive capacity' and 'new production of knowledge'. The construction industry by comparison to sectors like technology and industry, reinvests very little into research and development. This is true in the U.K. and many other countries. Though Scandinavian countries and Japan are known to reinvest more in research and development, this is confirmed by several case studies referencing the Swedish firm, Skanska. Generally, construction companies are not set up in such a way that they can absorb and implement new ideas. Gann notes that interactions between researchers and industry personnel have been on the rise.

Frödell's and Koch wrote a 2013 article about the barriers that exist in integrating the purchasing organization in large construction companies. They developed a theoretical framework based on purchasing literature and then followed that with a two-year case-study that looked at the internal purchasing structure and external supplier relationships of a large Swedish contractor. They found that contractors will invest resources to develop ongoing relationships with customers, but do not put any real effort into developing supplier relationships. The authors hypothesize that because of the large supply spend on most projects, contractors would benefit from more supplier collaboration. The historical purchasing model has been decentralized with individuals within a company purchasing on a project level, this leads the supplier to view each project as a customer rather than the contractor as one large supplier. Six barriers to purchasing integration are identified; 1) framework agreements subordinated to purchase orders 2) short-term incentive systems 3) inconsistent procedures from project to project 4) purchasing isolated from changing client demands on the project 5) Geographic considerations that make a national contractor appear small on a local scale 6) market changes over time that make the contractor

seem inconsistent to the supplier over time. The study is limited in that it was conducted in Sweden with only one contractor and may not be indicative of other markets or companies.

Alioni, Dumlin, Minnino and Ponticelli published an article in 2012 identifying the risks that would be taken when implementing supply chain management concepts in the construction industry. This was done by reviewing and analyzing 140 peer-reviewed articles which were classified and analyzed from a risk management perspective. The authors identified 13 internal and external risk factors that limit adoption of modern supply chain practices. The authors recommend additional studies on this topic to support their conclusion and feel the study could be limited by its narrow scope.

Bildsten and Manley wrote a 2019 article for *Construction Management and Economics* detailing a framework for understanding the purchasing function of a construction company. They start by understanding the purchasing process from design to supplier selection (and eventually supplier feedback). Next, they identify the key roles; user, influencer, decider, purchaser and gatekeeper, and how each one influences a purchase decision. The framework was developed through a study of multiple individual cases, interviews were the primary method of information gathering. The authors believe that the framework should be tested and evaluated in different geographies and contexts.

Hewavitharana and Perera conducted a gap analysis between enterprise resource planning (ERP) software and typical construction procedures in a 2002 journal article. The research was carried out via questionnaire and interview. According to previous literature they found that gaps were a result of issues falling into three categories; organizational, technological, or social. Then based on the reason for the gap a recommendation is made as to how to overcome it. Once

a gap has been overcome it can be eliminated, helping to provide a custom fit of contractor and software. This article is helpful for understanding the challenges faced when implementing ERP software, which would be the same or at least like challenges arising from implementing a VMI program.

III. DISCUSSION

Multiple authors have painted a picture of the construction industry as slow to adopt change and reliant on low risk, tried and true best practices. By shying away from innovation, contractors pass up the opportunity to potentially increase profit margins in order to take the less risky path of utilizing traditional means and methods which have a lower profit ceiling, but less overall risk. Due to the low margin nature of the industry, as David Gann has pointed out, contributions to research and development are extremely low in comparison to technology and manufacturing sectors (2001, p. 327).

The construction industry also differs from the manufacturing industry in that it is project based rather than factory based. The process of completing a construction project involves an owner, designer, architect, general contractor, sub-contractors and tiered sub-contractors. There is often little to no carry over of these parties from one project to the next project. The procedures, policies, requirements and processes can vary greatly for a sub-contractor from one project to the next depending on who they are working for. Each stakeholder has little gain from the overall success of the project as whole, beyond their contract and scope. Performance on one project does not guarantee future work as each project is awarded individually, typically to the lowest bidder. As a result, contractors will often submit a low bid with razor thin profit margins and rely on aggressively priced change orders to move from the red to the black. This business

structure also requires that contractors aggressively pursue low-cost suppliers and price reductions on material in order to make money. According to Cox and Ireland, “there is a school of thought that argues that lean principles will only work successfully in high volume, low variety and predictable environments.” (2002, p. 412).

In addition to the project-based nature of construction, the manufacturing aspect of construction largely takes place on a continuously evolving jobsite that is exposed to the weather. This is in stark contrast to the controlled and efficient atmosphere of a well-designed factory used in the manufacturing sector. Construction sites will have limited power and water and rely on temporary elevators and cranes to move materials. Evolving site conditions can range muddy conditions that prevent vehicles from moving materials around to a congested traffic jam of cement mixing trucks queued up around the block to feed the awaiting pump. Material is stored on site to feed the production machine, but storage space is limited, and material may need to be moved multiple times before being integrated into the structure. Suppliers will push discounts for buying in bulk while contractors struggle to store the material, protect it from the weather, incidental damage or even pilfering.

The purchasing structure of a construction organization can vary from centralized through the purchasing department to decentralized and carried out by the field. Most organizations are a combination of both. By operating with a centralized purchasing structure, supplier development strategies can be implemented. This allows for the negotiations and establishment of supplier agreements. A decentralized purchasing structure can gain some advantages as far as speed and responsiveness, but it does not have the same long-term outlook (Frödell, Josephson, & Koch, 2013). In an interview conducted by Ellegard and Koch a

purchasing manager describes his experience with project managers negotiating prices with suppliers onsite:

It is this “I have saved 50-60%!” mentality – damn it. Then we ask them what they have saved it on. Their answer is “supplier’s pricelist” – “but you know we have purchasing agreement net prices on all items, which are about 80% lower than pricelist!” They are so focused on “ah now I have just saved us 50%” – some strange, fuzzy things they frequently measure themselves on. And they think it is super funny to negotiate – they have the money so the supplier listens a lot to what they want. (2014, p. 337)

This practice can be detrimental to a contractor’s ability to meet its obligations to a supplier agreement. A purchasing manager for example could make an agreement with a supplier to provide drywall and drywall mud for a specific project. The drywall may be priced aggressively on the condition that they drywall mud (which is not as aggressively priced) is purchased with it. If the project manager then negotiates his own deal on drywall mud to save a few dollars he potentially passes up significant material savings by not taking the best overall deal. Ellegard and Koch make a strong argument that if management cannot mitigate the inter-functional conflict that can arise between purchasing (procurement managers) and production (project managers), then they will be unable to optimize functional and corporate performance (2014, p. 341).

The adversarial nature of contractor-supplier relationships, along with low levels of trust have formed barriers to the development of supply chain innovations. Rather than seeking cost reductions and risk mitigation contractors should seek enhanced relationships and innovation, but that opportunity is often wasted via the adversarial positions typical of these relationships

(Sariola, 2018). Rami Sariola also makes the case that purchasing managers should be reasonable when negotiating with suppliers and not continually try to push their margins down to nothing (2018, p. 178). Mikael Frödell similarly advocates for a total cost focus rather than purchasing managers trying to use their leverage to continually decrease the supplier's margins. A purchasing manager that Frödell cites, declared that "we do not have any use for the suppliers if they go bankrupt" (2011, p. 389).

Mutual attraction between the contractor organization and the supplier is a prerequisite to building trust (Frödell, 2011). Attraction can exist in the absence of an adversarial outlook. This requires effective communication and conflict resolution. Frödell lists communication from the contractor as being essential for the supplier to be able to provide a high level of service. Regular communication should be both formal and informal in order to develop a relationship. Not all suppliers are candidates for long term relationship development. Suppliers that have potential for development should be vetted to ensure that the corporate cultures are compatible and that there is a mutual commitment towards quality improvement (2011, p. 384). Frödell concludes that an efficient supplier-contractor relationship is characterized by cost and lead time reduction achieved through mutual collaboration of value creating process (2011, p. 391). Cox and Ireland identify four supplier relationship management options based on a matrix of the "share of value appropriation" (equal or unequal) and "way of working" (adversarial or collaborative)

RELATIVE SHARE OF VALUE APPROPRIATION	INEQUALITY	ADVERSARIAL ARM'S LENGTH RELATIONSHIP	ADVERSARIAL COLLABORATIVE RELATIONSHIP
	EQUALITY	NON-ADVERSARIAL ARM'S LENGTH RELATIONSHIP	NON-ADVERSARIAL COLLABORATIVE RELATIONSHIP
		ARM'S LENGTH	COLLABORATIVE
WAY OF WORKING			

Figure 3 The alternative relationship management choices. Source: Cox (2001).

(Cox & Ireland, 2002)

By choosing to partner with a supplier in this method the goal is not to milk the supplier for all that they are worth, but rather establish a relationship that is sustainable and mutually beneficial where both parties see an equitable share of value. The promise of sustained business of multiple years and projects can allow the supplier to offer better value without feeling the need to maximize revenue on a single project.

Tanskanen, Holmström, Elfving, and Talvitie wrote a 2009 journal article about the challenges of logistics in the construction industry and make a case that vendor-managed-inventory (while not a blanket solution) could be used to address the challenges of managing small items on a project. A project manager may be able to keep track of the drywall and metal studs needed to complete a portion of the project, but could easily lose track of some of the smaller items needed to complete the application, such as drill bits, cutting blades or screws. Running out of one of these items could lead to significant production delays and require an

expensive rush delivery or necessitate having a highly paid worker make a costly trip to a hardware store to make a purchase. The solution that they proposed was to setup a small item store on the jobsite and utilizing a vendor managed inventory arrangement. This could be a locker or storage container, setup with shelves with an agreed upon selection of products and inventory levels. Each item would have a designated storage location and be clearly labeled, so there would be no confusion as to what is in or out of stock. A point of sale system used by the contractor would be used 'check out' items from the store. This data would be visible to the supplier and serve as the supplier Kanban, which would transmit the replenishment signal (Arbulu, Ballard & Harper, 2003). The supplier would be responsible for reordering and restocking the inventory as the stock fell below agreed upon inventory levels. The system was piloted on three different construction projects. It was found that utilizing this system reduced rush orders and shopping visits to zero. It also had significant reductions in the time to process invoices and time spent trying to locate items. The authors found that the supplier in the case study did not feel the need to charge a premium for this service, meaning that the process itself created value for the supplier. However, the authors were unable to attribute a specific number to that value because the supplier was not forthcoming because that number could be used against them in future negotiations with the contractor.

Proper selection of a supplier to partner with in a VMI arrangement is crucial. If a supplier does not understand the supporting principles, then the process will be a failure. The article, Kanban in construction, identifies four qualities that should be the focus of supplier selection and integration:

1. Evaluating suppliers' capabilities and level of flexibility to adopt new processes

2. Identifying and eliminating waste in the supply chain, focusing on creating value for everyone involved and not only the final customer
3. Working with suppliers to understand the root cause of a particular problem and the corresponding solution
4. Acting proactively to identify potential improvements to the supply chain as a whole (Arbulu, Ballard & Harper, 2003)

This process would require utilizing a top tier supplier capable of supply chain integration. The increased responsiveness of vendor managed inventory versus traditional purchasing structures, has more similarity to the benefits of a decentralized purchasing model.

IV. CONCLUSION

Research clearly shows that the construction industry faces some unique challenges that are not posed to the manufacturing sector. This makes the adoption of many modern supply chain management innovations difficult. However, there is the possibility to adapt some of the innovations used by the manufacturing industry. In particular, vendor managed inventory of small goods on construction sites seems to have a great amount of untapped potential. Provided a project is of appropriate scale, the contractor has a forward leaning supply chain strategy and selects a capable supplier to partner with, their supply chains should be able to integrate and both groups should benefit from the value created by that partnership.

There is very limited research available regarding contractor-supplier relationships in the construction sector. Even more limited is the amount of research dedicated to vendor managed inventory in the construction industry. Additional case studies should be explored and examined

in order to assess all of the potential benefits and risks involved in this type of supply chain partnering. Additionally, researchers should look at the potential benefits to be achieved via the mitigations of the bull-whip effect as more data is freely shared up and down the supply chain.

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