DEFINING 'PULL SCHEDULING'

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INTRODUCTION

Although 'push/pull' systems have already been discussed for many years by many people in production and inventory management, the new term of 'pull scheduling' has not been examined enough so far. The term has not been even widely recognised yet. However, it will be one of the key concepts for the SCM (Supply Chain Management) system in the beginning of 21st century. Since the pull system should not rely to any plan scheduled in advance, the wording of 'pull scheduling' apparently has a contradiction within the conventional definition. The purpose of this paper is to clarify under what conditions the term of pull scheduling becomes meaningful. Eventually, the definition of pull scheduling will be made up of the three enumerated conditions.

DIFFERENCES OF 'PUSH' AND 'PULL'

The Generic Meanings

An English dictionary (Webster's, 1971) defines 'push' and 'pull' as follows:
"*Push - to exert physical force upon so as to cause or tend to cause motion away from the force. Pull - to exert force upon so as to cause or tend to cause motion toward the force.*"

As a matter of course, according to the dictionary, 'push' is interpreted as action that is basically taken from the side of the provider while 'pull' is action that is from the side of the receiver. If the relation of supplier and customer is built from a push position, a supplier produces products/services and pushes them towards the customer according to the supplier's best plan. Conversely, if the relation is built from a pull position, the customer pulls some products/services from the supplier according to the customer's needs.

Both terms of push and pull are also used for information providing systems by mass communications and the Internet. In the case of mass communications, the push type of service sends various information regardless whether a user wants something else. On the other hand, retrieving information from a WWW homepage, it is called a pull type.

Toyota's Kanban as a Pull System

The usage of the term 'pull system' was known from the Toyota Motors' explanation of their Kanban system. In this case, their system operates by either the demand pulled by the

customer or the next process in the factory. Toyota's success with this unique system in production management is generally known. Moreover, it is also known that the Kanban system touched off the popularity of using pull system terminology.

When Toyota constructed a new assembly factory for military trucks during World War II, Kiichiro Toyoda, the company's founder, instructed his engineers to apply Just-In-Time system to the parts supply (Shochiku movie, 1980). This is the beginning of Toyota's JIT system, although it may be a kind of myth. After the war, the company invented the Kanban system to cope with the increasing consumers' demand for volume and variety.

Others explain that the Japanese concept of a pull system originated from a 'Takt system' (Shinohara, 1996). The word of 'Takt' comes from German and the English translation is time or rhythm. An expression of 'den Takt halten' which means 'keep in time' in English shows the sense. The Takt system was also developed during World War II at fighter assembly plants such as the ones at Mitsubishi Heavy Industries, Nakajima Aeroplane and the Imperial Naval Factories (JMA, 1982). Since the system was one of the recent innovations in production management at the time, it was not only a matter of concern for engineers and managers, but many academic researchers also studied and wrote papers on the Japanese Takt system.

However, from a modern perspective the system seems to be primarily for raising labour performance on the assembly lines. This pull system was not oriented towards satisfying customers' demands and could not make up for the chronic material shortage in war time. In that case, the customer was the military and their demanded delivery date was to match their war plans.

Although the Takt system is not same as the Kanban system, the so-called Toyota system, after the war the Kanban system employed the essence of the Takt system for increasing workpace and productivity. Namely, instead of using work measurements which control the productivity by standard time, it uses a system enhancing the operators' efforts toward productivity improvement by pulling the tasks and their materials physically towards the work site just on the time for the operations to be done.

Taiichi Ohno, the inventor of the Kanban system and a former executive vice president of Toyota Motors, once denied the effectiveness of using standard time in the company (Ohno, 1980). The reason for his denial was that standard time hinders further improvement in productivity, because production people easily think standard time is a kind of ceiling and thus there is no necessity for further improvement beyond the current task standard. This is the secret of 'kaizen', the Japanese word for amelioration. The philosophy of 'kaizen' is that further improvements are 'pulled' or inspired by the production people's independent efforts, and not 'pushed' by any standard or by any plan sent down by management.

From his book (Ohno, 1978), "*When IE (Industrial Engineering) was introduced to Japan, someone stated that the Toyota production system is a kind of ME (Method Engineering), but it is not IE.*" The person who made this comment to Ohno might think that IE has to have

work measurements, however, it can be seen that the Toyota production system does not have this as a primary function.

Considering the above historical background, the pull system can have two purposes, 1) to pull the necessary materials and works-in-process to get the finished products just on time for the customer, and 2) to raise labour productivity. In this paper, the term of pull system is applied entirely to the former implication, the pulling of the flow-of-goods according to the customer's needs.

Definition by APICS

American Production and Inventory Control Society (APICS) publishes a dictionary which is recognised as a collection of the standardised terminology in the area of production and inventory management. In the dictionary, the two terms are defined as follows:
"Push (system)- 1) In production, the production of items at times required by a given schedule planned in advance. 2) In material control, the issuing of material according to a given schedule or issuing material to a job order at its start time. 3) In distribution, a system for replenishing field warehouse inventories where replenishment decision-making is centralised, usually at the manufacturing site or central supply facility.
Pull (system)- 1) In production, the production of items only as demanded for use or to replace those taken for use. 2) In material control, the withdrawal of inventory as demanded by the using operations. Material is not issued until a signal comes from the user. 3) In distribution, a system for replenishment decisions are made at the field warehouse itself, not at the central warehouse or plant." (APICS, 1995)

Reasons of Needs for Pull System

Pull system has been introduced not only to the automotive industry successfully but also to other industries as well. The reasons why the system is required are as follows.

1. To solve a shortage problem of stock space

The following two cases tell typically the reason.

a) Automotive parts inventory

Maintaining a certain level of stock in the factory warehouse takes a lot of space. Naturally, they tend to believe that the parts should be supplied just when they are needed and by the required volume, otherwise they have to build enormous warehouses for the parts.

b) Goods supply at convenience store

The same reason can be applied to a convenience store's case. If we remember a traditional shop of the type before the transformation to a convenience store, it was just a small shop that stores and sells various kinds of daily goods. It may have extra stock behind the

display in the shop which is called 'backyard stock'. That is, only half the space was used as the store display for customers. On the other hand, 'convenience' means that at any time anybody can buy any goods of daily necessity. The number of goods ordinary people need in their daily life has been estimated at three thousand items. For selling three thousand items within the limited space of a shop located at an ordinary shopping mall, there is no room for much stock on each of the three thousand items. There is room for only five or six pieces for each item. Naturally, when two or three pieces of an item are sold, the item should be replenished immediately, otherwise stock-out may occur. The supply of goods should be executed timely and frequently. That is the reason why goods to convenience store should be supplied by a demand pull method. The 'convenience store' concept does not work if they employ the push system to the goods supply.

2. To reduce inventory

Keen competition in business requires reducing inventory as much as possible. It comes from the following two reasons.

a) Reducing cost

Needless to say, reducing inventory or lead time considerably reduces costs. Moreover, it is not too much to say that shortening lead time is the primary purpose of SCM. For this reason, many companies today proceed with their improvement projects to reduce lead time or inventory.

b) Avoiding deterioration

Rapid change of demand leads to deterioration of goods. If much stock remains and will not be sold any more, these goods become dead stock. This is true, in particular, for the fashion oriented industry. Goods deterioration is also critical in the food industry where an 'eat before' date is applied. In this case of production and distribution where quality damage happens, the system should be strictly based on demand-pull principle.

3. Agility to change

Agility in the system reduces costs and avoids deterioration risks as stated above. In addition to these advantages, there is also an essential strategic aspect. Keeping pace with rapid change in demand is a matter of management strategy. If not kept up with, the company may loose sales and cannot be the front runner in a competitive business.

PROPOSING PULL SCHEDULING

An Example of Using the Term Pull Scheduling

An existing example in which the term pull scheduling was used is shown in (Ninneman, 1997), although the usage does not seem to be based on the precise definition.

"For the past three years, a team at U. S. Steel has been developing a new scheduling system to reduce cycle times and improve customer delivery. The steelmaker has implemented the team's recommendations at its Fairless, Pa., Works and its tin mill in Gary, Ind. Fairless Works reduced its cycle times by 35 percent after adopting the reengineering program. Better scheduling throughout the plant led to less inventory in front of the galvanizing line. Fairless Works once had ten weeks of cold-rolled coils before the galvanizing line; now it carries three weeks' worth. U. S. Steel officials call the new system 'pull scheduling'. Downstream processes, like galvanizing, pull steel through the entire plant based on a customer's desired delivery date. In U. S. Steel's original system, steel for an order would spend one week at each applicable mill operation. In the production of a galvanized coil, steel for the coil would spend one week in the melt shop, one week in the hot-strip mill, one week in pickling/cold rolling, one week in annealing, one week in galvanizing, and one week on the shipping floor. In this system, a customer could expect a minimum lead time of six weeks. One-week delays aren't built into the new scheduling system."

From the above explanation, a loose definition is suggested. It is pulling work through the entire process based on a customer's desired delivery date. This is the pull scheduling system, it says. However, the definition has a contradiction in its meaning. Even if it was scheduled in advance in some way, the question is whether or not it can still be called a pull system. APICS explains that a push system makes products by a given schedule planned in advance. If the schedule is planned by the customer's requested delivery, the question is if it can be a pull system or be a push system. The above loose definition is not sufficient to explain it fully. The purpose of this paper, therefore, is to give rigour to a definition.

Proposing a New Definition of Pull Scheduling

A new definition of pull scheduling is explained as follows. First of all, the meaning of pull system has already been clarified. Then, defining 'scheduling' is necessary. Although scheduling is to make a schedule, in this paper, 'schedule' has to be defined more meaningfully for the purpose of describing pull scheduling. The traditional image of schedule is just a sequence of work lots in a time scale, preciseness of which depends on the kinds of schedule, such as monthly schedule for giving lump-sum plan, daily schedule which shows exact time of start and end of each activity. To gain greater precision many people think that drawing lines in a Gantt-like chart is scheduling. However, drawing lines itself is not sufficient for making a schedule. This is the key point which should be recognised in this paper. Schedule has to be one which satisfies with the following three requisites.

- The schedule has to be able to meet with the delivery date designated by the customer, or meet with the deadline to replenish the finished goods inventory. For satisfying the delivery date which is the most important thing in logistics, the other two conditions are also considered.
- According to the schedule, all the necessary materials should be supplied. If material availability is not satisfied, the production cannot be started by the scheduled

instruction.

- Schedule is an allocated result to the production capacity. Any schedule without considering capacity is meaningless, because the schedule is not guaranteed to be accurate according to the planned date/time.

A planned sequence of work-lots in a time scale satisfying these three requirements now fully defines a 'schedule'.

Contradiction in Wording of Pull Scheduling

One of the clear differences between push and pull is whether it is scheduled beforehand or not. This is stated in the definition by APICS. In other words, wherever any schedule is planned, it is said that the system becomes a push type. The wording of pull scheduling, therefore, is contradictory to the APICS definition. The question is how the scheduling can be a pull system, because making a schedule seems to be a synonym for using the push method. However, pull scheduling should be a meaningful term and it is not too much to say that the term is one of the keys for the secret of successful SCM.

Pull Scheduling as a Key Factor in SMC

Reasons why pull scheduling becomes one of the key factors for success in SCM are as follows.

1. **All activities are basically pulled by demand.**

Of course, there is some chance to start the activities not by demand pull but by their own reason. However, demand pull is a very basic rule in most industries and businesses. It is necessary to know what item, when, and how much volume should be started. Otherwise, unrestricted instruction of starting activities may occur. This leads to inflated inventory and lead time. At least, the latest starting time for a particular activity tells what the lead time should be for whole processes, even if it may start earlier for some practical reason to fulfil the lowest expected utilisation of the production capacity.

2. **Thanks to recent IT progress, a computerised dynamic scheduling system becomes practical.**

Although several years ago employing a dynamic scheduling system in practice was not realistic, now it becomes a practical issue. 'Dynamic' should be defined here as 'changing daily'. In other words, the schedule should be planned everyday according to the demand change of each day. For reducing lead time or inventory more, it is necessary to be exceedingly sensitive to the daily demand data. That is why many companies continue to try to shorten the planning cycle. For example, the production plan has been made monthly at most manufacturers, and some advanced companies have already introduced a biweekly planning system or a weekly planning system. At this point it becomes appropriate to introduce even a daily planning cycle. This is indebted to the recent progress of IT

(Information Technology), in particular, increased capability of PC and network technology.

Capability of Today's IT

The following items are the reasons for the recent realisation of a computerised dynamic scheduling system.

1. Man-machine interactions

Decision making about the schedule is an interaction between the computer and the planner. A Mainframe computer can provide the scheduled results to the planner by one way communication and does not allow to do any reciprocal adjustment. For this reason, using a PC is essential for a practical decision making system. Moreover, GUI (Graphical User Interface) is also very helpful to adjust and finish the scheduling. If there were no good human interface, the screen handling would be a quite difficult one and thus the scheduling system would not be successfully introduced.

2. Processing speed of PC

Until recently it was believed that scheduling takes much time for processing. Because of the complicated algorithm and the voluminous data to be processed, the processing time might be several hours or even one day. However, today's PC can handle such data processing within a short time. Not only increased speed of CPU contributes to faster processing, but also extended main memory makes it faster. By increasing the main memory size as much as needed, frequency of access to hard disk is decreased, thus the total processing time can be reduced considerably.

3. Openness of database connectivity in networks

Making schedule needs for various data, such as order data from customers, inventory data, work-in-process data, material availability data, capacity data, other current status data and a number of master data defining various conditions for scheduling. The variety and volume of this data can be read without any difficulty when making the schedule. Today's progress in database connectivity has made it possible.

CONDITIONS TO BE PULL SCHEDULING

For making the definition of pull scheduling, the three conditions are proposed here. Pull type scheduling which conforms with these conditions can be defined as pull scheduling. Namely, the three conditions are requisites to make the scheduling to be pull scheduling.

(1) It is not a schedule when production is started unnecessarily early from the

deadline. The production schedule should be planned backwards, so that the production starts at the latest time to meet the customer's request. The customer may be the real customer, or may be the finished goods warehouse, or may be the next process. In most cases, lack of visibility leads to the unnecessarily early start of production. Everyone is usually very careful about delays or out-of-stock happenings, but they are not so care about early starts. For this reason, so called 'lead-time inflation' (Wight, 1984) sometimes occurs.

(2) It is not a plan for maintaining higher utilisation of production capacity. If any lot or job is allocated to the production schedule for raising the machine and/or man-hour utilisation against the capacity, it becomes a push type of production. This is the most important key factor to divide into the two categories, push and pull. The following explanation is useful to understand this condition. "*The distinction we believe is useful pertains to whether individual work centers are allowed to utilize capacity without being driven by a specific end item schedule.*" (Vollmann et al., 1997)

(3) The production schedule is planned/reviewed in a short cycle. Pull scheduling must be dynamic. Pull means that all the production activities are pulled tightly by the customers' demands which vary everyday. Constant and no-changing demand cannot be expected today for most industries. This is a generally accepted fact. In case the demand volume is summarised monthly or weekly, the production based on its planned demand can never be called a pull type. In the opposite extreme, even under the newest IT environment, it seems impossible to employ real-time scheduling for ordinary factories. Consequently, daily scheduling, that is, once a day scheduling is the closest method that can be achieved for a status tightly pulled by the customers' demands. Of course, the following explanations are possible theoretically.

- If all the customer orders/requests really come only on a particular day in a month, even if the orders can be accepted to the company everyday, there is no need to make a planning cycle which is shorter than one month.
- If all the customer orders/requests come and processed on a particular day in a week, there is no need to make a planning cycle which is shorter than one week.

However, there is no such circumstance today to afford long cycles of rigid planning. Daily cycles seems to be the best way and has become the target cycle when designing new systems.

COMPARISONS

To explain the meaning of pull scheduling more clearly, comparisons of some terms are useful. While pull schedule is planned by backward scheduling method, push schedule is by forward scheduling method. Comparisons of these terms, therefore, are necessary. For example, pull scheduling is synonymous with backward scheduling, or not. Static schedul-

ing of pull type is possible, or not. This kind of questions have to be answered by the comparisons for making the definition of pull scheduling more lucid.

Comparisons of Pull Scheduling and Push Scheduling

Push Scheduling	−forward allocation (NB—1) −dynamic scheduling (NB—2) −management intention to control productivity	−higher productivity = operating by independent decisions −necessary to check the actual lead time with the lead time as it should be −ATP(available to promise) > CTP(capable to promise) −suitable for production using high−priced machine
Pull Scheduling	−backward allocation −dynamic scheduling −management intention to reduce the lead time or the inventory	−shorter lead time = tight rope pulled by demand −necessary to control the production capacity −ATP < CTP −suitable for stockless and quick production

(NB-1) If it is static and without any managerial connotation, it is forward scheduling.
(NB-2) Dynamic means here that daily changing data is employed in the scheduling. The planning cycle is, therefore, a day.

PRACTICAL USAGE OF PULL SCHEDULING

Productions of all the processes are tightly pulled by demands, if pull scheduling is executed. This leads to the minimum inventory or minimum lead time, however there is also another problem. That is, if the total work load is more than the production capacity, unallocated work load remains. If the total work load is less than the capacity, some vacancy occurs today or during the coming several days including today. This means that there is nothing to do at that moment. Under these conditions, pull scheduling can not be used in practice. Because any company does not like to close the factory even when there is nothing to do today but it knows there is likely something to do within a few days. In reality, the following procedure will be utilised by this order.

1. Execute pull scheduling.
2. Adjust the production capacity, to increase or to decrease the capacity to coincide with the current total work load.
3. Execute push scheduling. The schedule for today is instructed to the shop floor to tell what jobs should be processed today. This is a dispatching function.

It is deducted that if the capacity adjustment can be done to one hundred percent of the requirement, the results of pull scheduling and the results of push scheduling become

exactly the same.

Although pull scheduling is the main topic of this paper, push scheduling is executed and it is released as the production instruction in the final stage of the above procedure. It is necessary, therefore, to explain in what way pull scheduling is valid. There are three reasons of executing pull scheduling.

1. It is easier to estimate sufficiency and insufficiency of the production capacity so that this leads to appropriate actions for capacity control.
2. The scheduled start time at the next process becomes a priority for selecting which one to be allocated to this process. Work of the highest priority comes first.
3. The latest start time of each work can be known. It is the deadline for starting, otherwise it will be delayed eventually against the delivery date to the customer or out-of-stock may happen.

CONCLUSIONS

Finally, the definition of pull scheduling can be now summarised. "Pull scheduling is a concept of dynamic scheduling which is rescheduled in a short planning cycle, for example, daily by backward allocation." The backward system instructs the schedule not to start the production unnecessarily earlier and not to start the production by considering to raise the machine or labour utilisation. Finally, with its use management should intend to reduce the lead time or the inventory.

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《**Summary**》

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Although 'push/pull' systems have already been discussed for many years by many people in production and inventory management, the new term of 'pull scheduling' has not been examined enough so far. However, it will be one of the key concepts for the SCM (Supply Chain Management) system. The purpose of this paper is to clarify under what conditions the term of pull scheduling becomes meaningful.

The definition of pull scheduling is summarised as follows. "Pull scheduling is a concept of dynamic scheduling which is rescheduled in a short planning cycle, for example, daily by backward allocation."

Eventually, the three enumerated conditions which make up pull scheduling as the requisites were proposed.