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Mathematical Approach for Determining the Number of Kanbans: a Step Towards Non-Stock Production in Manufacturing Scenario

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ABSTRACT

Just-in-time (JIT) production is a philosophy that calls for reducing work-in-process (WIP) inventory to aid process improvement and reduce process variability. Kanban act as the nerve of a JIT production system whose functions is to direct materials just-in-time to workstations in stages of manufacturing, and pass information as to what and how much to produce. Indeed, the number of kanbans between two adjacent workstations decides the inventory level of that pair of workstations. With the objective of minimizing WIP inventory level, is developed for deciding the optimum number of kanbans. In the present work the mathematical model for calculating optimum number of kanbans and solution procedure are illustrated with a numerical example.

Keywords: *Work In Process; Kanban System.*

1.0 Introduction

JIT can be defined as the ideal of having the necessary amount of material available where it is needed and when it is needed. It is an attempt to produce items in the smallest possible quantities, with minimal waste of human and natural resources, and only when they are needed. JIT systems have proven to be effective at meeting production goals in environments with high process reliability, low setup times and low demand variability [1].

In general, JIT has a pull system of coordination between stages of production. In a pull system, a production activity at a stage is initiated to replace a part used by the succeeding stage, whereas in a push system, production takes place for future need.

The advantages of JIT production include reduced inventories, reduced lead times, higher quality, reduced scrap and rework rates, ability to keep schedules, increased flexibility, easier automation, and better utilization of workers and equipment. one of the major elements of JIT philosophy and pull mechanism is the kanban system. Kanban is the Japanese word for visual record or card.

In this system, cards are used to authorize production of a given amount of material.

2.0 Kanban Calculation

In the present paper a mathematical approach is developed to calculate the optimum number of kanban cards to improve customer satisfaction by producing good quality products with shortest delivery time.

In order to illustrate the kanban calculation, here considering an example about an ELEMENT product, Element is the assembly of barrel and plunger used in diesel pumps. The daily based requisites (PR) of this product are around 1560 units/day, which corresponds to the quantity that has to produce on a daily basis.

The standard number of pieces (SNP) is 100 units. This means that one box with 100 units will correspond to a kanban. Production is based on a model that includes three work periods per day (24 hours =1440 minutes), including intervals of 135 minutes (including breaks) and intervals of 187 minutes, including stopping periods, namely due to line stopping, due to technical problems or related to quality requisites.

This conducts to an effective planned operating time (POT) of 1305 minutes (1440 minutes–135 minutes = 1305 minutes).

The number of kanban is calculated as

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$$K = RE + LO + WI + SA \quad (1)$$

Where, RE = Replenishment time coverage, LO = Lot size coverage, WI= Withdrawal peak coverage,

SA = Safety time coverage.

Replenishment time coverage (RE)

The replenishment time is the time between when a product is consumed to the moment a product is consumed until it is replenished back to the supermarket

$$RE = \frac{(RT\ Loop)}{(TT * NPK)} \quad (2)$$

Where,

PR = Requirement per period (customer demand per day), RT loop = Replenishment lead time for the loop [minutes.], NPK = Number of parts per kanban [pieces], TT =Customer takt time (seconds/pieces)

In other words, need to find the coverage for replenishment time, where,

RT loop= RT1 + RT2 + RT3+RT4+RT5+RT6

The schematic representation of the RT loop is shown in figure 1.

Fig 1: Schematic Representation of RT loop in kanban Calculation

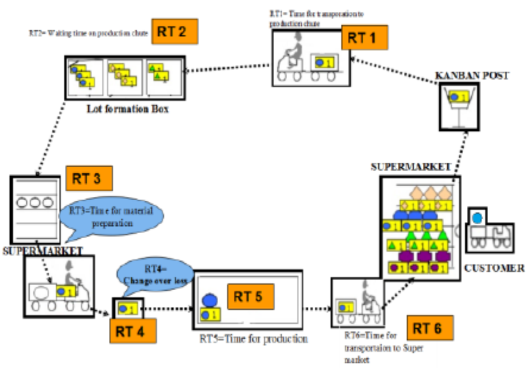
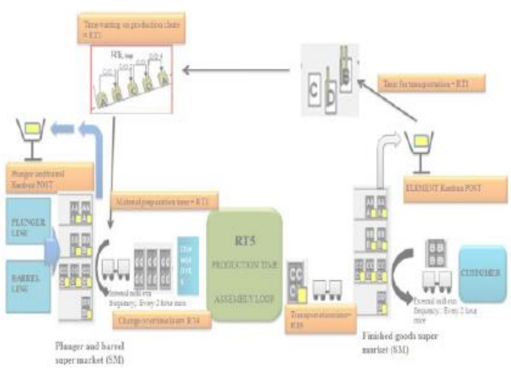


Fig 2: Shows Schematic Representation of RT2 Factor



RT1 is the transportation time from supermarket to production chute includes waiting time for the next milk runner frequency. In simple words it is the time between the withdrawal of the pieces from the supermarket and the arrival of the released Kanban on to the production chute and includes:

Waiting time of the Kanban in the lot formation box =120 minutes.

Transport time of the lot formation box to the production chute = 5 minutes.

RT1=125 Minutes, RT2 represents waiting time of kanban on the production chute and is based on the number of lots already waiting on the production chute & the time until these waiting lots leave the production chute Case 1: Where dedicated machine was allotted for specific type of product.

RT 2 = Waiting time in Production chute for pickup (For Type 1 part number) = 0 Minutes

Case 2: Where n number of parts are run on each machining center.

Where, LS typel =Lot size of typel product, CT typel =Cycle time for typel product, LS type2 =Lot size of type2 product, CT type2 =Cycle time for type2 product, RT2 =748 Mnutes, RT3= Material preparation time = 15 Minutes. ,RT4= Change over time loss =0

Note: [RT4 =0 if Change over (C/O) considered in RT2], RT5 is the production time for 1 Kanban Quantity. Details are shown in figure 3, Work in process (WIP) in production line = 429pieces

WIP on First in first out (FIFO) Chute = 18026 pieces Cycle time (CT max) of bottleneck in the line = 20 seconds/ piece, NPK =100 pieces/ Kanban

RT5=[(NPK-1)*CT max =32.67 minutes., RT 6 = Time for Transportation to Supermarket =125 Minutes.

RT LOOP = RT1+RT2+RT3+RT4+RT5+RT6 = 125 + 0 + 15 + 0 + 32.67 +125 = 298 Mnute

RE = (RT Loop)/ ((TT/60) x NPK) =4.9 Cards Where, TT = Customer Takt for typel part number is = [(POT*60)*Leveling period] / Requirement

= [1305*60)*6] / 12900 =36.42 sec/pc

Lot size coverage (LO): If one kanban is already waiting, till what time it has to wait until the lot is full? The schematic representation of Lot size coverage factor is shown in figure 4.

LO = (LS/NPK) – 1

(3)

LO = (Lot size in leveling period/NPK) - 1=21 cards

Where, LS=Lot size [pieces].

Withdrawal peak coverage [WI]

WI = [(WA - LS)/NPK]-RE-LO

(4)

Where, WA = withdrawal amount (Maximum forecast peak

withdrawal of the customer in the period.

SNP [pieces]: Standard number of pieces, LS [pieces]:

Defined production lot size

WI= (WA/NPK) -RE - LO But WA = [Lot in leveling

period (pieces)*RT loop)/POT] = 490.95 pieces

WI = -21 (if WI<0 then consider it as 0) = 0

Safety time coverage [SA]

SA =SA1+SA2+SA3

(5)

SA shows the additional Kanbans that are required to cover internal process instability & unknown customer fluctuation

Fig 3: Production Time for 1 Kanban Quantity

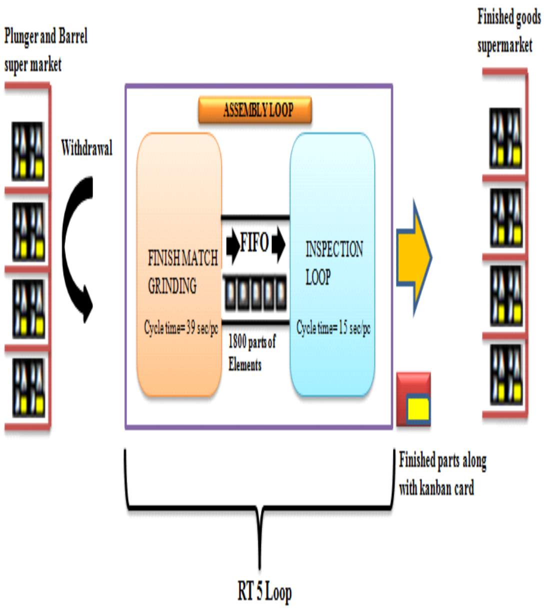
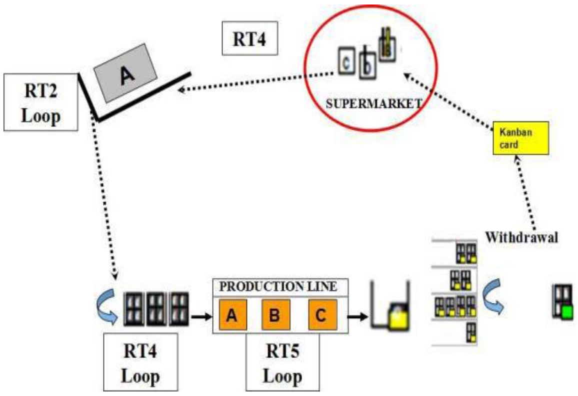


Fig 4: Schematic Representation of Lot Size Coverage Factor in Kanban Calculation



SA1= Unknown fluctuation in output and lead time in the

supplier process

SA2=Unknown fluctuations in customer withdrawals

SA3= Additional safety

SA1 = (WA extended - WA)/NPK

(i) WA extended = [(RT Loop extended) x (Lot size in leveling period)]/POT

(ii) RT Loop extended = (RT Loop + Losses coverage in Mnutes)

(iii) Losses Coverage = Coverage for Internal Losses (Overall equipment effectiveness (OEE*))

RT Loop extended = RT Loop + Losses in minutes.) = 624 Mnutes.

Average OEE Losses (in minutes) = (1-Average OEE)* POT = 326.25 Mnutes

WA extended = [(RT Loop extended) x (Lot size in leveling period)]/POT = 1028 Pieces * OEE = 75%

SA1= (1028 - 490)/100 =5.38 Cards

Unknown customer variation (From past)

SA2 = (WA/NPK) x % of Deviation in Customer Demand*= 0.73 cards

SA3 = Additional pieces (uneasiness for start of system) =

Additional Quantity/NPK = 100/100 = 1

SA = SA1+SA2+SA3 = 7.11 cards

Total No. of Kanban Card Required

K = RE+LO+WI+SA = 4.9+21+0+7.11 = 34 cards ,

*Percentage of customer deviation = 15%

3.0 Results and Discussion

Table 1 Number of kanban cards available at supplier end and on the shop floor when supplier is failing to give the raw materials

Day	Customer WIP	Kanban cards at Finished Goods Super Market	Supplier units	Note
1	18	9	0	Production delayed
2	15	12	0	Kanban Collected, Production begins
3	12	15	0	
4	9	6	4	
5	6	9	8	The product is shipped,
6	3+12=15	12	12	Kanban Collected, Production begins
7	12	3	4	
8	9	6	8	
9	6+12=18	9	12	The product is shipped
10	15	12	0	Kanban Collected, Production begins
11	12	3	4	The product is shipped
12	9	6	8	Kanban Collected, production begins

Table 1 show what happens if the supplier is down for a day. During the down time extra kanban accumulate. The supplier still collects 12 and supplies a normal lot, however after this lot is complete there are 12 kanban available which immediately authorizes the production of another lot. When this extra lot is sent the system returns to a steady state. This example demonstrates the advantage of extra capacity to make up for lost production time and the importance of proper safety stock levels

4.0 Conclusions

The use of kanban to control production has been widely practiced by Japanese for simplicity and visibility it offers on the shop floor. In this paper, the role of kanbans in a JIT production system was discussed in the context of maintaining a minimum level of in-process inventory level. A model for determining the optimum number of kanbans is presented to better aid planners in setting the number of kanbans at each workstation in the system. Careful analysis can yield immediate benefits by reducing inventories and providing a comprehensive picture of current activities. JIT is multi-facet manufacturing concept involving productivity, quality, production planning, and production control. With the certain planning and control efforts, the kanban component can be implemented to reduce inventory cost For the first 4 days the supplier does not have enough kanban to authorize a lot of 12.

At the end of day 5 the supplier has 12 kanban and production can begin. The supplier finishes the lot of 12 in 3 days and ships the whole lot at once. The Customer receives the 12 units just as it reaches its safety level of 2 days of WIP. From day 4 onward the system is in steady state, the customer uses 3 units per day and the supplier works 3 days to supply 12 units for every 4 days and the customer never falls below the safety level.

If for some reason the supplier cannot meet demand temporarily then the customer has 2 days of safety material. Once the supplier is ready to supply again the excess capacity allows the supplier to catch up to the customers demand Table 2 shows what happens if the supplier is down for a day. During the down time extra kanban accumulate.

The supplier still collects 12 and supplies a normal lot, however after this lot is complete there are 12 kanban available which immediately authorizes the production of another lot. When this extra lot is sent the system returns to a steady state. This example demonstrates the advantage of extra capacity to make up for lost production time and the importance of proper safety stock levels

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