To Pull or Not to Pull: A Concept Lost in Translation?

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Though the term "pull" has become a cornerstone of modern manufacturing operations, there seems to be mixed views and interpretations of the pull concept across different contexts, in particular production management, supply chain management, and project management. We conduct a review of relevant extant literature in order to provide an overview of the different interpretations of the term, and we offer a set of three context-dependent definitions of the pull concept.

"Disagreements over terminology are the natural consequences of competing paradigms"

- Ballard and Howell (2004)

INTRODUCTION

Originally focusing purely on operational issues at the shop floor level, the Operations Management field has over the past decades expanded its scope, and has now grown to encompass far more strategic issues such as the management of global manufacturing supply chains (Kleindorfer *et al.*, 2005). This means that certain concepts that were originally developed on the shop floor are now being transferred and extended to applications in other areas; not just on a greater scale, but also seemingly across different and sometimes competing paradigms. The pull concept is certainly no exception to this phenomenon.

Pull systems have been part of the manufacturing lexicon for more than a quarter of a century (Hopp and Spearman, 2004). Having started out as a term synonymous with the Kanban system developed at Toyota (e.g. Ohno, 1988; Sugimori *et al.*, 1977), the word "pull" is now used to describe a number of different situations within operations management literature, some of which are seemingly contradictory in nature. Having taught on various Master level education programs within the fields of production logistics and supply chain management for several years, we tend to agree with Hopp and Spearman (2004), who described an increasing confusion amongst students regarding the various interpretations of the pull concept. For example, many students are quick to equate pull with a make-to-order strategy, which is in direct contradiction with the original thinking behind the supermarket pull systems developed to support the just-in-time (JIT) concept described by Sugimori *et al.* (1977). This observation was also recognized by Hopp and Spearman (2004), who essentially concluded that pull be defined in terms of a cap on work-in-process (WIP) inventory. However, although these authors compared and contrasted the

fundamental differences between push and pull and make-to-stock and make-to-order, we feel that there remains a significant lack of clarity when the pull concept is transferred from the production management context to other domains, such as supply chain management and project management. Thus, the aim of this paper is to carry out a review of the most imperative extant literature in order to offer more robust, context-dependent definitions of the term "pull".

RESEARCH METHOD

We adopt literature review as our research method for this investigation. We analyze an array of articles from leading scientific journals such as the Journal of Operations Management, the International Journal of Production Research, the International Journal of Production Economics, and the International Journal of Operations and Production Management. We also considered several peer-reviewed conference papers. These articles were retrieved using online journal databases (e.g. Science Direct and Google Scholar). In order to gain relevant insight in terms of the challenges experienced in defining the term "pull" for educational purposes, we also considered the more popular textbooks used in educational programs. It became clear that there were a number of different attempts to define and explain the word "pull" across the various fields, i.e. production management, supply chain management and project management. These various interpretations are explored in the following section.

PULL: ONE WORD, MANY INTERPRETATIONS…

In order to address the pull concept across several different contexts, we first consider the basic semantics of the word. The Oxford English dictionary identifies several definitions of pull, including:

(Verb) To apply force to, so as to cause or tend to cause motion toward the source of the force; To remove from a fixed position; To extract; To draw out; To remove.

In contrast, push can be defined as:

(Verb) To exert outward pressure or force against something; To urge forward.

Thus, it goes to say that pull and push, though two very distinctive actions, can indeed be considered as having the same objective: to move an object; where push means moving the object away from the source of the force, and pull means moving it towards the source of the force.

In this paper, we use basic semantics to define the various connotations of the pull concept in the context of various domains. In the next section, we consider pull in the context of production management, supply chain management and project management.

Production Management

In the production management domain, pull has grown to be a central element of Lean production, which can be described as a development of the just-in-time (JIT) philosophy, itself stemming from the Toyota Production System (Papadopoulou and Özbayrak, 2005). We suggest that the evolution of Lean thinking is perhaps one of the reasons for the confusion behind the meaning of the word "pull" – whereas JIT researchers and Kanban practitioners in the 1980s tended to describe pull with respect to the Just-in-Time supermarket pull systems that were being implemented at that time (e.g. Demmy and Constable, 1988; Fry and Leong, 1986; Karmarkar, 1986; Ketcham, 1988; Spurgeon, 1986); the tables were seemingly turned in the 1990s when Lean researchers introduced pull as "*the ability to design, schedule, and make exactly what the customer wants just when the customer wants it*" (Womack and Jones, 1996 p.24), unintentionally giving the false impression that pull is a make-to-order concept. We use the word "unintentionally" here as Womack and Jones later referred to pull in the original JIT context:

"…but they flowed only when pulled by the next step. That is the blanking machine did nothing until it received a signal from the stamping machines and the stamping machines did nothing until instructed to do so by the welding booth. Each activity pulled the next. The shipping schedule became the pacemaker for the entire operation"

(Womack and Jones, 1996 p.70).

A similar contradiction can also be found in Cortes-Comerer (1986), who describes JIT in terms of the more conventional pull system, yet chooses to state in the title of the work "*JIT is made to order*". We assert that such oversimplifications have lead many researchers and practitioners to falsely equate pull in the most literal sense with a make-to-order approach.

Supply Chain Management

"Traditional supply chains are often categorized as either push or pull strategies. Probably, this stems from the manufacturing revolution of the 1980s, in which manufacturing systems were divided into these categories".

- Ahn and Kaminsky (2005)

This statement from Ahn and Kaminsky illustrates the point made initially by Kleindorfer *et al.* (2005). Terminology and concepts are being transferred from the shop floor manufacturing environment and expanded to suit the needs of other contexts, in this case that of supply chain management. In fact, Billington (1999) discusses in some detail the language of supply chains, and suggests that:

"In formulating a supply chain grammar, the most important syntactical feature is something we call the push-pull boundary. This inflection point is where demand information – the actual customer order – exerts its influence on manufacturing".

Billington states that after orders are received, the product is pulled by demand. Though this may in fact be the case from the supply chain management perspective, we suggest that it was the onset of the push-pull boundary concept that has also contributed to creating the somewhat restricted view that equates push with make-to-stock and pull with make-to-order.

Indeed, when we consider supply chain management in general and Lean supply chain management in particular, we also quickly discover the concept of Leagility (Ben Naylor *et al.*, 1999; Mason-Jones *et al.*, 2000b; Mason-Jones *et al.*, 2000a; Naim and Gosling, 2011). The notion of Leagility seemingly develops the push-pull boundary concept to include an element of pull upstream of the customer order decoupling point (CODP), a term we feel is much better suited for the order penetration point than push-pull boundary. For example, Naylor *et al.* (1999) suggest that though upstream of the decoupling point the supply chain is initially forecast driven, the advent of Kanban-driven supply means that this part of the supply chain has become more than simply a push system. Thus, there is a need for clarification of the word "pull" in the context of supply chain management as an alternative to the definition most commonly used in the context of production management.

Project Management

A considerable amount of the literature regarding pull in the context of project management rightfully stems from the Lean Construction movement (Ballard and Howell, 1994; Koskela, 1997; Koskela, 1999). Due to the project-based nature of this type of production, there is of course an inherent focus on activity planning, rather than the material requirements focus typically found in the manufacturing industry. As such, much of the literature from the Lean Construction domain discusses Pull planning (Johansen, 2002) or Pull scheduling (Ballard and Howell, 2003). In this sense, resources are procured and distributed in

accordance with schedules, but no value-adding activity is performed until the plan "pulls" forward resources and materials (Ballard and Howell, 1995).

TOWARDS MORE CONTEXT-DEPENDENT DEFINITIONS OF PULL

By analyzing the various definitions and accounts of pull that can be found in the most prominent extant literature, we draw useful insights that enable us to offer more context-dependent definitions of the pull concept. Our analysis can be seen in Table 1, where we present the most significant findings of our literature review. In total, we analyzed in detail some 32 articles. Interestingly, the results of our study indicate a strong trend towards the possibility for three context-dependent definitions of pull: Demand-pull, Production-pull, and Plan-pull.

Demand-pull

Many of the authors across the various domains opt to discuss pull in terms of production and logistics "in response of customer demand". Though one might expect this from the supply chain management literature, it was very interesting to observe that many of the definitions of pull retrieved from the production management literature also related more to a supply chain perspective than to the original definitions of pull seen from the shop floor perspective (e.g. Monden, 1998; Ohno, 1988). As such, our first context-dependent definition of the pull concept is Demand-pull, for which we offer the following:

In Demand-pull, value-adding activities only take place in response of real customer demand. However, production can still be either pull-based or push-based.

This goes to say that a state of Demand-pull is present if operations are carried out in response of customer demand as opposed to being based on forecasts. In this context, it is possible to equate Demand-pull with make-to-order, for example. Relating back to the previous definition of pull from the Oxford English Dictionary, we can equate Demand-pull with "*causing motion toward the source of the force*", where the source of the force is customer demand. We can also say that Demand-pull is a context-dependent definition of pull at the macro-level. Notice, however, that production operations can themselves still be carried out using either pull- or push-based approaches. This means that when we move to the production management and project management domains, we require the adoption of a more micro-level perspective for our analysis in order to distinguish between such pull- and push-based approaches.

TABLE 1
DEFINITIONS OF PULL IN THE LITERATURE

Production Management		**Unit**
Arnold *et al.* (2008)	*The underlying concept is not to preplan and generate schedules but instead to react to the final customer order and produce only what is needed to satisfy demand and also only when it is needed.*	Pull system
Cortes-Comerer (1986)	*A method of handling the flow of materials from one stage of manufacturing to another by having operations in the downstream stage of production draw work from the previous stage; removal of a piece for final assembly typically initiates the back-to-front chain reaction.*	Pull production
Hopp and Spearman (2004)	*A pull production system is one that explicitly limits the amount of work in process that can be in the system.*	Pull production system
Huang and Kusiak (1996)	*The Kanban system is known as a 'pull' system in the sense that the production of the current stage depends on the demand of the subsequent stages, i.e. the preceding stage must produce only the exact quantity withdrawn by the subsequent manufacturing stage.*	'Pull' system
Ketcham (1988)	*With demand-pull scheduling, such as JIT, production is initiated and*	Demand-pull

	sub-assemblies are drawn from inventory based on product demands, not material arrivals…in a "pull" environment, sub-assemblies are "pulled" from operation to operation in response to requests generated elsewhere in the system.	scheduling, "pull" environment
Monden (1998)	*The subsequent process will withdraw the parts from the preceding process, a method known as the pull system…Further, each part-producing process withdraws the necessary parts or materials from preceding processes further down the line.*	Pulling system, Pull system
Narasimhan *et al.* (1995)	*Subassemblies and parts required for the final assembly schedule need to be pulled in small batches from the supplying work centers whenever they are required; hence "pull" is associated with JIT systems.*	"Pull"
Ohno (1988)	*In the pull method, the final process withdraws the required quantities from the preceding process at a certain time, and this procedure is repeated in reverse order up through all the earlier processes.*	Pull method
Schonberger (2007)	*The pull system – a customer's use as signal to produce (is a TPS basic, but one that Japanese and later Western manufacturers were tending to apply restrictively: within manufacturing).*	Pull system
Schönsleben (2012)	*Value-adding takes place only on customer demand (or to replace a use of items). Each customer, through coordination with the supplier, "pulls" the order on up through the process levels.* *The Kanban card operates as a pull signal: it entails an order release according to consumption and a (stock) replenishment order.*	Pull system, Pull logistics Pull signal
Seidmann (1988)	*During the plant operation the workstations pull their input parts from the cells. According to this pull system the quantity produced by the cell is not based on estimated future requirements but simply serves to replace the parts actually withdrawn by the workstations.*	Pull system
Slack *et al.* (2007)	*Pull is a term used in planning and control to indicate that a workstation requests work from the previous station only when it is required, one of the fundamental principles of just-in-time planning and control.*	Pull control
Vollmann *et al.* (2005)	*A "pull" system exists when a work center is authorized to produce only when it has been signaled that there's a need for more parts in a downstream (user) department.*	"Pull" system
Supply Chain Management		
Christopher (1998)	*Essentially, JIT is a "pull" concept, where demand at the end of the pipeline pulls products towards the market and behind those products the flow of components is also determined by the same demand…thus no products should be made, no components ordered, until there is a downstream requirement.*	Demand "pull"
Ahn and Kaminsky (2005)	*In a pull-based supply chain, production and distribution are demand driven so that they are coordinated with true customer demand rather than forecast demand.*	Pull-based supply chain
Collier and Evans (2006)	*A pull system produces only what is needed at upstream stages in the supply chain in response to customer demand signals in the downstream stages.*	Pull system
Chopra and Meindl (2007)	*Pull processes may be referred to as reactive processes because they react to customer demand…execution is initiated in response to a customer order.*	Pull processes
Jammernegg and Reiner (2007)	*The trade-off between inventory cost reduction and increased cost for resources depends on the positioning of the CODP in the supply chain process (push/pull boundary). Upstream of CODP is forecast driven…Downstream of the CODP, the process is demand (customer) driven.*	Push/pull boundary
Klug (2006)	*Pull logistics is a demand-driven system.*	Pull logistics
Ng and Chung (2008)	*The upstream of the decoupling point is where the push strategy is used and activities are based on forecast-driven planning. On the other hand, the downstream of the decoupling point is where the "pull" strategy is used and activities are based on order-driven.*	"Pull" strategy
Simchi-Levi *et al.* (2008)	*In a pull-based supply chain, production and distribution are demand driven so that they are coordinated with true customer demand rather than forecast demand…in a pure pull system, the firm does not hold any*	Pull-based supply chain; Pure pull system

	inventory and only responds to specific orders.	
Swaminathan and Nitsch (2007)	*Another common term used in literature is the push-pull boundary. This refers to the point where production switches from being a "make-to-stock" to a "make-to-order" environment.*	Push-pull boundary
Project Management		
Arbulu *et al.* (2003)	*The aim of a 'pull' system is to produce only what is needed, when it is needed, and in the right quantities*	'Pull' system
Arbulu and Ballard (2004)	*…engineered-to-order and make-to-order products can be pulled from suppliers.*	Lean supply systems
Ballard (1999)	*Pull-based systems allow work into production processes based on the state of the process…a simple type of pulling is to limit the amount of inventory that can be placed between manufacturing workstations…pulling is a technique for matching up the various elements needed to actually perform work…in general, we can say regarding pull systems that CAN overrides SHOULD.*	Pull techniques
Ballard and Howell (2003)	*A pull technique is based on working from a target completion date backwards…A rule of 'pulling' is only to do work that releases work to someone else.*	Pull scheduling; Pull technique
Ballard and Howell (1995)	*Make ready processes produce inventories of workable assignments by "pulling" forward resources needed to do that work that will best contribute to throughput at each point in time…Resources are first procured and distributed in accordance with schedules; i.e. the work was driven by schedule push. Now the driving mechanism becomes plan-pull.*	Construction JIT, Plan-pull
Tommelein (1998)	*The main objective of a pull-driven approach is to produce finished products as optimally as possible in terms of quality, time, and cost, so as to satisfy customer demand…to pull means that resources must be selectively drawn from queues – but chosen so that the activity's output is a product needed further downstream in the process, and needed more so than its output using other resources in the queue would have been.*	"Pull-driven" approach
Yang and Ioannou (2001)	*A push system approach cannot ensure the continuous utilization of resources because work continuity must also "pull" preceding activities or segments to eliminate gaps…we use the term pull in applying repetitive scheduling ideas to lean construction in a new way.*	Pull-system

Production-pull

At the micro-level perspective, we consider pull production in the context of shop floor operations. By considering the earliest texts that describe Just-in-Time pull systems and the Toyota Production System (e.g. Monden, 1998; Ohno, 1988) and the more current literature that makes reference to these (e.g. Schonberger, 2007), as well as a range of other articles and books from the production management domain; our second context-dependent definition of pull is *Production-pull*. As such, we suggest the following as a best-fit description of pull in the context of production management:

In Production-pull, value-adding activities take place in response of a specific withdrawal from an explicitly limited inventory buffer, or supermarket. The direction of information flow is the reverse direction of material flow, and production takes place in order to replenish an exact amount of consumed products and / or components.

Notice that there are three fundamental elements that make up Production-pull:

1. A withdrawal
2. An explicit limit of the inventory (supermarket)
3. The direction of information flow is opposite to the direction of material flow

Thus, we suggest that when all three elements are in play, a state of Production-pull is achieved. Again, referring back to the definition of pull retrieved from the Oxford English Dictionary, we can now add the

"*remove*" dimension to our definition, as we have a *removal* (withdrawal) from inventory that has *caused motion* (i.e. production), also towards the *source of the force* (the customer). In theory, this gives us two sources of force causing the motion, the external customer demand (Demand-pull) and the internal withdrawal (Production-pull). However, as with the original JIT Kanban system, a number of prerequisites exist for Production-pull to function effectively, particularly the need of a smooth demand for standardized products in relatively high volumes. If these prerequisites do not exist, we need an alternative context-dependent pull mechanism that can be applied at the micro-level perspective, or what we call *Plan-pull*.

Plan-pull

Because not all producers have a limited portfolio of standard products that are made in high volumes, we require an alternative way of thinking in terms of pull for those that produce low-volume, high variety products (often one-of-a-kind). We can call these project-based manufacturers. As such, our third and final context-dependent pull definition has its roots firmly set in the project management field. We propose the following context-dependent definition for pull in the perspective of project management:

In the case of high variety, low volume (project-based) production, Plan-pull is the appropriate pull-mechanism. The focus here is on the finished items and respective due dates, and value-adding activities take place based on a priority rule such as earliest due date (EDD) and constraint management.

Plan-pull can be exemplified by referring to two application areas. Firstly, in construction management (more notable Lean construction), a method known as phase "pull" planning is used in order to translate the project master schedule (usually based on major milestones) into a pull schedule by considering and managing constraints (in this case activities that are required to be completed before further progress can be achieved) and identifying any potential operational conflicts. The idea is to begin with the end milestone or project goal and then identify all activities that are required to achieve this in reverse order. In doing so, internal customers within the project can pull work from the internal (or indeed external) suppliers, and the sequence of activities can be carried out in just-in-time fashion.

Secondly, Plan-pull can also be operationalized and exemplified in relation to the Quick Response Manufacturing (QRM) paradigm (Riezebos, 2010; Suri, 1998), which uses high-level MRP (HL-MRP) and Paired-cell Overlapping Loops of Cards with Authorization (POLCA) as two fundamental components of production planning and control for quick response. HL-MRP is applied in order to present a simple dispatch- or release list of production orders for finished items, often organized by earliest due date (EDD). POLCA is then used as an alternative to Kanban. Like Kanban, it is a card-based pull system, yet POLCA cards authorize production based on available capacity between production cells (i.e. constraint management), as opposed to providing authorization to replenish a specific consumption of inventory (see Riezebos, 2010). It is for this reason that QRM has many successful applications in high variety, low volume producers, for example in engineer-to-order (ETO) or make-to-order (MTO) manufacturers.

Finally, in relation to the originally stated Oxford English Dictionary definition of the word "pull", in both examples of Plan-pull we again have two "sources" of force causing motion. Firstly, at the macro-level, we have a Demand-pull, i.e. the real customer demand. This is because project-based manufacturing can be classified as make-to-order (MTO) or even engineer-to-order (ETO), which explicitly requires a true customer demand before value-adding activities are carried out. Secondly, and this time at the micro-level, we have an internal force causing production to be pulled through the system. In the case of the construction example, internal customers draw (or pull) work from their supplier/s that is required to enable them to complete their own work (i.e. pull through effective constraint management). In the QRM example, the existence of available capacity and orders requiring completion pulls materials into the system.

CONCLUSION AND FURTHER WORK

In this paper, we set out to investigate the various interpretations of the pull concept that can today be found in a wealth of extant literature. By conducting a detailed analysis of 32 texts from three different contexts: Production Management, Supply Chain Management, and Project Management; we uncovered pertinent factors and useful insights that enabled us to propose three context-dependent definitions of the pull concept, each corresponding to one of the three distinct domains: Demand-pull, Production-pull, and Plan-pull. All three of the context-dependent definitions were compared to the original meaning of the word "pull" in the Oxford English Dictionary, which enabled us to justify the relevance of each.

Furthermore, an interesting observation that was made during this investigation was the shear number of authors that used the word "pull" with the seemingly unnecessary use of inverted commas (e.g. 'pull' or "pull"). Though this could be completely innocent and arbitrary, it does somehow give the impression of confusion or uncertainty for the use of the term "pull" on the part of the respective author/s. As such, we hope that this work can in some way increase the understanding of the pull concept across the various domains. If not just to increase the confidence of future authors to use the terminology without the need for inverted commas, we suggest that this paper could also offer a more structured approach for educational purposes, in order to encourage future students to think beyond settling for the oversimplification of "pull equals make-to-order".

We also suggest several topics for future research, which are relevant for both practice and theory. For example, we suggest that an interesting study could be conducted in order to identify suitable configurations of the various context-dependent pull concepts for different manufacturing strategies, e.g. make-to-stock (MTS), assemble-to-order (ATO), make-to-order (MTO), and engineer-to-order (ETO). Such a study could result in a comprehensive typology or framework for the applicability of the distinctive pull mechanisms in various environments. Furthermore, an investigation of relevant methods and tools that can be applied to support and achieve the identified pull configurations would also serve as a complementary supplement to this work.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the Peder Sæther Center, an International Research and Educational Collaboration between UC Berkeley and universities in Norway which provided funding for the research project OPERATION: Operational Excellence in Engineer-to-Order Manufacturing. The authors would also like to acknowledge the continued support and funding from the Research Council of Norway, through both the SFI NORMAN (Norwegian Manufacturing Future) research program; and SoundChain, a user-driven research-based innovation project in cooperation with Kongsberg Maritime Subsea in Horten, Norway.

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