SYSTEM DYNAMIC MODELLING AND ANALYSIS OF A SINGLE STAGE SINGLE PRODUCT KANBAN PRODUCTION SYSTEM

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Abstract: System dynamic (SD) provides a useful interpretation of business contexts, analysing how policies and decisions affect the structure of companies and the dynamics of the available resources. For this reason, it has successfully applied to many problems related to industrial management and operation research. Due to its ability to model and simulate the complex system for understanding the system behaviour over time horizon, it can be applied to Kanban production system to meet the customer demand in right quantity and time. This article presents the application of system dynamics approach in KANBAN production system. SD models for single stage single product kanban system is developed and simulated over different time horizon to study the behaviour of kanban production system. Simulation results are discussed later.

Keywords:System Dynamics, JIT, KANBAN System, Industrial Management

I. INTRODUCTION

In order to remain competitive and economically successful, every organization focuses on increasing productivity, improving the quality of its products, and raising the standards of efficiency within its company. The just-in-time (JIT) management allows the organization to achieve this goal by increasing the efficiency of the production, reducing the level of wasted materials, time and effort involved in the production process. JIT philosophy recommends that a manufacturer reduce inventory by making components just in time for the subassemblies and by making the subassemblies just in time for the final assembly. Reduction in inventory is not the only goal of the JIT philosophy and it affects overall productivity in more than one beneficial way. [15]

To implement the JIT philosophy, a kanban technique is introduced as an efficient operational mechanism. The improvements in reduction of inventory and wasted labor, and enhancement of customer service are usually accomplished through kanban operations. Thus, a kanban mechanism ensures the organizations to run their supply chain systems in JIT policy. In a kanban controlled system, production is triggered by the demand at the final stage. At each intermediate stage, it is triggered by its succeeding stage(s)—this process is carried all the way from the final stage to the beginning stage. Thus, the production is controlled (i.e., pulled) by demand of the succeeding stage, the customer of the preceding stage. Thus, this approach leads itself to a very simple control mechanism, best known as kanban (or pull) system. [17]

Kanban controlled production systems have received much attention in the past because of the ease in which they can implement the pull control policy using a make to stock production. The production system is decomposed into several stages, each of which corresponds to a subpart of the system, where production is controlled by way of cards (called kanbans), acting as production orders. [16]

A. Kanban System

The Kanban system can be viewed as an information system that controls JIT production. Kanban is the inventory replenishment system developed by Toyota to accomplished JIT production. In Kanban production system, the production processes for various products are controlled as per the customer's order. Generally speaking, each item consumed, determines a replenishment signal: a production card (Kanban) is collected in a special Kanban board that displays items consumption and then used to start production or order placing according to the sequencing rules of the upstream section. There are two types of Kanbans: withdrawal kanban and production kanban. Withdrawal Kanban specifies the kind and quantity of product to be withdrawn from the subsequent process. While the production Kanban

specifies the kind and quantity of product to be produced. The withdrawal Kanban is used as an inter-process signal to move physical units from one process to another process that takes place at a different location, whereas the Production Kanban is an intra-process signal to issue production orders in a particular process. As a result of this dual chain of Kanbans, the rate of production of the succeeding process is transmitted to the preceding and every process receives the necessary units at necessary time in necessary quantities. [14]

A kanban usually includes the information such as part number, description, container, unit load (quantity per container), stock location (from), end process (to), and some optional information (lot size, number of kanbans per lot, machine number of final operation, individual kanban).
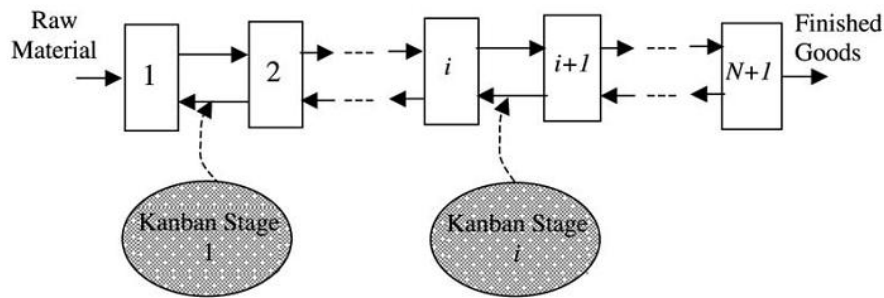

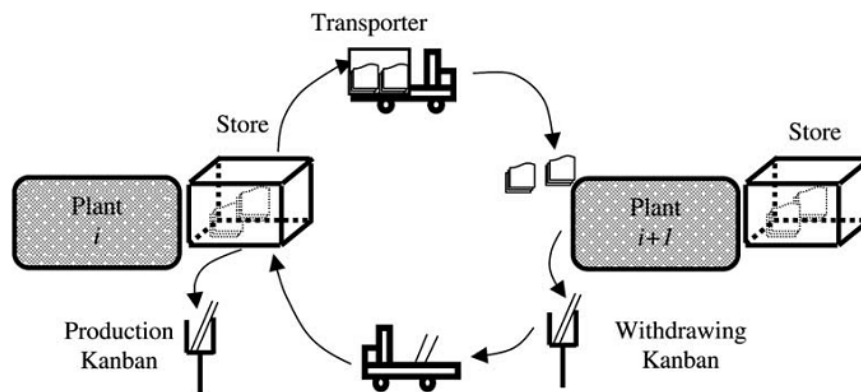Fig.1 A Multi-Stage Supply Chain System with Kanban Operations [17]

Fig. 2 Operation of Kanban Production System [17]

The function of the kanban is best explained through the use of an N-stage production system as illustrated in Fig. 1. Two adjacent plants, i and i +1, in Fig. 1 are isolated for illustrative purpose as shown in Fig. 2.

The kanban operation can be explained as, a withdrawal kanban attached to a loaded container in a succeeding plant (i+1) is detached from the container to the kanban board as the first part from the container is to be used. Then withdrawal kanbans from the kanbans board are collected and brought to the proceeding plant i at a fixed or nonfixed interval of time called kanban cycle. The withdrawal kanban is then attached to the container in a store at the preceding plant in place of the detached production-ordering kanban that triggers the production of the preceding plant to produce the required amount of parts. The containers filled with parts together with the withdrawal kanban are brought to the succeeding plant by the material handling devices called transporter. This kanban cycle realizes smooth, timely, and optimal flow of parts between preceding and succeeding plants.

As the system is operated under the JIT philosophy, the stock levels in each stage should run ideally as low as possible. First, the number of kanbans in each stage should be determined; that is, the number of batches at each stage that is to be shipped by kanbans should be determined. Considering the delivering time and loading/unloading time, the number of kanbans needed to transport the batches is determined. Second, the ordering policy for the suppliers at the first stage and delivering policy for the retailers at the last stage are to be decided as well. Next, all stages should be linked together to balance the material flow in the supply pipeline. All these apparently discrete problems should be solved collectively based to minimize the total operational cost. Finally, the kanban operations at each stage should be scheduled. [17]

B. Implementation of System Dynamics in Kanban Production System

System dynamics is an approach to understanding the behaviour of complex systems over time. It is a methodology and mathematical modelling technique for framing, understanding, and discussing complex issues and problems. It deals with internal feedback loops and time delays that affect the behaviour of the entire system.

System dynamics was developed by Jay W. Forrester (1950) in Massachusetts Institute of Technology (MIT). This framework is focused on systems thinking, but takes the additional some steps of constructing and testing a computer simulation model. System dynamics simulation is performed to learn about the dynamics of the system behaviour that may impact the planning solution by using closed-loop feedback and to design policies to improve system performance. It treats the interactions among the flows of information, money, orders, materials, personnel, and capital equipment in a company, an industry, or a national economy. The main characteristics of this method are the existence of complex system, the change of system behaviour from time to time and also the existence of the closed loop feedback. This feedback describes the new information about the system condition that will yield the next decision. [10]

In industrial management (IM), the actual socio-economic dynamics, the aggressive competition on a global scale, more educated and demanding customers and a rapid pace of change in process technology, lead companies to frequent revision of their organizational structure, strategic objectives and decision making processes. This essentially means that companies have to show great ability in adapting to changes imposed by their own target market. Organizations need, therefore, some methods that can provide for an innovative approach to their investigations to business problems in order to identify the main cause-effect relations which characterize the environment in which they operate and find new approaches allowing for better control on production systems and more effective use of the enterprise resources. In this regard, system dynamics (SD) provides a useful interpretation of business contexts, analysing how policies and decisions affect the structure of companies and the dynamics of the available resources. [2]

Due to its ability to model and simulate the complex system for understanding the system behaviour over time horizon, SD modelling and simulation can be used for demand forecasting and decision making on order placing or production planning and control in Kanban production system to meet the customer demand in right quantity and time. It will also help in policy analysis and its effects on system behaviour. It can be further used for understanding of system behaviour in respect to unexpected circumstances such as normal response, changing no. of kanbans, a breakdown, small and large demand increase, bottlenecks and capacity planning and point out some of the managerial trade-offs involved in kanban production.

II. LITERATURE REVIEW

Table 1 includes the review of articles on system dynamics related to Industrial Management problems and kanban system.

Table 1-Review of Related Articles

Year	Author/s	Contribution
2012	Ching-Fang Leea and Chien-Ping Chung [3]	Made an extension from the study of Rau et al. (2004) and applied system dynamics simulation methodology to conduct a systematically simulation for an inventory model for deteriorating items in a supply chain. They modified the order system proposed by Rau et al., and suggested that the SD model and simulation can provide a more thorough, robust and long-term perspective solution. The simulation results showed that system dynamics simulation methodology is proper to be applied at time evolution related research subjects.
2012	Robert Maidstone [5]	Presented discussion and comparison between three different simulation methods: discrete event simulation, system dynamics and agent based simulation.
2012	Erma Suryani, Shuo-Yan Chou and Chih-Hsien Chen[9]	Developed model to forecast air cargo demand in the future to determine terminal capacity required to support long-term growth. They analysed air cargo demand in Taiwan Taoyuan International Airport (TTIA) by utilizing system dynamics model. An evaluative comparison of air cargo demand forecast is made between the system dynamics results (optimistic and pessimistic projection) and statistics results by utilizing lease squares method and Holt's model. To balance capacity and demand, it is required to forecast the future demand based on optimistic and pessimistic projections to decide when and how much, the airport should expand the capacity. They concluded that GDP Growth has a very strong effect to air cargo demand compared to other factors such as FDI, import, and transit growths.
2011	Antuela A. Tako and Stewart Robinson[4]	Explored the application of DES and SD as decision support systems (DSS) for LSCM by looking at the nature and level of issues modelled. A total of 127 journal articles are analysed to identify the frequency with which the two simulation approaches are used as modelling tools for DSS in LSCM. The results of this study inform the existing literature about the use of DES and SD as DSS tools in LSCM.
2011	Patroklos and Georgiadis, Charalampos Michaloudis[8]	Proposed a comprehensive real-time PPC system for arbitrary capacitated job-shop manufacturing. They adopt a system dynamics (SD) approach and studied the system's response, under different arrival patterns for customer orders and the existence of various types real-time events related to customer orders and machine failures. They determine the near-optimal values of control variables, which improve the shop performance in terms of average backlogged orders, work in process inventories and tardy jobs.

2010	L. Guerra, T. Murino and E. Romano[2]	Proposed a system dynamic model for single stage multi product kanban system and tested under different demand patterns. They analysed the effects of the dynamic behaviour of a Single-Stage Multi-Product Kanban system on the suitable size of its supermarket. The system consists of one production unit in which three different products are made, one supermarket and one kanban board to collect and manage work orders according to pull logic. Simulations were carried out to test the model in two scenarios characterized by different demand trends.
2010	Antuela A. Tako and Stewart Robinson[6]	Contributed towards the comparison of DES and SD. The model development process followed by experts in discrete-event simulation (DES) and system dynamics (SD) modelling is undertaken. Verbal protocol analysis (VPA) is used to study the modelling process followed by ten expert modellers (5 SD and 5 DES). Participants are asked to build simulation models based on a case study and to think aloud while modelling. Observations are made revealing some interesting differences in the way the two groups of modellers tackle the case.
2010	Erma Suryani, Shuo-Yan Chou, Rudi Hartono and Chih-Hsien Chen[10]	Establishes an approach to develop models for forecasting demand and evaluating policy scenarios related to "planned capacity expansion" for meeting optimistic and pessimistic future demand projections. They utilized cement as an example product, where it has short production cycles and is produced in big batches. The demand of this commodity varies regionally, seasonally, and secularly. The cement industry has often struggled to have the right amount of capacity in the right places and at right time.
2006	Shaojun Wang and Bhaba R. Sarker[17]	Studies a multi-stage supply chain system that operates under a JIT (just-in-time) delivery policy. For a multi-stage supply chain system, a mixed-integer nonlinear programming (MINLP) problem is formulated from the perspective of JIT delivery policy. The number of kanbans, the batch size, the number of batches and the total quantity over one period are determined optimally. It is solved optimally by branch and bound method.
2005	J. Ashayeri and L. Lemmes.[11]	Proposes a system dynamics simulation modelling framework that allows different managers to examine how improvements in their demand reliability will impact the overall corporate bottom-line. For example, supply chain managers can investigate how proposed changes in the supply chain demand forecasting structure, different suppliers, different logistics routes, or alternative inventory methods, may increase the overall profitability. The simulation model has been tested, validated with a real-life case of LG. Philips Displays Europe.
2005	Zofiia Verwater-Lukszo and Tri Susilowati Christina.[7]	Described a novel modelling approach aimed at improving complex inventory management of many product grades in a multi-product batch-wise industrial plant. The system dynamics approach is applied in a chemical multi-product plant producing a number of grades of resins with different priorities. Capturing the complexity of inventory management through an aggregate model, which can accurately simulate the effects of improvement options and take into account the production and capacity constraints helps to find a trade-off between inventory costs and customer satisfaction level.
2004	Andrea Matta, Yves Dallery and Maria Di Mascolo[16]	Deals with the problem of evaluating the performance of assembly systems managed with kanbans. They analyze kanban systems functioning with different control policies depending on how kanbans are released in assembly stages. Simultaneous and independent releases of kanbans are considered in the analysis as alternative control policies to be used in assembly systems. They used queuing network techniques to calculate the major system performance measures such as throughput of the system, percentage of satisfied orders and average level of finished products and average time delay of unsatisfied orders. They compared simultaneous and independent kanban assembly systems in some numerical cases and evaluate the differences, in terms of performance, between the two alternative kanban control policies so that the proper control policy can be selected in the design phase of the system. Simulation results are also reported to validate the approximation of the analytical method used to calculate the performance of assembly kanban systems.
1993	Sankar Sengupta, Robert P. Davis and William G. Ferrell[15]	Illustrates the usefulness of using both mathematical programming and simulation modelling to investigate the material flow characteristics of a "Just in time" system with part quality requirements. They highlight the utility of using both normative models and simulation models in the planning, design and control of production systems.
1992	Pratap K. J. Mohapatra, Purnendu Mandal and Biswajit Mahanty[13]	Presented SD model for age distribution and age based policies in manpower planning. Modelling for age and retirement becomes essential in many situations where promotion is age based and retirement takes place on attaining a particular age. They presented a step-by-step approach to modelling retirement and average age of population through system dynamics. The proposed model has been tested for plausibility under various test conditions and also discusses a few age based policies. The model behaviour with these policies is presented and discussed.
1986	Ramon O'callaghan[14]	Developed a simulation model of a kanaban based JIT production system. The formulation effort begins with the simple structure of single production stage. They developed a complete multi-stage manufacturing system by connecting few of these basic structures and adding market interface module. To test internal consistency of the model, several simulation experiments were conducted. The simulations are designed to show, the different management policies and the behaviour of the system in respect to unexpected circumstances. The considered cases are: normal response, changing no. of kanbans, a breakdown, small and large demand increase, bottlenecks and capacity planning. Finally, the results of these simulations used to point out some of the managerial trade-

offs involved in JIT production.
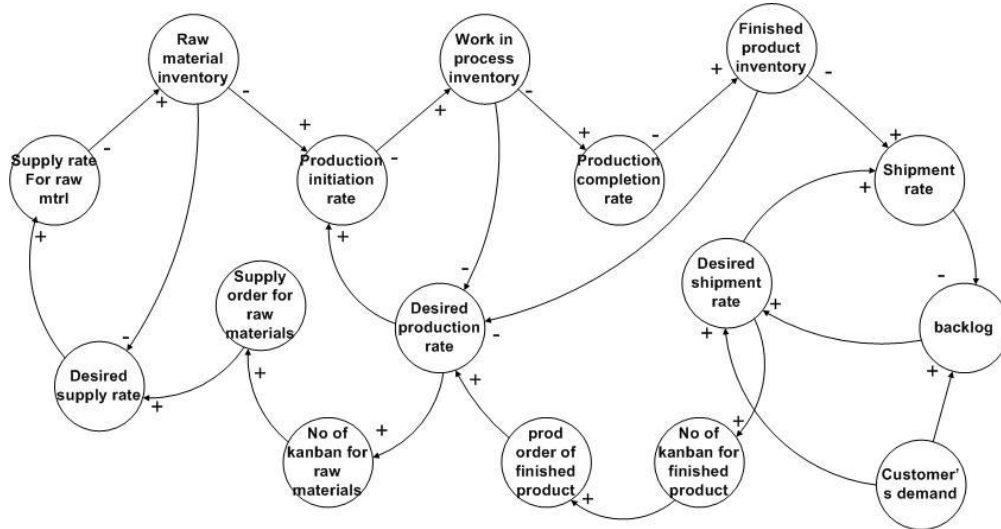
III. SD MODELLING OF KANBAN SYSTEM

Fig. 3 Causal Loop Diagram for Single Stage Single Product Kanban System

Fig. 3 shows causal loop diagram for single stage single product kanban system. It is created by connecting various stocks, flows and other parameters which affect the system structure and behaviour by arrows denoting the causal influences among them. This causal loop diagram shows cause and effect relations between all the variables. Each arrow represents a cause and effect relationship between two variables. The '+' and '−' signs represent the direction of causality. A '+' sign indicates that if the cause increases, the effect increases; whereas the '−' sign refers to the effect decreases as the cause increases. Casual loop diagram represents a closed loop of cause-effect linkages that intends to capture how system variables interrelate. However, link polarities only describe the structure of the system but not the behaviour of the variables.
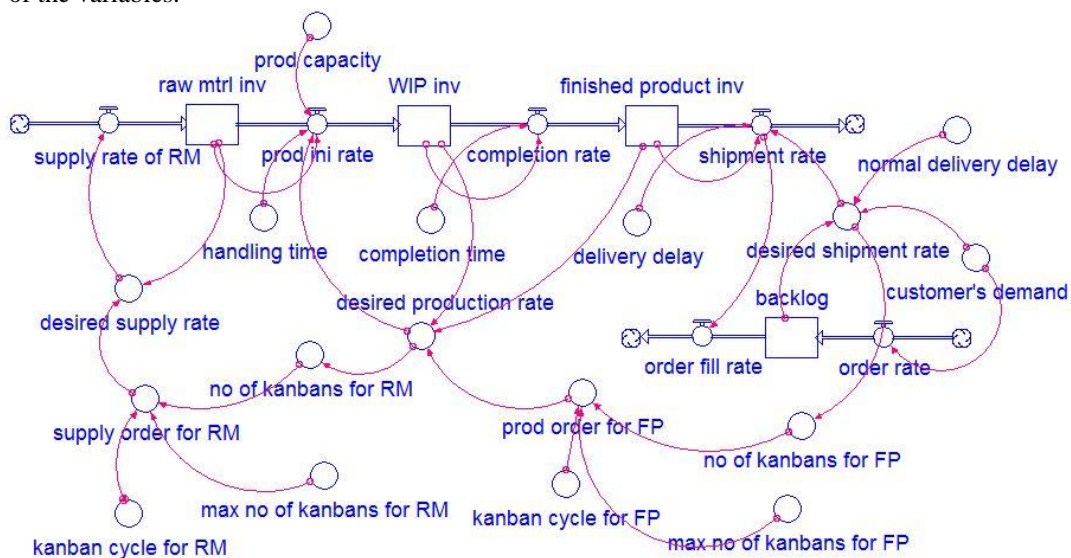

Fig.4 System Dynamic Model of Single Stage Single Product Kanban System

We have generated simple SD model for kanban system from this causal loop diagram using STELLA software. Fig. 4 shows the basic SD model for single stage single product kanban system. It is also called stock and flow diagram (SFD). Stock and flow diagram provides the storage element of the manufacturing systems that is accumulating or draining over certain amount of time. The storage element, like stock or level, is the memory of a system and is only affected by flows. The stock is an accumulation of any particular manufacturing stage. It represents the accumulated difference

between inflow and outflow rates, illustrating the results of dynamics within the system over time. Stocks are conserved quantities that can be changed only moving contents in and out.

Here, supply rate for raw material, production initiation rate, completion rate and shipment rate are the flow rates and affect various inventory levels. Desired supply rate, desired production rate and desired shipment rate are the parameters which control the supply rate, production initiation rate and shipment rate respectively. Production initiation rate, completion rate and shipment rate also depends upon inventories of raw material, work in process and finished product respectively and time delays like handling time, completion time and delivery delay respectively. Production initiation rate is further limited by production capacity of the production unit or machining centre.

Raw material inventory represents the accumulated difference between supply rate and production initiation rate during a certain handling time. Same way, work in process inventory represents the accumulated difference between production initiation rate and completion rate over a completion time and finished product inventory represents the accumulated difference between completion rate and shipment rate over a delivery delay. They illustrate the results of dynamics within the system over time. Another level is provided in the present model represents the backlog that is accumulated difference between order rate and order fill rate. Here, order rate is equals to customer's demand and order fill rate is equals to shipment rate of finished goods.

Kanbans for finished product and raw material are detached depending on desired production rate and desired supply rate. No of kanbans for finished product and raw material represents the kanban board. They define the inventory allowed in the entire system. Kanbans may be withdrawal kanban or production kanban. Max no of kanbans for finished product and raw material are the upper limits for kanban board. Here, detached kanbans from kanban boards for finished product and raw material are converted into production order of finished product and supply order of raw material respectively depending on type of kanbans at regular interval of time that is kanban cycle time for both finished product and raw materials. Kanban cycle determines how fast the system reacts to changes in production rate.

Handling time, completion time and delivery delay are time delays. Normal delivery delay is the sum of all these time delay associated with supply chain. It affects the desired shipment rate. Desired shipment rate is defined by sum of the customer's demand and backlog multiplied by normal delivery delay. The time delays make corrective actions to continue even after the state of the system reaches its goal, forcing the system to adjust too much, and triggering a new correction in the opposite direction.

The most fundamental modes of system dynamic behaviour are defined as exponential growth, goal seeking, and oscillation. Each of these modes is caused by a simple feedback structure: positive feedback loop yields exponential growth, goal seeking arises from negative feedback, and negative feedback loops with time delays give system oscillation. More complex modes such as S-shaped growth and overshoot and collapse arise from the nonlinear interaction of these fundamental feedback structures. Exponential growth arises from positive feedback. The larger the quantity, the greater its net increases, further boosting the quantity and guiding even faster growth whereas, a negative loops seek balance and equilibrium. Negative feedback loops act to bring the state of the system in line with a goal or desired state. Like goal-seeking behaviour, oscillations are also caused by negative feedback loops. The state of the system is compared to its goal, and corrective actions are taken to eliminate any discrepancies. In an oscillatory system, the state of the system constantly overshoots its goal or equilibrium state, reverses, and then undershoots, and so on. The overshooting proceeds from the presence of significant time delays in the negative loop. The time delays make corrective actions to continue even after the state of the system reaches its goal, forcing the system to adjust too much, and triggering a new correction in the opposite direction. In contrast, S-shaped growth begins with an exponential growth at first, and then it gradually slows until the state of the system reaches an equilibrium level.

IV. SIMULATION RESULTS AND DISCUSSION

The simulation process is carried out using STELLA 9.0 to understand the system behaviour over different time horizon. It enables us to change the input variables in SD model to study its effects on system behaviour so that we can optimize some critical parameters to solve problems involved in SD model and improve the system performance. We can also change the system policies for each parameter or flows for each runs so that we can get the best policies that appropriate for the present issues. Thus it can be helpful in policy analysis.

In this model production capacity, max no of kanbans and kanban cycles for both finished product and inventory are the parameters which controls the whole production system. We can optimize these parameters by changing them and simulate each time to study the effects on system behaviour and performance.

We arbitrarily choose the following system parameter values for the single stage single product kanban system model from Fig.4:

Table 2 - Parameter Values for the Single Stage Single Product Kanban System

Customer's demand	300 units
Prod capacity	330 units/day
handling time	0.3 day

completion time	0.5 day
Delivery delay	0.3 day
Kanban cycle for FP	0.3 day
Kanban cycle for RM	0.3 day
Max no of kanbans for FP	180 kanbans
Max no of kanbans for RM	180 kanbans

It is assumed that all the inventories in this model are initially being zero.

The simulation carried out in STELLA 9.0 gives the results in graphical form and tabular form with respect to time duration for which SD model has run (simulated). Following figures show the simulation results for single stage single product kanban system in graphical form.
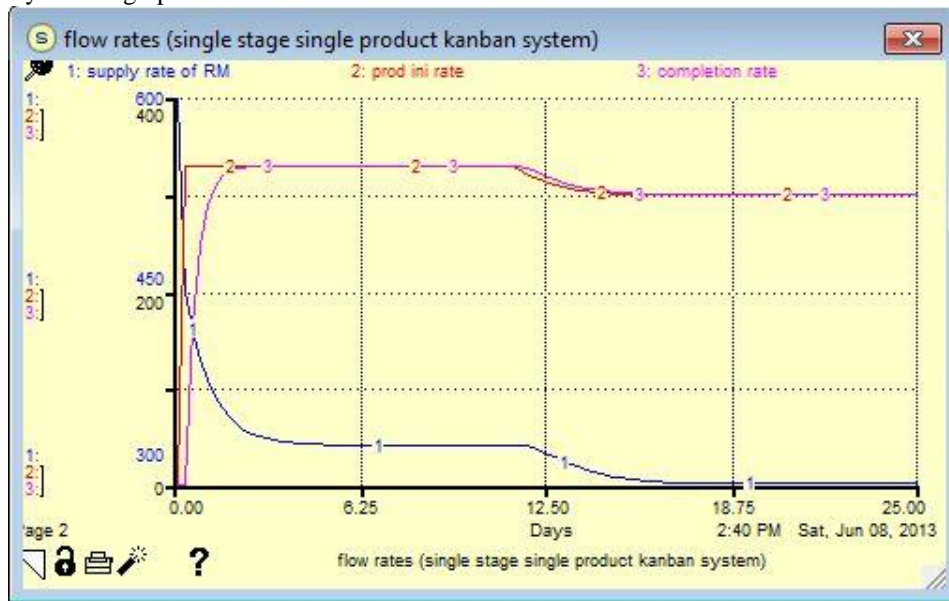

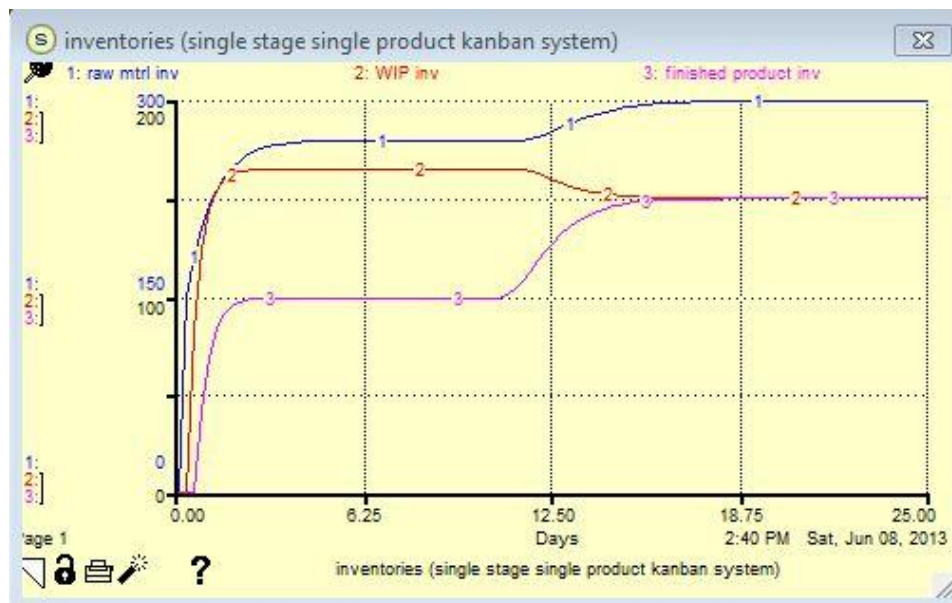Fig. 5 Flow Rates of Single Stage Single Product Kanban System

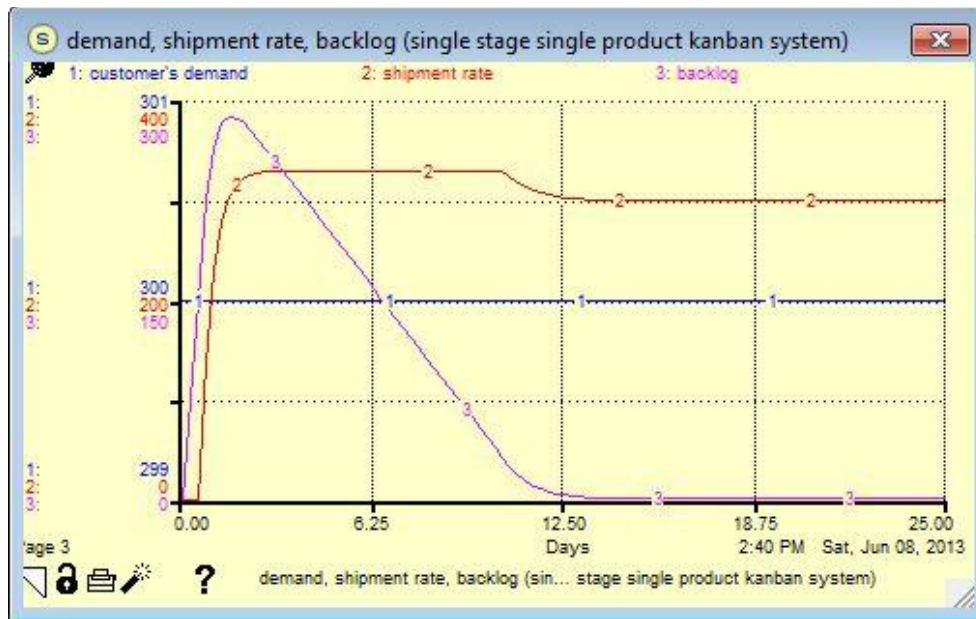Fig. 6 Inventories of Single Stage Single Product Kanban System

Fig. 7 Customer's Demand, Shipment Rate and Backlog of Single Stage Single Product Kanban System

The system dynamics model has run for 25 days. The system behaves similar to a goal seeking feedback loop structure. Fig. 5 shows the behaviour of supply rate of raw material, production initiation rate and completion rate over time. Fig, 6 shows the behaviour of raw material inventory, work in process inventory and finished product inventory over time. Similarly fig. 7 shows the behaviour of customer's demand, shipment rate and backlog over time. Here, we have chosen the short time period of kanban cycle as 0.3 day for both finished product and raw material so that the kanbans for production and supply are detached quickly to start the production. So the supply rate for raw material is initially at peak value to initiate the production. It will increase the raw material. As the raw material is available, the production starts and production initiation rate increases quickly from 0 to 330unit/day. This will increase work in process inventory that defines the incomplete product inventory which is under process Here, note that we have selected the production capacity as 330unit/day. It means production is carried out on max capacity of a production unit to compensate for the backlog. Here, backlog is increased rapidly as there is no finished product to deliver. Now, as the production completes, it will increase the finished product inventory. This will increase the shipment rate from 0 to 330unit/day. This will decrease the backlog level. Backlog remains zero after 14 day as it has compensated by producing parts at max capacity. The production is carried out at production capacity (330 unit/day) over first 10.5 days and then decreased from 330 to 300 unit/day. The completion rate and shipment rate behaves similar to the production initiation rate as shown in fig. 5 and 7.

Raw material inventory, work in process inventory and finished product inventory shows the inventory level over time. We can see that all inventories rises initially from zero for few days as the kanbans for raw material and finished product are detached. Then, it remains constant as the production continues at max capacity. As the backlog is compensated, production rate of machining centre decreases to market demand (300units/day). This increases the raw material inventory and finished product inventory to some extent and then it remains constant. Meanwhile, work in process inventories is decrease to some extent as the production is completed.

The system behaves similar to a goal seeking feedback loop structure. Here, the goal was to deliver 300 units of finished goods per day to meet the market demand. The production is achieved and controlled through kanban system.

V. CONCLUSIONS AND FUTURE WORK

SD has been applied to a wide range of problems. In industrial management (IM), it is necessary to analyse, evaluate and modify the strategy and policy issues and have to make decision frequently due to dynamic environment of the market. SD has been widely used to understand the system structure and its behaviour over different time span and to spot the difficulties within the system.SD has been successfully applied to any industrial management problems like inventory management, logistic and supply chain management, production planning and control, demand forecasting and capacity expansion, human resource management, etc.

In the present study, system dynamics is applied to analyse and simulate the dynamic behaviour of a Pull Kanban production system to understand and prediction of system behaviour and to point out the difficulties associated within the system structure or system policies.

This paper helps to understand how kanban production system works and controls the whole production process. It can be also helpful to analyse system strategies and policies.

SD model of kanban system could be simulated under different circumstances to find out difficulties in certain situations. It could be used to find out the effects of various parameters on system behaviour by changing the input parameter and for optimization of these parameters.

REFERENCES

[1]   Daniel Tesfamariam and Bengt Lindberg, Aggregate analysis of manufacturing systems using system dynamics and ANP, Computers & Industrial Engineering, Vol. 49, pp. 98–117, 2005.

[2]   L. Guerra, T. Murino and E. Romano, A System Dynamics Model for a Single-Stage Multi-Product Kanban Production System, ICAI'10 Proceedings of the 11th WSEAS international conference on Automation & information, pp. 171-176, 2010.

[3]   Ching-Fang Leea and Chien-Ping Chung, An Inventory Model for Deteriorating Items in a Supply Chain with System Dynamics Analysis, Procedia-Social and Behavioral Sciences, Vol. 40, pp. 41 – 51, 2012.

[4]   Antuela A. Tako and Stewart Robinson, The application of discrete event simulation and system dynamics in the logistics and supply chain context, Decision Support Systems, Vol. 52,pp. 802–815, 2012.

[5]   Robert Maidstone, Discrete Event Simulation, System Dynamics and Agent Based Simulation: Discussion and Comparison.

[6]   Antuela A. Tako and Stewart Robinson, Model development in discrete-event simulation and system dynamics: An empirical study of expert modellers, European Journal of Operational Research, Vol. 207, pp.784–794, 2010.

[7]   Zofia Verwater-Lukszo and Tri Susilowati Christina, System-Dynamics modelling to improve complex inventory management in a batch-wise plant, European Symposium on Computer Aided Process Engineering, Vol.15, 2005.

[8]   Patroklos Georgiadis and Charalampos Michaloudis, Real-time production planning and control system for job-shop manufacturing: A system dynamics analysis, European Journal of Operational Research, Vol.216,pp.94–104, 2012.

[9]   Erma Suryani, Shuo-Yan Chou and Chih-Hsien Chen, Dynamic simulation model of air cargo demand forecast and terminal capacity planning, Simulation Modelling Practice and Theory,Vol.28, pp. 27–41, 2012.

[10] Erma Suryani, Shuo-Yan Chou and Chih-Hsien Chen, Demand scenario analysis and planned capacity expansion: A system dynamics framework, Simulation Modelling Practice and Theory, Vol.18, pp.732–751, 2010.

[11] J. Ashayeri and L. Lemmes, Economic value added of supply chain demand planning: A system dynamics simulation, Robotics and Computer-Integrated Manufacturing, Vol.22, pp.550–556, 2006.

[12] Izidean Aburawi and Khalid Hafeez, Managing dynamics of human resource and knowledge management in organizations through system dynamics modelling

[13] Pratap K. J. Mohapatra, Purnendu Mandal and Biswajit Mahanty, Dynamic modelling for age distribution and agebased policies in manpower planning, Appl. Math. Modelling, Vol. 16, 1992.

[14] Ramon O'callaghan, A System dynamic perspective on JIT-KANBAN, the international conference of the system dynamics society. Sevilla, October, 1986.

[15] Sankar Sengupta, Robert P. Davis and William G. Farrel, Production Planning and control in a JIT environment, Appl. Math. Modelling, Vol. 17, 1993.

[16] Andrea Matta, Yves Dallery and Maria Di Mascolo, Production, Manufacturing and Logistics Analysis of assembly systems controlled with kanbans, European Journal of Operational Research, Vol.166, pp. 310–336, 2005.

[17] Shaojun Wang and Bhaba R. Sarker, Production, Manufacturing and Logistics Optimal models for a multi-stage supply chain system controlled by kanban under just-in-time philosophy, European Journal of Operational Research, Vol.172, pp.179–200, 2006.