# Simulation and Application to Measure Comparable Performance of Push,Pull and Hybrid Manufacturing Systems

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## Abstract

In this paper we are going to integrate the most popular production systems nowadays that is; push ,pull production system, ,then we compare the performance of the integrated production model or the hybrid outcome system to push and pull, by introduce a technique that optimizes production control of single product flow shop under the three production control through using the production control framework. Evaluating a production control policy usually requires simulation modelling due to the complex interaction that occur,a point was considered by simulation package exploit. Then we demonstrate how this template can be used in conjuction with this existing simulation software to find an optimal production control policy. Our decision variables are location of the push-pull interface. An experemental research prototype of such push, pull and hybrid control system has been constructed to emulate a motor production at real world plant in which unit process and operational decisions are integrated. The simulation software implemented to support the manufacturing system planning and its operational control.the system configuration, modelling feature and its verification modelling, feature and its verification through an application of the practical manufacturing line will be described.


**Keywords:** push ,pull ,hybrid systems,kanban,discrete event simulation

## محاكاة قياس اداء أ نظمة الدفع والسحب والنظام الهجين, التصنيعية


**الخلاصة**

نسعى في هذا البحث الى تحقيق تكامل نظامي التصنيع الاكثر شيوعا في الاونة الاخيرة, وهما نظاما السحب و الدفع. يهدف البحث لأجراء مقارنة اداء النظام الهجين الناتج مع اداء كلا النظامين المكونين له آنفة الذكروذلك بعرض تقنية لأنسياب المنتج داخل المصنع أثناءالبدئ بالانتاج وفق قواعد التصنيع بالانظمة الثلاثة. أن ادراك النشاطات الواقعه عادة ما تتطلب اجراء تركيب نموذج محاكاه لها, أذ يحدث ان تتصرف هذه الانظمة بصيغ متداخلة و مكتظة.لذلك بنيت الانظمة باستخدام منظومة محاكاة مدمجة وجاهزه لهذا الغرض. يتيح أستخدام أنموذج المحاكاة ايجاد افضل منهجية سيطرة ممكنة للانتاج بفضل أستخدام معيار أعلى تحميل ناشئ على وسائل الانتاج أو ما يدعى بعنق الزجاجة. أجريت هيكلة منظومة انتاج حقيقية لتوافق مصنع لانتاج محرك صغير في الشركة العامة للصناعات الكهربائية. اثناء اشتغاله بسلوك نمط الانظمة في موضوع بحثنا. ثم أجريت عملية محاكاه المعدات حسب ازمنة التشغيل الفعلية في الشركة وقد تسنى لناتقييم عدة محددات مشتركة في هذه الانظمة ولتبرز تفوق اداء النظام الهجين.


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## 1. Introduction

For today's manufacturing systems, the Material Requirements Planning (MRP) technique which is involved in the push production systems and the just-in-time (JIT) technique which is involved in pull systems using the Kanban technique are the two major production control systems. Each of them results in different system performances, especially in both production and inventory control. The push systems using the MRP technique are simply schedule-based systems starting from forecasting and can be implemented using a master production schedule. The resulting system performance can be easily identified as increasing the throughput and enhancing machine utilization. This is simply because a system using the master production schedule, which is based upon forecasts, tends to send parts and materials to a plant regardless of what is required for next operation. On the other hand, pull systems using the Kanban technique manufacture or replenish parts only after being requested by the succeeding operations or machines. This indicates that machines only produce the goods that the customer required and so the systems will produce a low work in process WIP. Although we can achieve improved system performance either by maximizing utilization and throughput or minimizing the WIP inventory by selecting either push or pull systems, the disadvantages, which are produced by those two production paradigms, cannot be neglected. Selecting a push system may increase WIP, create capacity, and flow disorder. Choosing a pull paradigm, the system performance may result in low facility use. Therefore, trying to integrate both push and pull production paradigms for modeling a new production paradigm is the major concern of this paper.

## 2. Hybrid approaches (literature review)

In this section we review representative techniques available in the literature during the last couple decades. The advantages and disadvantages of push system such as (MRP) and pull system such as kanban controlled (JIT) have been well documented in the literature , see for example Krajewski [19], Hopp& Spearman[14] Davis [8] and Ronald.G.Askin[2]. production control strategies that combine push and pull are commonly termed hybrid or hybrid push/pull control **.**

**Karmarker (1991)** proposes that an unlimited number of control methods can be developed in this way and goes on to identify three such systems that combine MRP with other technique. **1-** JIT-MRP: this is a modification of existing MRP II system that adds pull elements while eliminating problems that are associated to the systems lack of responsiveness. **2-** Tandem push-pull:These are characteristic of repetitive batch environments where lead times are stable. **3-** Requirement driven-kanban:Iin this setting, individual cells within a manufacturing chain are run using kanban control while MRP runs the remaining processes. One approach to the issue he suggested, of designing hybrid push-pull systems can be framed as trying to maintain the incentives present in Kanban systems, while adding some information about future demand and parameter variations, he also demonstrate a typical application of this concept would be in a firm that procures raw material and components form a geographically diverse supplier base, fabricates some parts, and assembles one or more final products. Such a firm might use a push approach for purchase orders from distant suppliers particularly in categories (such as castings) where lead times are long. [17].

**Hopp and Spearman( 1991)** describe the push, pull interface as the point in the manufacturing system at which upstream pull production control meets downstream push control (this point is located at the exit of input buffer within the interface workstation) production is matched to demand at the push, pull interface provide a survey of these studies in the context of manufacturing cells they approximated the throughput of a flow-shop (sequence of tandem queues) under hybrid control. They assumed that processing times are deterministic but service can be interrupted by machine failures that are exponentially distributed in duration. Example – in IBM Company to Panel Plant for semi-conductor manufacturing [14].

**Beamon and Bermudo (2000)** have developed a hybrid push/pull production control algorithmis developed and tested for use in a multi-stage, multi-line, assembly-type repetitive manufacturing environment. The algorithm is primarily based on a JIT approach but uses dependent demand aspects of manufacturing resource planning (MRPII) to manage the intermediate inventories. The experimental results indicated that the hybrid system at 95% confidence level outperforms the pure pull system in term of lead-time and outperforms the pure push system in term of WIP . In order to study the effectiveness of the hybrid algorithm, a simulation study was performed using SIMAN/ARENA [3].

**Ho, and Chang (2001)** developed a production planning and scheduling framework to address the multi-stage production-inventory, system problem by integrating (MRP) and (JIT) production. The objective is to find detailed shop-floor schedules, which specify the quantity of an operation to be processed, at what time, and by which machine, so as to minimize total cost.The proposed integrated system gets rid of the major problems existing in (MRP) and (JIT) This work developed a heuristic production activity control model to schedule and control wafer manufacturing in a hybrid wafer production environment (MTO and MTS). a virtual wafer fabrication shop was designed with the SIMPLE C++. The data were obtained from a Taiwan semi-conductor manufacturing plant, and four different products were created [13].

**Kailani and Cochran (2002)** have investigated the possibility of applying hybrid push/pull production control strategies in an aerospace transmission overhaul shop at the Boeing facility in Mesa; The shop currently uses MRP/push system. A simulation model of a horizontally integrated hybrid system which is half push and half pull representing the shop processes is developed and used to evaluate systems performance,. The proposed method employs genetic algorithm driving the parameterized stimulation model [18].

**Sara Hewitt (2002)** compares a created analytical hybrid push, pull system with discrete -event hybrid simulation model, highlightened similarities and the differences modeling a flow shop with process drift was an iterative process of first aligning the underlying assumptions of the model and the system, and then isolating the variability inherent to the simulation.. She constructs a simulation model of push and pull production control system by ARENA software. simulation model of the push and the hybrid production control agreed with their analytical models while the pull production control model does not[12].

**Ramachandran *et al.* (2002)** have presented three criteria, the customization point, the bottleneck operation and the ABC analysis as a method to determine the push-pull boundary in a hybrid system. Any one of these three criteria that is more applicable to the manufacturers convenience can be implemented for efficient operation of the factory. They develope and extend the methodology that determines stages in a production system that should work in pull and those should work in a push environment. This methodology was conducted first by [Ölhager and ostland]. The objective of such mixed system; is to get the required part to the appropriate place at the right time as they concluded. This system combines planning and scheduling strategies into one single structure[28].

**H.H.Huang (2002)** aims at finding a production model for manufacturers to apply in continuously, and unanticipated changing competitive environments. He integrates push and pull production models and applies the new method to an agile manufacturing environment. The integrated production model is possible made by introducing the concept of the theory of constraint (TOC) and optimized production technology (OPT). He was able to manipulate constraint resources in a production line by employing both the push and pull concepts he uses the ProModel simulator and obtain the results from the simulation applied to multi-product factory. Then he concludes that the push–pull integrated model has the best performances among the three models [15].

**Chang *et.al* (2003)** have developed a heuristic production activity control model ,to schedule and control wafer manufacturing in a hybrid wafer production (semi-conductors industries) environment manufacturing push and pull. They consider cycle time and due date reduction for pull orders.The proposed model develops a method of releasing the orders ,so as to fill up the remaining capacity (after the pull planning ) without distributing the released orders, they argued that the proposed model outperformes the other models [6].

**Suri and A. Krishnamurthy ( 2003 )** discuss the planning and implementation of POLCA, (Paired-cell Overlapping Loops of Cards with Authorization) a hybrid push pull material control system suited for manufacturing environments with high-variety and/or customized products they briefly describe the operation of the POLCA system and discuses how its features enable it to overcome the drawbacks of conventional push/MRP and pull/Kanban systems in such environments. Next, they present a detailed procedure for implementing POLCA in a factory. Finally, through case studies they describe how this procedure was applied to implement POLCA at several facilities. Results from these implementations indicate that POLCA has helped these facilities significantly improve the effectiveness of their operations [30].

**Heng cao and Smith( 2003)** have developed an RL (Reinforcement Learning) based approach to solving a capacity constraint multi-period production planning problem in the fabrication/fulfillment manufacturing process. The near-optimal build plan for each planning period is learned by the RL learner through trial and error interaction with a Monte Carlo supply chain simulator. Through this simulation based approach, real-world situations such as multiechelon BOM structure and manufacturing lead-time randomness was effectively addressed. To efficiently search in the very large state and action spaces, they designed a two phase learning scheme, where the first phase learns the near optimal usage ratios of the capacity, based on which a detailed build plan is derived in the second phase. Preliminary numerical results have confirmed the validity of theme approach, when they test the methodology with real-word model and data. To improve learning efficiency, the simulation results from the first phase should be incorporated to initialize the second-phase table. [5].

**Karlsson (2003)** has developed a high performance manufacturing system. The focus of the research is not only to provide means for accomplishing manufacturing that can handle changes but also to accomplish flexibility in another area. The developed strategy was called assembly- initiated production method. An implementation of the strategy should provide high manufacturing system flexibility but at the same time contribute to the principle of (JIT) in lowering of inventory levels and lead times., mainly the implementation of MRP scheduling in a JIT environment. The suggested solution could provide the functions and properties of the prevailing methods this solution is more decentralized control concept within the company with amore modular approach where each sub control system covers only apart of the production system.The objective of his research is to provide means for accomplishing and upholding high manufacturing system performance, aiding in the task of reaching individual company-specific performance goals. His application focused mainly, on Swedish automobiles manufacturing [16].

**Abdullah (2003)** identified the hybrid system in his application through unit transition from non discrete to the discrete condition, at some point during the manufacturing process in the push pull boundary, that is decoupling point . He adress the application of lean manufacturing concept to the continuous production/process sector with a focous on the steel industriy inside USA[1] .

**Goncalves,P (2003)** investigates how a semiconductor manufacturers hybrid push-pull production system, responds to customer demands, when inventory availability influences demand. He analyzed a model that gives insights into the costs of lean inventory strategies in the context of hybrid production system.his work contributes to the literature by introducing a novel method of analysis. The research relies not only on simulation, the traditional approach to investigate the behavior of systems of nonlinear ordinary, but also on Eigen value elasticity theory to analyze the model and derive the main insights for microprocessor fabrication at Intel Company [11].

**Teeravaraprug,j *et* al. (2004)** apply the concept of hybrid push and pull systems to a repetitive manufacturing process. Moreover, they have also enhanced the concepts by combining those systems into a "mixed push-pull" system. In attempt to give a comparative study of push, pull systems in terms of work-in-process and production lead-time, they have demonstrate first them application by using ideal systems with bottleneck consideration, and then they studied the integration of ideal system and bottleneck in the view of production inventory system. Results and analyses are based on the simulation method through a simulation program called ARENA [31] .

**Gahagan and Herman (2005)** introduce a technique that optimizes production control of single product flow shops under hybrid production control by using the Production Control Framework. This simulation modeling template is designed to explore the production control domain. They demonstrate how this template can be used in conjunction with existing simulation optimization software to find an optimal production control policy. The decision variables are location of the push-pull interface and the number of kanbans at each workstation. The objectives include improving customer service and reducing work-in-process inventory. The example system of different hybrid production policies on the performance of a four-stage, single product flow line, was modeled using a template developed in ARENA [9].

**Bo Li, *et.al* (2005 )** provide an integration to MRPII and JIT using the basic resource of the BOM after analyzing the characteristics of the automobile assembling enterprise in china. Then the key business process after reengineered is showed, and the logistics management information system of modern enterprise with the BOM is built for optimizing the logistics management of the enterprise. Lastly the detailed realization process of this system is provided. They came to a conclusion that It is important to actualize the logistics management information system, hence it can connect the "original information isolated island" and make the information integrated synchronously. Therefore, the information is more precise and real-time than before and the responsible speed of supply chain is also increased. [4].

**Cheng,F *et al*. (2006)** introduce a general-purpose simulation mechanism that integrates construction simulation software CYCLONE with GA to find the best resource combination for the construction operation. They also provides a decision support for supply chain operations in hybrid push-pull system with multiple Products and complex bills-of-materials. They formulate **first** a multiple-period production-inventory optimization problem with service level constraints defined at the product level for each period; the optimization problem is applicable to large class of hybrid push-pull manufacturing strategy. **Second**; they present two variants of the problem that both have distinct advantages of the common practice. **Third**; they exploit the structure of the problem formulation to develop numerical algorithm. Finally; they demonstrate the efficacy of the approach by numerical experiment with realistic production data. They study the actual hybrid push-pull manufacturing system that the IBM Systems Group implemented as a response to a complex configuration environment [7].

**3. Mapping manufacturing methods to production control phlosophies**

To map the push and lean (pull) manufacturing philosophies to manufacturing methods, the philosophies can be mapped to four key manufacturing methods:make-to-stock (MTS), assemble-to-order (ATO), make-to-order (MTO),and enginner-to-order (ETO) as in figure[1].All of these methods have value,dpending on the needs of the bussiness environment and the need for supply chain networks to keep up with the variability introduced as a result of proliferation of products, customers,and channels. Producers almost always have to addopt a hybrid mix of these manufacturing processes. The push manufacturing philosophy, which focuses on maximizing capacity, is most suited to an environment with predictable demand. It meets the need of a traditional supply chain operation and a master production schedule. Thus it works best in an environment where production complexity as well as demand variability low. In an MTS manufacturing strategy, the supply side process is completely forcast-based and stretches from the acquistion of raw materials to the deployment of finished goods inventories into the channel. The delivery process involves taking an order and delivering it to the customer.The lean manufacturing philosophy also work best in an environment with stable demand,and low product variability but it has a far grater pull focous. Typical lean manufacturing environment are amix of push and pull, with the pull point being further upstream than it is in push manufacturing. Therefore the ATO process is a good fit here-in addition to the MTS process. In lean manufacturing the supply side of the process is focused on staging of raw materials or build-to-stock (BTS) semi-finished assemlies throughout the supply network,while the delivery sides includes taking an order, doing final assembly, and delivering the product to the customer. Figure [1] maps manufacturing processes to push and pull supply chain, the push part is primarly forecast driven whereas pull part is demand driven.

## 4. Push system

Actually, the push method is a demand-estimated-based system [26].this system work well in enviroments where there is high customer demand and quick product turnaround times. Order for component parts are timed to coincide with the production schedule of the products in which they are used. A knowledge of each part and subassembly are combined where to appear in final products with the planned production of those final products, and then attempt centralized control for coordinated production of all items. Orders are pushed into work centers to coordinated the flow of related parts so that all parts come together in time and place as detailed by the product design,, as a result. If every think goes according to plan, no need to carry any unnecessary safety stock or carry any cycle inventories during period of low demand for apart. This approach to coordinated scheduling for dependent-demand items is known as materials requirements planning (MRP) or push system [2]. Figure [2] represent block diagram for a push system,that represent “plan-driven”philisophy [28].

**5. Pull system**

In recent decades, the remarkable success stories of Japanese concept to production planning and control systems introduced a new paradigm for production research literature[22]. The so-called just in time (JIT) system organizes the production such that materials arrive just as they are needed in relatively small batches through an attached, well-known card called 'kanban' (signal card) which identified standard quantities of transfer batch or size of a container. JIT has been widely accepted and gained remarkable attention among researchers as well as practioners [24]. Kanban production control systems are an elegant demonstration of the value of simplicity [2]. JIT uses a pull method of production coordination. In a pull system, production is initiated only to replenish what have been actually used at the next stage of the production system, as represented in figure [3], that represent "process-driven"philosophy[28].

Kanban Functions as a pull system in that, as a material are used in a downstream stage of the production system, replenishment orders for component materials are relayed to the upstream stages in a progressive cascade upwards [27]. Because actual usage of materials downstream is the only trigger for making more of same thing upstream. Production initiated only when needed and automatically stopped when demand ceases [29]. In kanban system communication (exchange information) occurs by a successor workstation that issues the request for parts to the output buffer of a predecessor work center reacts to replace the removed parts and to maintain a balanced, target level of finished parts. Coordination between the production levels occurs automatically by each work center as it strives to maintain a fixed output buffer, and the system can be modeledas closed queuing networks [2] .

## 6. Hybrid push/pull system

A hybrid push-pull production system combines a push system at the upstream stage and a pull system at the downstream stages [12] or pull system at the upstream and push system at the down stream [10,15].

Material control schemes can be classified as push, pull or hybrid strategies [21]. Several hybrid strategies such as CONWIP and POLCA have been proposed[7]. A hybrid push-pull strategy that combine the best features of pull (kanban) and push (MRP)systems while avoiding their drawbacks [30].

The manufacturer's hybrid push-pull production system is very effective in meeting customer demand. A hybrid production control policy is one in which there are multiple workstations some operating with push policy and some operating with a pull policy [9]. Figure [4] below represents a hybrid system representation.Once an order is received it is pushed through the shop, it is required to setup the system such that no late delivery with a minimum inventory. To achieve this goal the shop is modeled as integrated hybrid production system consisting of (m) stages. Parts use pure push control followed by pure pull control with semi-finished products stored at the transition, which is called the junction point [18]. By separating the concepts of push and pull from their specific implementations, it is observed that most real-word systems are actually mixtures or hybrids of push and pull [23]. The better performance of the pure push strategy suggest that specific hybrid (push/pull)strategies might be required to control production on such lines [20]. Hybrid systems such as the push-pull system, gives better control under certain conditions [25]. The developed hybrid system that combines MRP at the plant -wide level with kanban at the local cell level. This system allows the cell to be able to react to changing demand by making use of advance information about the demand. Simultaneously, the reactive abilities and incentive structure of the kanban/pull system are incorporated.

## 7. Proposed Methodology

**The main methodology phases as shown in figure[5] are the following:-**

1- **Initializing** adopt a structured approach as a plan that conform a holistic methodology with supporting tools which will allow to deal with all aspects of a discrete event simulation, the interrelationships and the difficult process of planning and managing change.

2- The **function** aimed to suggest a methodological framework for integration discrete event simulation into manufacturing system development.

3- The **methodology requirements** should be generic that is applicable across a wide range of manufacturing enterprises also should be holistic system from all its perspective through a structured action, easy to understand and use.

4- **Process and simulation awareness**
Understand the process and the requirements and constraints it puts on simulation (knowing that "understanding the process" has several implications, including a thorough knowledge of the system, its performance measures, and so on). understand the process and the requirements thoroughly; what are the constraints and its performance measure.

5- Determine the **performance measure** that is relevant to the simulation activities.

6- **Simulation integration** putting together heterogeneous components to form a synergistic whole, the aim is putting together all relevant components of discrete simulation with those of the manufacturing system development process.

7- Formulate a **simulation strategy:** simulation strategy including a desired level of integration based on process and simulation knowledge and higher-level strategic objectives, i.e. those emanating from manufacturing, business and corporate strategies.

8- **Identification** :Identify the construct of the strategy, the data, the operation, and the enablers tools that are relevant to the operation and a theoretical description of how these component are fit together.

9- **Mapping** to reference architecture, with respect to real word condition and, strategic objectives.

10- **Benefit analysis**; analyze simulation benefit.

11- **Software evolution**: apply further upgrade improvement.

12- **Definition**: define an action plan for adoption and simulation integration through well-documented guidelines for all constraints.

13- **Plan excution or implementation**: execute the proposed plan.

## 8. Conceptual model

The assumed model is a discrete job-shop with a different servers arranged in U-shape layout. Each server applies certain operation on a particular part with a certain processing time. Jobs have different routings on each machine where the final operations take place at the last machine. Finished product implies job with existing demand while raw materials is for job without routing the facilities are arranged in series compatible to the job treatment machining operation Figure (5). The three different control systems will be applied mainly, based on this model layout i.e.; the model will undergo push, pull then hybrid system application in the intended simulation.

## 9 . Performance measures

To make fair comparison, models must set to be conducted in the same environment, and with the same values of input factors. Experiment with (10) replication with length of (1) day long of an (8) working hours, without a warm-up period. Intended Simulation was employed to examine the time consuming non-value added that yield a recognizable insights in the study, which includes throughput, work in process, utilization percentage, buffer waiting time, queue length, throughput time, idle time and cycle time. Performance measure allocated summarized in table (1). Model output provides performance measures of patch system. For the purpose of performance evaluation between push, pull, and integrated model, the performance measures are estimated in the studied model.

## 10. Methodology implimintation

A methodology is a set of instructions provided through methods, models, tools, and guidelines that are to be used in structured way. In this case, methodological bases can be described as a set of multiple steps as shown in figure [7]. The objective of the methodology is to help manage adoption and integration of (operation) into three manufacturing system development at State Company For Electrical Industries (SCFEI),to the product shown in figure[6].embeeding, the data in table [2].

**10.1 Model steps conceptualization**

1- **Problem formulation and setting of objectives Initialization** assumes general problem identification and to rely on simulation as the preferred technique.

2- **Model conceptualization** denotes both conceptual model and communicative model.

3- **Input data, collection:** this phase include all the data identification, generation, collect, transform and parameter choose.

4- **Model translation**: that phase means translating the model from its conceptual form to one that can be understood by a computer. It is a conceptual model adaptation to a model that is described by the programming language used by the simulation software application directly.

5- **Preliminary experimental model:** this step means running the simulation program or model according to the parameters set in an experimental phase. The way the model behaves during experimentation may lead to a redefinition of the model.

6- **Model verification**: it compares the computer-translated model to the conceptual model it affirms that the model was constructed in the right manner.

7- **Model validation**: it determines that the model built is a correct model of reality it confirms that the constructed model is the right destination.

8- **Experimentation**: this step means running the simulation program according to selective parameters.

9- **Output data analysis**: the result obtained will determine whether more experimentation is required.

10- **Documentation**: every simulation project must be continuously documented, throughout all steps.

11- **Implementation and exclusion**: the last step is the implementation or the results obtained. The success depend on how will the previous phases have been performed. Exclusion highlights need for the researcher involve in the simulation study to perform his perceived intention according to experiences made during the implementation phase .

**10.2 Monte Carlo simulation**

A common requirement for such activities is to set a random processing or delay time; this is accomplished by the simulation package. Adding randomness to a deterministic model changes it to a *stochastic* or *Monte Carlo* model.

To perform Monte Carlo simulation,by embeeding "EXTEND" simulation package select distribution required, normal and specifies the value of the parameter, such as a mean of (2) unit and a standard deviation of (0.2),see figure [8],[9]. The processing time will then be normally distributed and the machine block will process each item for approximately (2) item unit. Process times at each workstation may depend on product type**.**By assigining (10)buffer items as bottleneck inventory The random numbers is employed in a first step to synchronize usage of random number in all the systems, so that the systems are compared under similar conditions each system experience the same sequence of arrivals and stick to the same job processing times at each workstation.,

Figures [10 ,11and ,12] shows push, pull and hybrid control system respectly represented in "EXTEND.

**10.3 Bottleneck allocation**

A hybrid system is considered in relation to the bottleneck resources. The bottleneck stage is the stage having a higher cycle time than the others in our case it is the stator station fabrication. The early stages, the stage between the first stage and bottleneck stages, may result in a number of work-in- process inventories, hence a push system is applied to control work-in- process of these stages. The latter stages, the stages between the bottleneck stage and the last stage, can be controlled by a pull system since the system is controlled by the bottleneck stage. The effects of system are studied by addressing bottleneck position. In a push system demand is sent to the raw materials stage and the processed forwardly to other stages while in pull system, demand is sent to the last production stage. In a mixed push pull system order or demand is sent to the bottleneck stage.

## 11. Hybrid system performance

In a hybrid system if the demand can be satisfied the production is process forwardly till the last process. If not the stage will order and withdraw parts from the buffer storage of the preceding stage and so on. Integration of the existing manufacturing push, pull technique methods is the cure for alleviating the problems due to the complexity and variation in the system. A typical horizontally integrated hybrid production system consisting of M stage. Parts use pure push control followed by pure pull control with semi finished product store at the transition, which is the linkage junction point where it's the last push station and marks the transition from the push to the pull subsystems.

**Table [3] Models performance comparision results**

## 12. Design assumptions

The following present the detailed assumption made at the design stage of the model and the limitation imposed because of this assumption.

**1**-The system produces a single product.**2-** The hypothetical system under study suits to a repetitive manufacturing environment. Product is standardized, high volumes with little variability in mix of product provided.**3-**Models are designed to produce products on predetermined operation. **4-** Processed part are keep in the buffer store, and part movement depend on control mechanism each buffer is addressed specific machine.**5-**The first stations of all fabrication lines are fed by raw parts which are assumed to be infinite (never starved).**6-** Machine capacity is assumed unlimited to meet demand of product. **7-**Machine breakdown are not including in the model and operating time is assumed continuous operation.**8-** Processing time, consisting of the machine down time only, the transportation time record between the machines is very small and can be overlooked more over there is no setup time at each machine.**9-**Based on the production routine, the different standard time for each product has to be established as a basis for comparison calculation. **10-** Part authorized for loading follow a first come first serve (FIFO) dispatching policy at all station container size (bin) is assumed to be one for all individual parts, in the JIT system; load size of one is applied for operation at all work centers. And finally; There is an unlimited demand at the end of the production line in the final stage.

## 13. Discussion

The proposed mix system is an organized methodology aims in the first step to combine the complementary set of strength found in both systems. The proposed system result (refer to table 3) in a better performance if compared to pure push system in terms of building-up of WIP that is (28) item, although it is more than the (5) items yielded fromout pure pull system implementation , which is incomparable factor due to the pull system strength. This rule include another parameters such as the part waiting time , where the integrated system extend for 3000 second whereas it was (4600) second in pure push system , moreover ,the integrated waiting time behaves in constant level in the first quarter , while it keeps raising slightly along the working shift in the push model. Consequently, the queue length it expands to (25) items, while it was( 36) in the push system . Cycle time and throughput time as a comparable factors extend fairly reasonable as (5100) and (2135) second for the integrated system, while it was (7620) and (395) second respectively in the pure push system. Again pull system cycle time and throughput time is incomparable due to kanban. Kanban keep its amount constant along the experiment by (1110) and (1116) second, respectively , it was represented as a steady horizontal line in the graph sketching. Moreover the hybrid system performed very well in terms of total output ,the observer may count (135) item against (120) and slightly more than this value in the other pure models. Finally at the work shop level a (99%),is extremely highest utilization ,in the system performance ,it is an ultimate value that outperformed the other push and pull models which in turns leads to the lowest idle time level in such integrated models. Less WIP, ultimate highest utilization, best outcome production, the shortest queue length for the WIP in buffer and consequently, least waiting time. All above conclusions were precisely reached through employing an advanced simulation package.

Many significant experiments were performed in order to attain accurate dependable results. Finally, the researcher find it is crucial to such systems be chased (persuit) precisely, among execution through exploring possibility of using a chase demand strategy, which prevents from unnecessary stock building. Short periods are also preferred, as this result in less nervous plans.

## 14. Conclusions

The main conclusions that can be drawn from the research are:

**1.** The proposed methodology of integrating push-pull systems outperforms both; pure push, and pure pull system applications according to a stabilizing combination of performance measures.

**2.** The proposed integrated system lends adequate flexibility due to pull sector impedance, usually because a pull system contributes agility and adaptability. Furthermore, the push sector is also flexible in terms of products and floor layout.

**3.** Fundamental reason for the hybrid policy to outperform other production control systems is that it considers the original dynamics of the whole system at every event is completion rather than selecting few.

**4.** Comparing system optimality in SCFEI as a multi complicated process industry plant, with three input scheduling rules and five bottleneck-scheduling rules, the suggested system shows the following quantifications; when compared to the current state:

**a-** Production level, elevation by (11.5%).

**b-** WIP amount reduction, by (37.7%).

**c-** Increase in machines utilization percentage by (2%), and consequently achieving (6.6%) reduction in the Idle time.

**5.** For evaluating system flexibility by marginal overtime, the system responds actively to additionally increasing its output by further (16.5%) over the current case.

These models have some inherent variability due to random nature of the simulation. These errors wile not always avoidable but it can be often examined and neutralized, such the erroneous assumption for the intermediate inventory or the whole make span time of (8) hours. The accuracy trade-off between the real time model and discrete event simulation model where proven slightly and start to shown up eventually when the push model yield round accurate results.

***PS:*** *When we address SCFEI,our intention was not performing a comparable evaluation to the current state map, versus our suggested method, in as much to only get benifts of the processing data,when imbeded to the push ,pull or hybrid control system,and then potentially comparing these control systems together by simulation.*

### 14.1. Future Research

The study has some restrictions, and some recommendations for further research to refine and extend the capacities of methodology and reality are as follows:

**1.** Many factors such as machine breakdown, load policies, contrasts of machine capacity, material-handling equipment etc. should be included to study their effects and to make simulation more realistic.

**2.** The system was assumed a First in First Serve (FIFO) rule in scheduling policy, and lot size of one unit for all stages in load policy. Future study should analyze changes in these policies that will affect the performance measures.

**3.** The study did not consider the system for multiple products within a planning horizon.

The integrated models can be extended to handle changes in product mix and volume.
**4.** A recommendation to use MRP for planning, and JIT for the execution in order to achieve an efficient, intrinsic objective, manufacturing system.

### *Appendix*

**The following equations can be used in performing only the analytical calculations, just to support software inclusion:**

**1-** Throughput rate ,(TH)this is measured by the average number of products produced per unit time during the time period [42].

$$TH = \sum_{i=1}^{T} Pi / T$$

Where, *Pi* is the number of products produced in time *i*, and *T* is the time period.

**2-** Total average **WIP**. This is measured by the average number of parts in the whole production system during the time period. This includes the products being processed on the machines and stored in the buffers [42].

$$WIP = \sum_{i=1}^{T} WIPi / T$$

3-**Utilization of server *n*** *[12]*

Let P*n* be the utilization of server *n* , $r_1 = \frac{l}{m_1}$ for the first station and

$r_2 = \frac{l}{m_2}$ for the second station

$l = arrival\ rate.$

$m = service\ rate.$

**Push System**

**4-** ***wq:*** average amount of time in queue.

**5-** ***ws:*** average amount of time in the system.

$$wq = \frac{r}{m(1-r)} \quad , \quad ws = \frac{1}{m(1-r)}$$

**Pull System**

The following equation apply for each section of a system that uses pull processing.

Let *zn*=number of kanbans circulating through the *n*th station. Let *ws* be the average
time in the system=average time in the queue (it take the customer no time to pick up inventory i.e. customer service time = 0).

**6-** If the customer has to wait for inventory to be delivered, that waiting time will be **(*wb*)** the total time that the customer spends at that station

$$wb = \frac{r^z}{m - l}.$$

**7-** The number of kanban available for the machine (queue kanban + process kanban) is given by:

$$E[\#\,kanbans\ available] = \frac{r}{1-r}\left(1 - r^z\right)$$

**8-** The part processed at station 1 will use the following equation for queue time and system time:

$$Lq = \#\,kanbans\,available - \#\,kanbans\,in\ process$$

$$= \frac{r\left(1 - r^z\right)}{1 - r} - r = \frac{r^2 - r^{z+1}}{(1 - r)}$$

**9-** $wq = \dfrac{r^2 - r^{z+1}}{l(1-r)}$

**10-** $ws = wq + \dfrac{1}{m} = \dfrac{r^2 - r^{z+1}}{l(1-r)} + \dfrac{1}{m}$

**11-** The average inventory level after a station is given by:

$$E[Inventory\ \ level] = z - \frac{r}{1-r}\left(1 - r^z\right)$$

.

**12-** The number of customer parts backlogged after a pull station is given by:

$$Lb = l\ wb = \frac{r^{z+1}}{1-r}.$$

**13-** For a multi stage pull system , the number of kanbans cycling through the *n*th processing station is equal to $Z'n$ .

$$Z'n = Zn - \#back\log ged$$

$$Z'n = Zn - \frac{r_1^{z_1+1}}{1-r_1}$$

**Multistage push model**

**14-** For a multistage push model, the total customer cycle time equals the total part cycle time and is given by:

$$ws_1 + ws_2 + ..... + ws_n = \frac{1}{m_1(1-r_1)} + \frac{1}{m_2(1-r_2)} + \mathbf{L} + \frac{1}{m_n(1-r_n)}$$

**15-** The number of parts in the system is equal to $Ls_1 + Ls_2$ which can find by littles law consequently

$$Ls_1 + Ls_2 + Ls_n = \frac{r_1}{1-r_1} + \frac{r_2}{1-r_2} + \frac{r_n}{1-r_n}$$

**Hybrid push-pull model**

**16-** For a hybrid push-pull model the total customer cycle time equals to:

$$wb + ws = \frac{r^{z1}}{m-l} + \frac{1}{m_2(1-r_2)} + \mathbf{L} + \frac{1}{m_n(1-r_n)}$$

**17-** While the number of parts in the system is giuven by:

$$Ls_1 + Ls_2 + ...... + Ls_n = z_1 + \frac{r_2}{1-r_2} + ...... + \frac{r_n}{1-r}$$

**Multi stage pull model**

**18-** In the multi stage pull model, the total customer cycle time equals:

$$w_{b_n} = \frac{r_n^{z'n}}{m_n - l}$$

**19-** The number of the parts in the system is fixed at:

$$Ls_1 + Ls_2 + ...... + Ls_n = z_1 + z_2 + ...... + z_n$$

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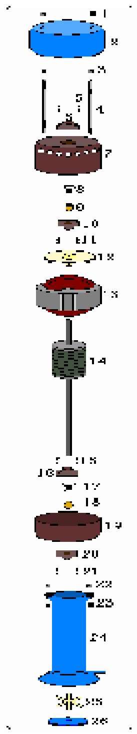


| No. | Name | Qty. |
|---|---|---|
| 1 | M4 Nuts | 2 |
| 2 | Plastic cover | 1 |
| 3 | M4 Nuts | 2 |
| 4 | Screwed studs | 2 |
| 5 | Brass pins | 4 |
| 6 | Upper bush cap | 1 |
| 7 | Upper cover | 1 |
| 8 | Spring | 1 |
| 9 | Brass bush | 1 |
| 10 | Lower bush cap | 1 |
| 11 | Male pins | 4 |
| 12 | Plastic Fan | 1 |
| 13 | Stator assembly | 1 |
| 14 | Rotor assembly | 1 |
| 15 | Female pins | 4 |
| 16 | Upper cap | 1 |
| 17 | spring | 1 |
| 18 | Brass bush | 1 |
| 19 | Lower cover | 1 |
| 20 | Lower cap | 1 |
| 21 | Male pins | 4 |
| 22 | M4 Nuts | 2 |
| 23 | M4 Nuts | 2 |
| 24 | Plastic Support base | 1 |
| 25 | Plastic impeller | 1 |
| 26 | Impeller room cover | 1 |

**Figure[7]Explosive schematic diagram with a notation to the product under study at SCFEI**

**Table (1) Performance measure**

| Comparison item | Description |
|---|---|
| Utilization rate (%) | Ratio of processing time to available time. The idle time rate is 1 minus the utilization rate. |
| Idle time (%) | Is the complement of the utilization amount or the inverse of utilization. |
| Throughput rate (part/sec.) | Number of products produced per unit of time. |
| Work-in-process(WIP) (part) | The level of in-process inventory at any point in time. The product of the throughput rate. |
| Processing time (Sec.) | Time it takes for an activity to be performed.(not to be included as a performance measure ;assumed deterministic) |
| Waiting time (Sec.) | A subset of cycle time, this is the time the customer waits before receiving service. |
| Queue length (part) | The number of customers waiting in line at any one time. Average queue length, and maximum queue length are often reported and analyzed ,separately. |
| Machine cycle time (Sec.) | Average time the equipment takes to perform one operation. Often includes factors for equipment downtime, operator fatigue |
| Throughput time (Sec) | A subset of lead-time, this is the time it takes to change the raw materials into finished goods. Also called Makespan or it is the time spent in the system including service [19].the overall elapsed time from when the manufacturer of a product is first begun to when that specific product is completed [9] |
| Finished output (part) | Overall production during one operation shift . |

]

Table [2] detailed processing times at SCFEI

| | Upper cover | Processing Time (Sec.) |
|---|---|---|
| 1- | Rolls Cutting | 1.7 |
| 2- | Punching and Blanking | 1.5 |
| 3- | Electrical zinc coating | 24 |
| 4- | Painting and drying furnace | 0.03<br>4.5 |
| 5- | Final assembly and perm wick injection | 30 |
| | **Bearing cap** | **Processing time (Sec.)** |
| 1- | Rolls cutting | 5 |
| 2- | Shaping and punching step die | 1.5 |
| 3- | Coating and drying | 2.4<br>0.5 |
| | **Bearing coil** | **Processing time (Sec.)** |
| 1- | Rolls Cutting | … |
| 2- | Shaping and punching step die | 1.5 |
| 3- | Electrical Coating | 0.5 |
| | Total | 71.6 |

| | Lower cover | Processing Time(Sec.) |
|---|---|---|
| 1- | Rools Cutting | 5 |
| 2- | Shaping and Punching | 45 |
| 3- | Coating operation | 5 |
| 4- | Painting Operation | 15 |
| 5- | Final assembly and perm wick injection | 35 |
| | Total | 105 |

| | Rotor Machining | Processing Time(Sec.) |
|---|---|---|
| | Electrical steel rolls cutting | 5 |
| 2- | Last sheet rolls cutting | 2 |
| 3- | Shaping and punching | 10 |
| 4- | Stacking operation | 10 |
| 5- | Aluminum molding and cleaning products | 10<br>40 |
| | **Shaft forming** | **Processing Time(Sec.)** |
| 1- | Index cutting & turning | 20 |
| 2- | Grinding operation | 20 |
| 3- | Knurling operation | 10 |
| 4- | Rotor pressing | 2 |
| 5- | Turning operation | 10 |
| 6- | alignment | 5 |
| 7- | Painting operation | 2 |
| | Total | 146 |

| | Stator | Processing Time(Sec.) |
|---|---|---|
| 1- | Rolls cutting | 3 |
| 2- | Shaping and punching | 95 |
| | **Last sheet** | **Processing time (Sec.)** |
| 1- | Rolls cutting | 5 |
| 2- | Shaping and punching | 0.375 |
| 3- | Welding operation | 12 |
| 4- | Aux. pole welding | 8 |
| 5- | Stator insulation | 5 |
| 6- | Coil winding | 0.08 |
| 7- | Manual operation | 0.09 |
| 8- | Manual wire bandaging & sewing | 50 |
| 9- | Emerging and drying | 57.6 |
| | Total | 232 |

| | Plastics injection | Processing Time(Sec.) |
|---|---|---|
| 1- | Impeller | 30 |
| 2- | Fan | 30 |
| 3- | Spacing bush | 35 |
| 4- | Uppre Cover | 30 |
| 5- | Cap | 30 |
| 6- | Stand Base | 40 |
| | Total | 195 |

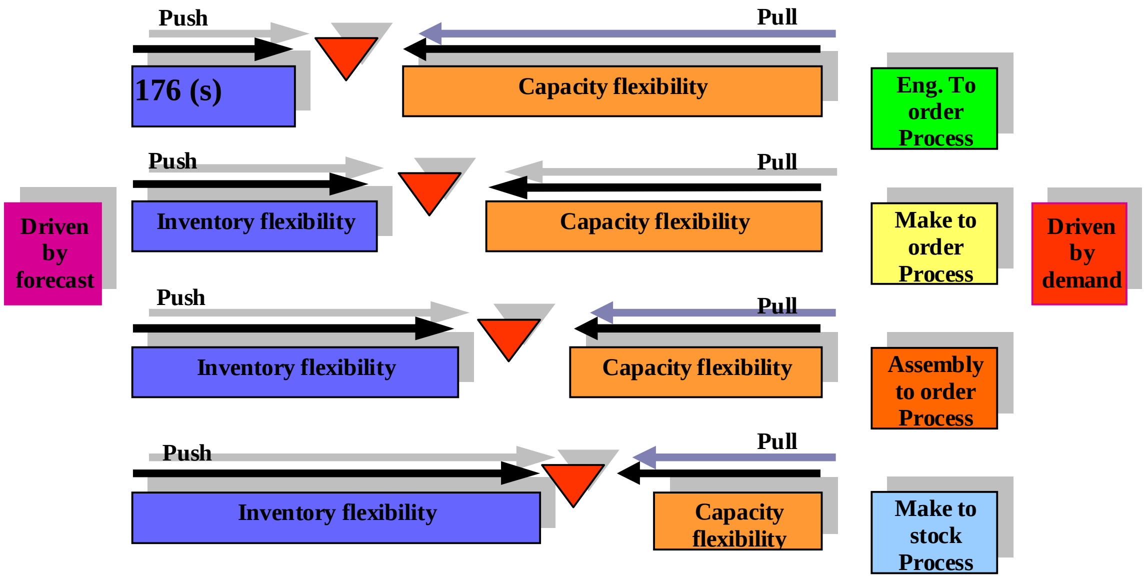



Figure [1] Mapping production practisies

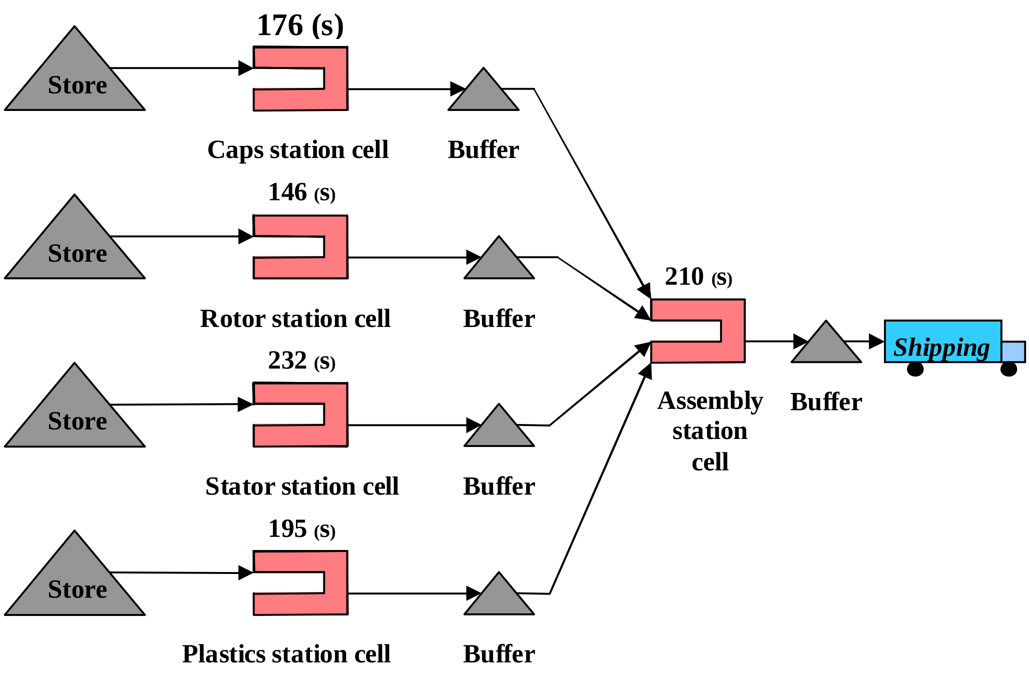



Figure [2] Push system

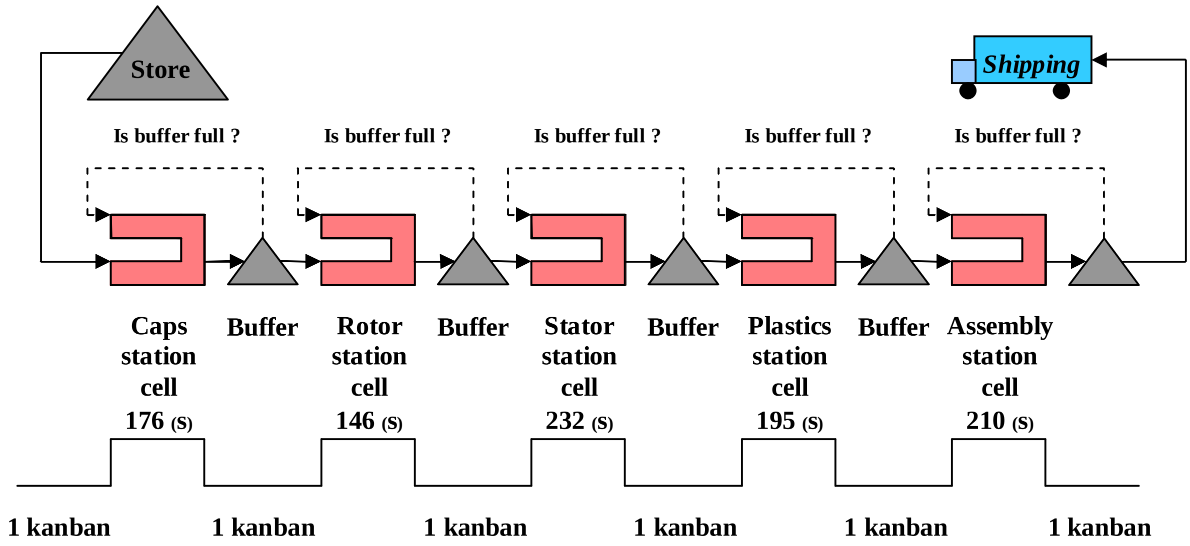



Figure [3] Pull system

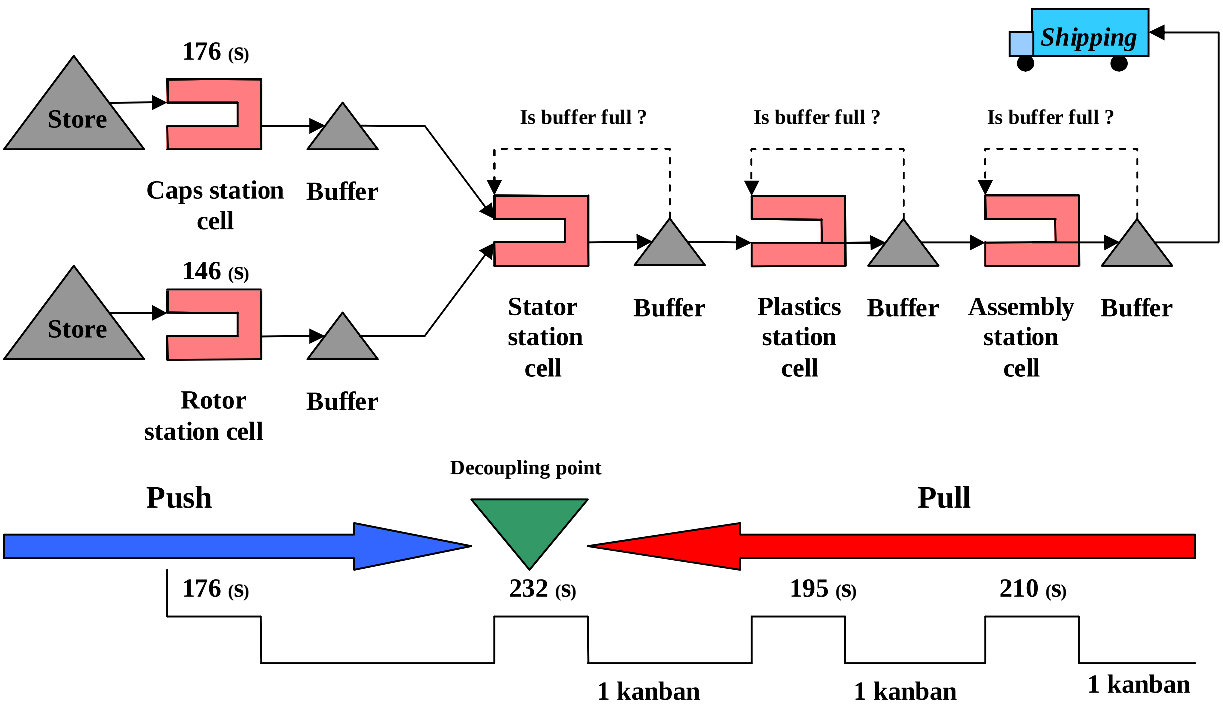
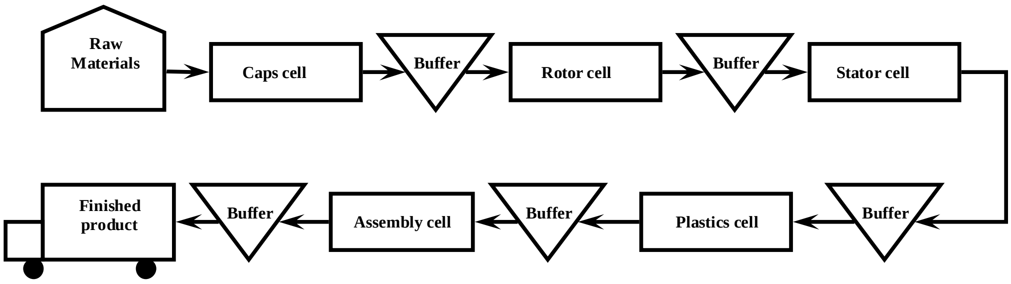



Figure [4] Hybrid system




Figure[5] The proposed model

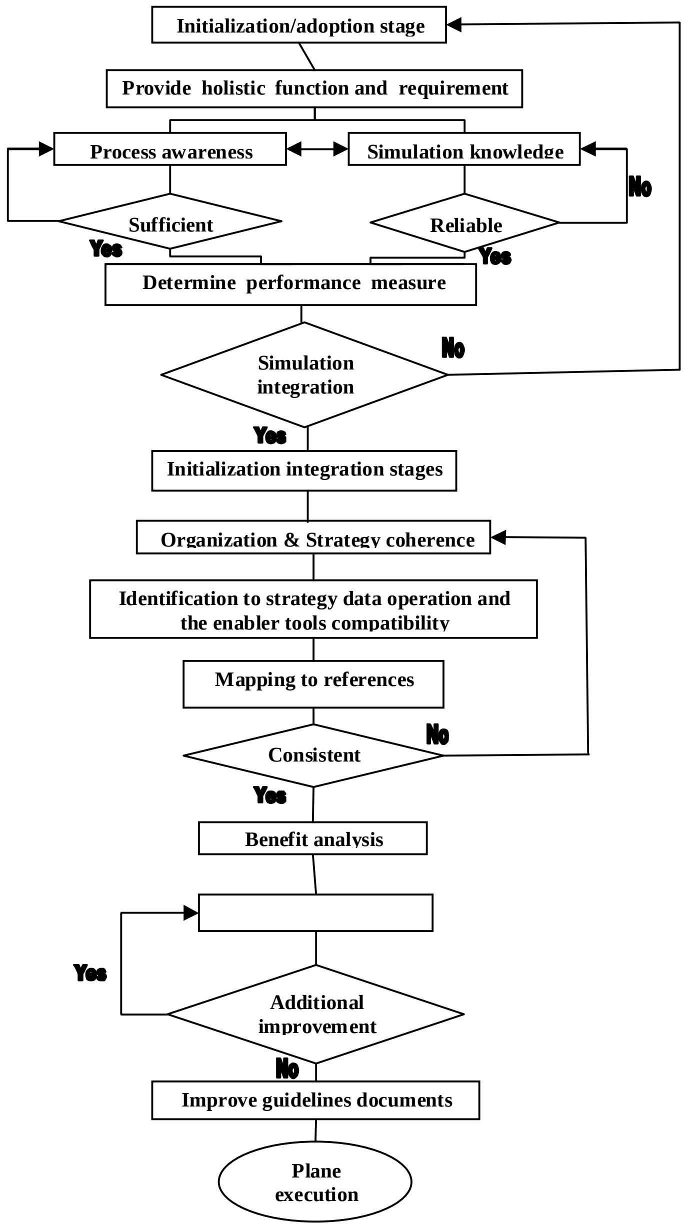



Figure [6] Proposed methodology

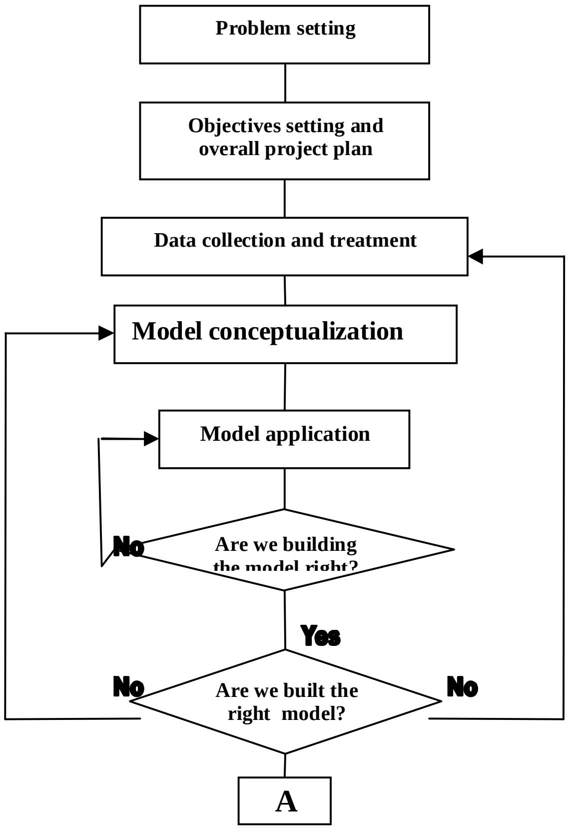
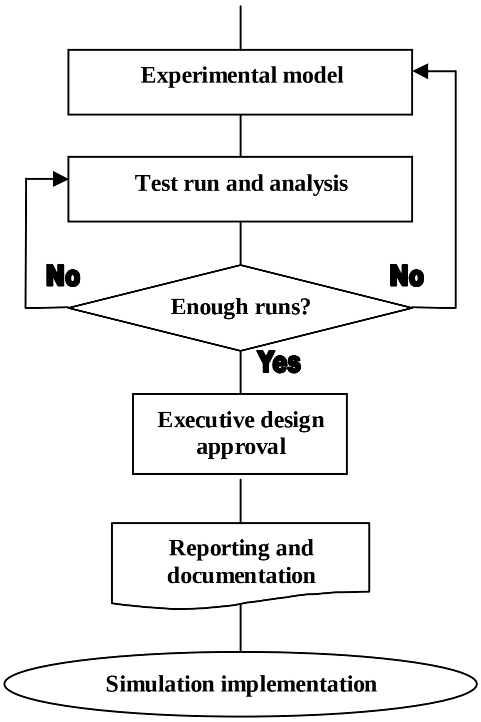
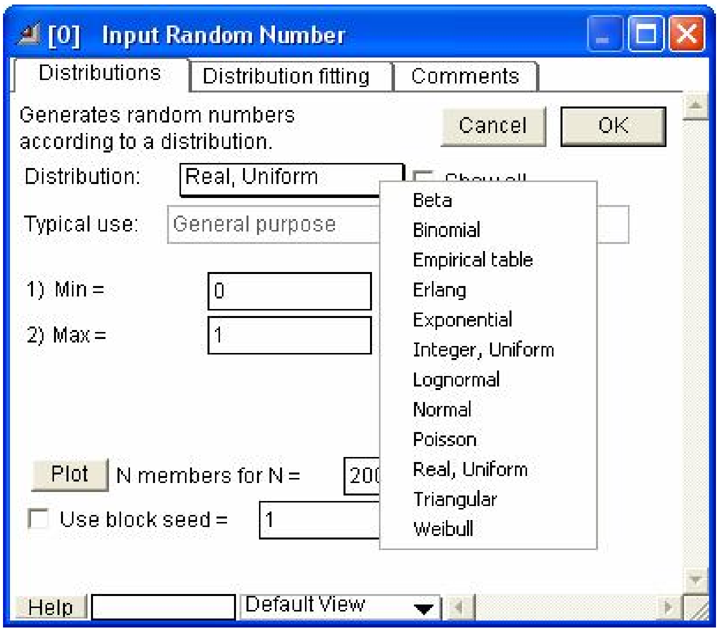
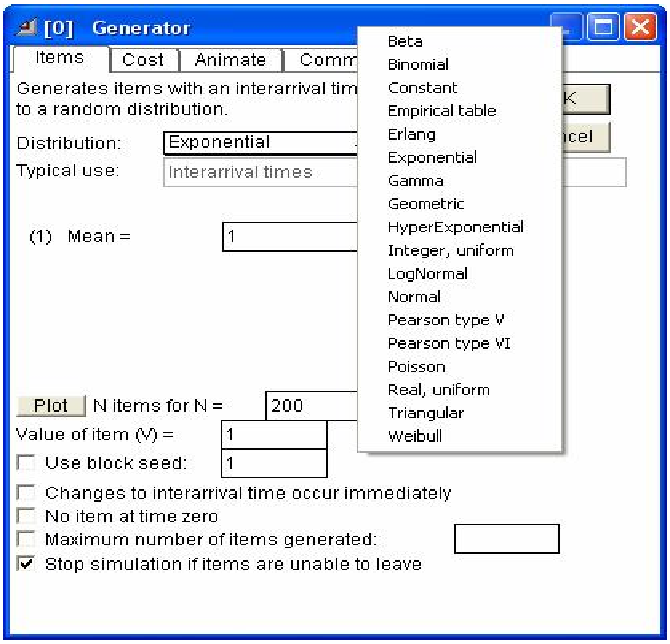



Figure [8] Methodology steps




Figure[9]input random number in EXTEND



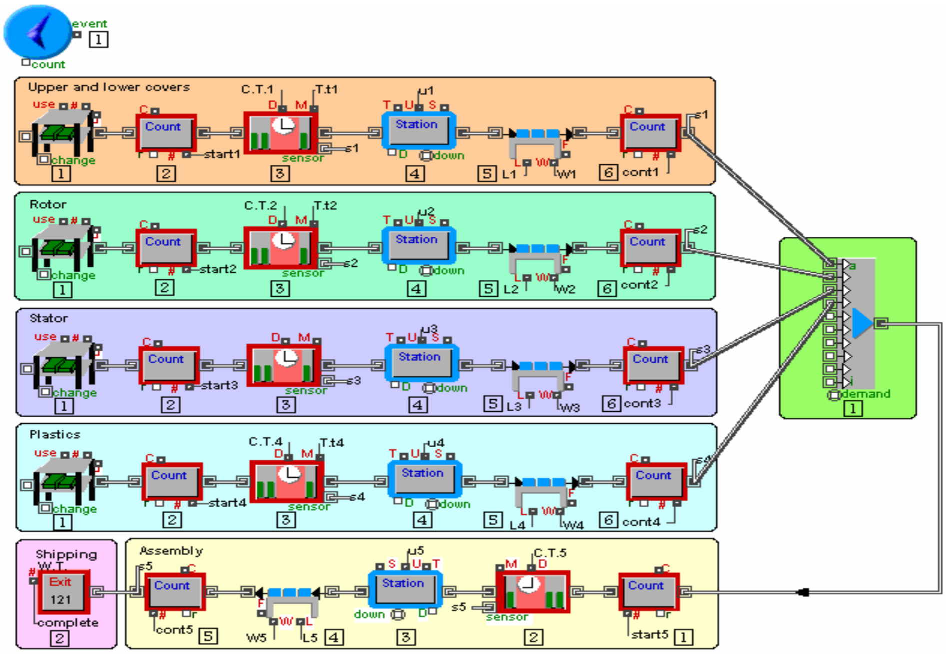




**Fig.[11]"EXTEND" push model animation**

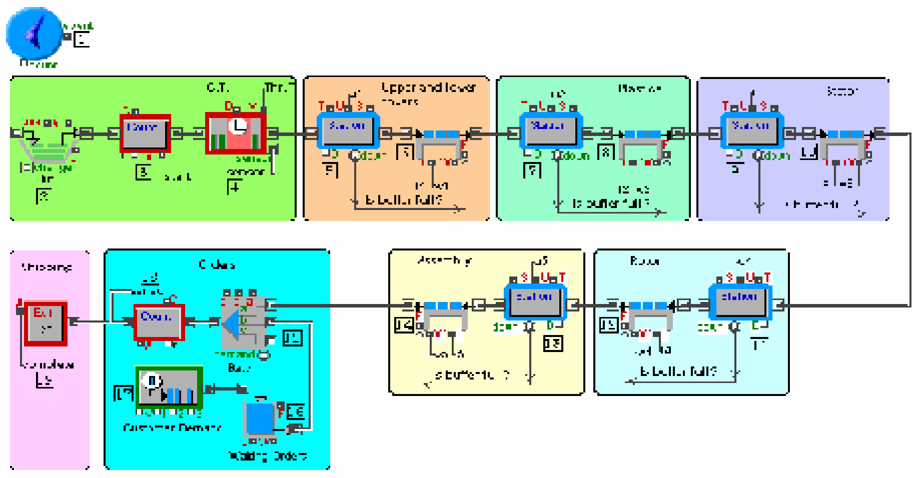


Fig.[12]"EXTEND" pull model animation

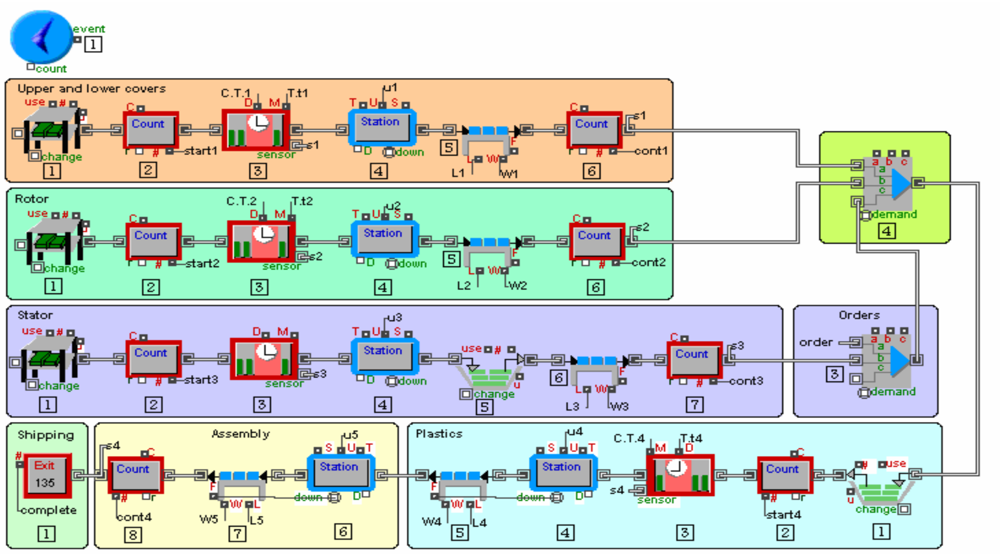
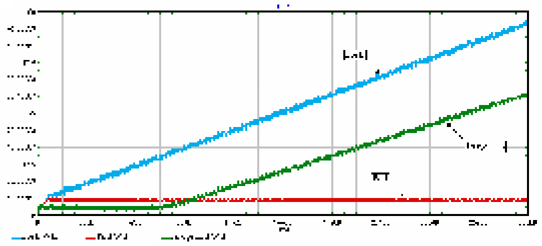



Fig.[13] "EXTEND" hybrid model animation

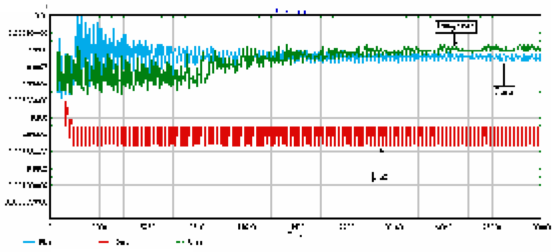
Part



One shift period (Sec.)

WIP

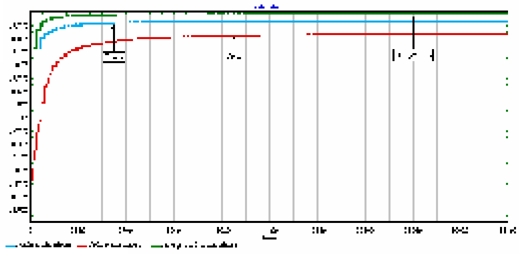
Part/sec.



One shift period (Sec.)

Throughput

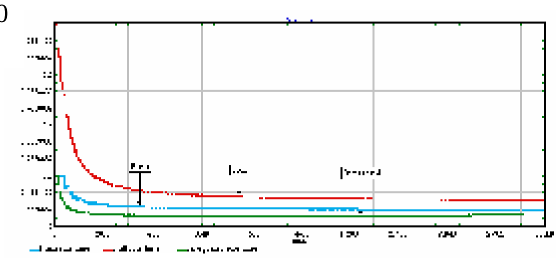
100 %



One shift period (Sec.)

Utilization

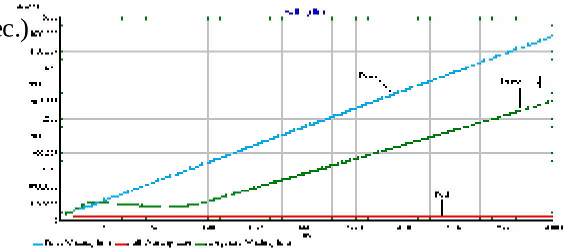
100 %



One shift period (Sec.)

Idle time

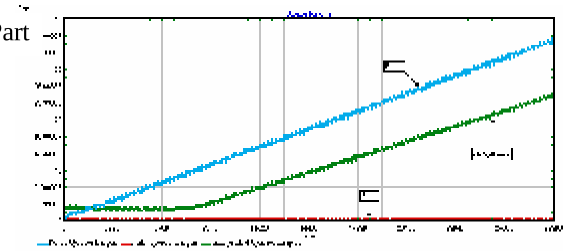
W. T. (Sec.)



One shift period (Sec.)

Waiting time

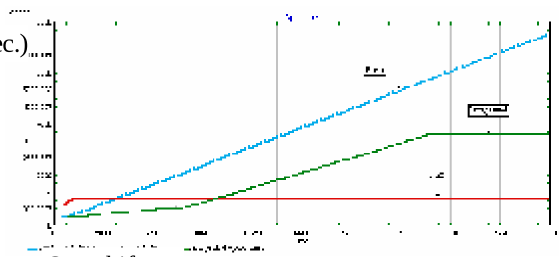
Part



One shift period (Sec.)

Queue length

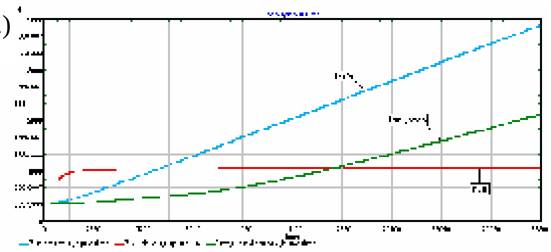
C. T. (Sec.)



One shift period (Sec.)

Cycle time

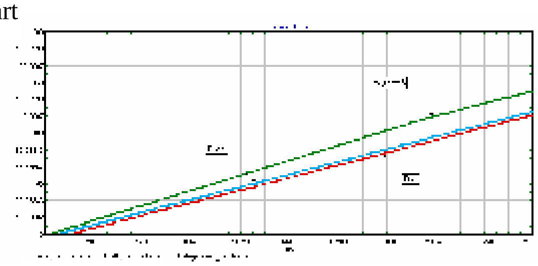
Th. T. (Sec.)



One shift period (Sec.)

me

Part



One shift period (Sec.)

Production