Optimisation of Supply Chain Network Modeling and Perfomance Measurement in Flow of Production

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Abstract

Present trend issues in supply chain management ability to execute the plan when forecast errors occur, how to improve service levels while simultaneously mitigating cost, and resurgence in contingency planning problem. Supply chain management plays a vital role in the growth of the industry, survival in the market, the production rate, and the dynamic interaction among the suppliers and the customers. Strategic decision makers need comprehensive models to guide them in efficient decision making that increases the profitability of the entire chain. System dynamic is a methodology whereby complex, dynamic and nonlinear interactions can be understood and analysed. This paper presents a supply chain model of a medium size industrial iron foundry which will produce gray cast iron and Spheroidal graphite cast iron, and also the dynamic interaction between the variables using system dynamic approach. Under different delay conditions, rejection rates, conditions, the policy experimentations carried out considering various factors of the foundry and their degree of development. The model results have been discussed and validated based on the actual results of a foundry. This paper has addressed many important issues related to demand, inventory, production rates of a foundry.

Keywords: Supply Chain Management, System Dynamic

Introduction

Supply chain management (SCM) plays a vital role in the growth of the industry, survival in the market, the production rate and the dynamic interaction among the suppliers and the customers. SCM has been met with increased recognition during the last decade both by academicians as well as practitioners. SCM of medium size iron foundry is taken and its system dynamic & simulation model is studied. System Dynamics (SD) is a methodology whereby complex, dynamic and nonlinear interactions in the systems can be analyzed and new structures and policies can be designed to improve the system behavior. SD modeling requires two types of flows, one is the physical flows, and another is the information flow. This paper presents a simulation of supply chain model of a medium size industrial iron foundry which will produce gray cast iron and Spheroidal graphite cast iron, and also the dynamic interaction between the variables using system dynamic approach. Under different delay conditions, rejection rates, conditions, the policy experimentations carried out considering various factors of the foundry and their degree of development. The model results have been discussed and validated based on the actual results of a foundry. Great attention has to be paid to reduce the information and material delay associate with the supply chain, to reduce the inventory between the members and maximize the supply chain efficiency. Broad objective of the study has been developing system dynamics model representing the behavior of foundry in India for policy analysis. The specific objectives are to develop a frame work on supply demand scenario casting foundry in India, to build a simulation model for castings and to generate future scenario against various policy options, to discuss policy options in terms of castings. This paper has addressed many important issues related to demand, inventory, and production rates of a foundry. In this paper, SC of medium size foundry is taken, production of gray iron castings is considered and system dynamic model is developed and discussed for the iron foundry. The remainder of the paper is organised as follows. The second section gives the information regarding the literature review; third section introduces the development of the model on gray & SG iron foundry; fourth section explains the system dynamic and simulation model, and model validation, and the last section talks about results and discussion and, finally it wrapped up with the conclusions in the last section.

Literature Review

Forrester (1961) developed industrial dynamics, which later extended and called system dynamics. Intact, he already developed a model for simple supply chain which has four links, namely retailer, wholesaler, distributor, and factory. He examined how these links react to deviations between actual and target inventories.

Williams (1983) develops a dynamic programming algorithm for simultaneously determining the production and distribution batch sizes at each node within a supply chain network. As in Williams (1981), it is assumed that the production process is an assembly process. The objective of the heuristic is to minimise the average cost per period over an infinite horizon, where the average cost is a function of processing costs and inventory holding costs for each node in the network.

Ishii *et al.* (1988) develop a deterministic model for determining the base stock levels and lead times associated with the lowest cost solution for an integrated supply chain on a finite horizon. The stock levels and lead times are determined in such a way as to prevent stock-out, and to minimise the amount of obsolete (.dead.) inventory at each stock point. Their model utilises a pull-type ordering system which is driven by, in this case, linear (and known) demand processes.

Cohen & Lee (1989) present a deterministic, mixed integer, non-linear mathematical programming model, based on economic order quantity (EOQ) techniques, to develop what the authors refer to as a .global resource deployment. policy. More specifically, the objective function used in their model maximises the total after-tax profit for the manufacturing facilities and distribution centers (total revenue less total before-tax costs less taxes due). This objective function is subject to a number of constraints, including managerial constraints (resource and production constraints) and logical consistency constraints (feasibility, availability, demand limits, and variable non-negativity).

Voudouris (1996) develops a mathematical model designed to improve efficiency and responsiveness in a supply chain. The model maximises system flexibility, as measured by the time-based sum of instantaneous differences between the capacities and utilizations of two types of resources: inventory resources and activity resources. Inventory resources are resources directly associated with the amount of inventory held; activity resources, then, are resources that are required to maintain material flow. The model requires, as input, product-based resource consumption data and bill-of-material information, and generates, as output: (1) a production, shipping, and delivery schedule for each product and (2) target inventory levels for each product.

M. M. Naim (1996), in his articles and books, developed a real world dynamic system. He developed a “real world dynamic analysis” of any business is extremely difficult to perform Supply chain management, i.e. the process of planning, implementing, and controlling operations of the supply chain while satisfying customer requirements as efficiently as possible. The process includes all internal functions, logistics, distribution, sourcing, customer service, sales, manufacturing, and finance departments of an organization.

Studying the different system dynamic papers and also books, Benita M. Beamon (1998) explained in his research paper, supply chain design and analysis: models and methods, reviewed literature in multi-stage supply chain modeling and also defined a research agenda for future research in this area.

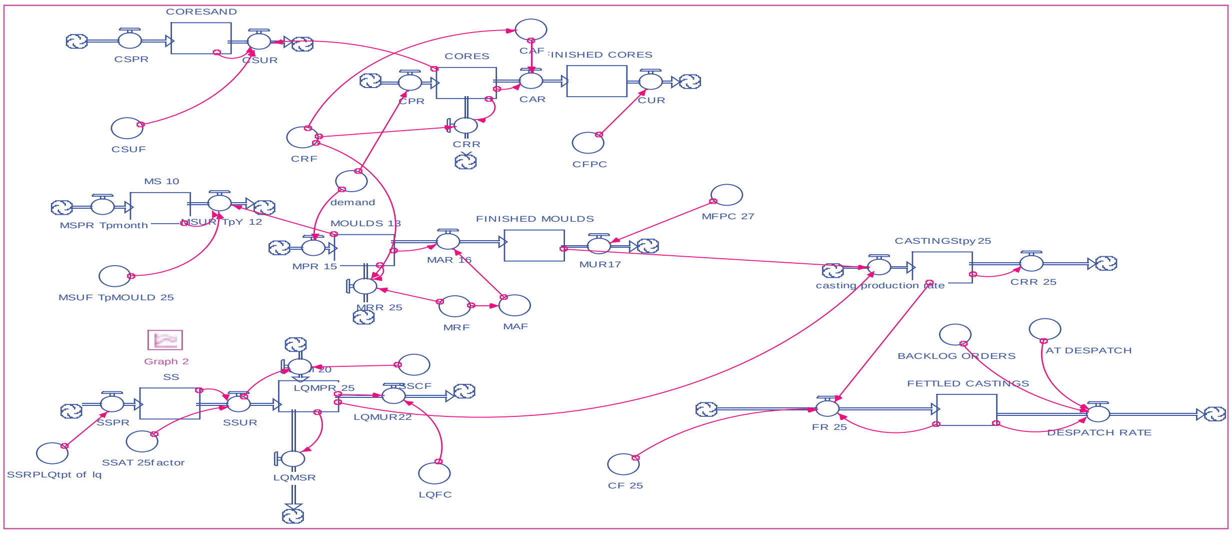
Shotaro Minegishi (2000), in system dynamics modeling and simulation of a particular food supply chain, showed dynamics could contribute to improve the knowledge of the complex logistic behavior of an integrated food industry. He presented practical simulations results are presented.

Patroklos (2005) adopted system dynamic methodology as a modeling and analysis tool for the strategic supply chain management.

Development of Model

Modeling is done on the basis of feedback system with symbols of level and flow variables. The “Level” variables describe the state of the systems by continuous integration of actions resulting from these systems. The flow variables express actions. This foundry contains one high pressure molding line which can produce one mould box per two minutes. It has cold box process to produce cores, one core per every four minutes. This foundry produces different types of castings like transmit ion case, axle housings, centre housings, differential carriers, hubs, trumpets, etc. for making different grades and types castings. To produce these castings it requires various types of cores, moulds, patterns, and also different liquid metal composition is required. The coordination between purchases, stores, core shop, molding and melting is very

Figure 1: Stock Flow Diagram for the Variables in Supply Chain of Iron Foundry



much required. The model is developed, considering purchase department, stores, moulding shop, core shop melting shop, and its process parameters, rate of rejections at various places, and also considering capacity constraints of melting shop, core shop and molding shops.

At present the model is developed for one of the product of the company, by using Stella software.

Table 1: Short Abbreviations are Written

Sr. No.	Acronyms/ abbreviation	Meaning
1	TIDC	Time to meet the inventory discrepancy of core chop sand
2	TIDM	Time to meet the inventory discrepancy of moulding sand
3	MMRC	Material requirement for core shop
4	CSPR	Core sand procurement rate
5	CSUR	Core sand utilisation rate
6	CSUF	Core sand utilisation factor
7	CPR	Cores production rate
8	CRR	Cores rejection rate
9	CAR	Cores acceptance rate
10	CUR	Cores utilisation rate
11	CRF	Core rejection factor
12	MSPR	Moulding sand procurement rate
13	MSUR	Moulding sand utilisation rate
14	MSPR	Moulding sand procurement rate
15	MSUF	Moulding sand utilisation factor
16	MPR	Mould production rate
17	MRR	Mould rejection rate
18	MUR	Mould utilisation rate
19	MAR	Mould acceptance rate
20	SSPR	Steel scrap procurement rate
21	SSUR	Steel scrap utilisation rate
22	LQMPR	Liquid metal production rate
23	LQMUR	Liquid metal utilisation rate
24	CR	Casting rejection rate
25	FR	Fettle ling rate

The Stella equations to produce the castings

CASTINGStpy25 (t) = CASTINGStpy25 (t - dt) + (casting_production_rate - CRR_25) * dt

INIT CASTINGStpy25 = 0

INFLOWS: casting_production_rate = (FINISHED_MOULDS* LQM_20)/1000

OUTFLOWS: CRR_25 = CASTINGStpy25*0.1

CORES (t) = CORES (t - dt) + (CPR - CAR - CRR) * dt

INIT CORES = 0

INFLOWS: CPR = demand

OUTFLOWS: CAR = CORES*CAF

CRR = CORES*CRF

CORESAND(t) = CORESAND(t - dt) + (CSPR - CSUR) * dt

INIT CORESAND = 0

INFLOWS: CSPR = 250

OUTFLOWS: CSUR = CORES*CSUF*CORESAND

FETTLED_CASTINGS (t) = FETTLED_CASTINGS (t - dt) + (FR_25 - DESPATCH_RATE) * dt

INIT FETTLED_CASTINGS = 10

INFLOWS: FR_25 = CASTINGStpy25-FETTLED_CASTINGS*CF_25

OUTFLOWS: DESPATCH_RATE = AT_DESPATCH+FETTLED_CASTINGS-BACKLOG_ORDERS

FINISHED_CORES (t) = FINISHED_CORES (t - dt) + (CAR - CUR) * dt

INIT FINISHED_CORES = 0

INFLOWS: CAR = CORES*CAF

OUTFLOWS: CUR = CFPC

FINISHED_MOULDS (t) = FINISHED_MOULDS (t - dt) + (MAR_16 - MUR17) * dt

INIT FINISHED_MOULDS = 0

INFLOWS: MAR_16 = MOULDS_13*MAF

OUTFLOWS: MUR17 = MFPC_27

LQM_20(t) = LQM_20(t - dt) + (SSUR + LQMPR_25 - LQMUR22 - LQMSR) * dt

INIT LQM_20 = 0

INFLOWS: SSUR = SS*SSAT_25factor

LQMPR_25 = SSUR*SSCF

OUTFLOWS: LQMUR22 = LQM_20*LQFC

LQMSR = LQM_20*0.1

MOULDS_13 (t) = MOULDS_13 (t - dt) + (MPR_15 - MAR_16 - MRR_25) * dt

INIT MOULDS_13 = 0

INFLOWS: MPR_15 = demand

OUTFLOWS: MAR_16 = MOULDS_13*MAF

MRR_25 = MOULDS_13*MRF*CRF

MS_10 (t) = MS_10 (t - dt) + (MSPR_Tpmonth - MSUR_TpY_12) * dt

INIT MS_10 = 0

INFLOWS: MSPR_Tpmonth = 500

OUTFLOWS: MSUR_TpY_12 = MOULDS_13*MSUF_TpMOULD_25*MS_10

SS(t) = SS(t - dt) + (SSPR - SSUR) * dt

INIT SS = 0

INFLOWS: SSPR = 275*SSRPLQtpt_of_lq

OUTFLOWS: SSUR = SS*SSAT_25factor

AT_DESPATCH = 0.1

BACKLOG_ORDERS = 0.05

CAF = 1-CRF

CFPC = 0.1

CF_25 = 300

CRF = 0.07

CSUF = 0.9

demand = 2250

LQFC = 0.1

MAF = 1-MRF

MFPC_27 = 0.05

MRF = 0.07

MSUF_TpMOULD_25 = 0.95

SSAT_25factor = 0.1

SSCF = 0.1

SSRPLQtpt_of_lq = 0.05

Figure 1 is the simulation model diagram; it gives the information flow, process flow and feedback mechanism. The supply chain model is developed for the production of transmission case iron castings. Core shop sand i.e. washed and dried sand is procured from the M/s southern silica mines, it is mixed with the resins, passed to cold box core shooters, then to core box, after passing the amine gas, the core will be produced. The moulding sand is prepared by mixing new sand with the additives-like old sand (used sand), bentonite, lustron and water. This passed through the conveyer to the hpml machine, which prepares moulds. The transmission cores are assembled in the drag mould box, and then closed with cope box, after that it is passed to the melting shop, where molten metal is pored into the assembled moulds. After solidification of liquid metal, castings are knocked out from the mould boxes, and then send to fettling shop, quality checking then the castings is dispatched. Purchasing materials like-steel scrap, carbon powder, sand for making the moulds and cores is called inbound supply chain. The different stages of production i.e. core making, mould making, melting, fettling; quality checking is called in process supply chain. Dispatch to, warehouse and customers is called as outbound supply chain management.

Model Validation

The simulated model results are compared with the actual results. To develop confidence in the model, the structure of the model is validated through the employers and experts. The initial values of model parameters were compiled and computed from secondary sources. The data is collected from the production reports, rejection reports of the company. Some data is collected by direct observations. This system model is developed for casting requirement. An overview diagram developed with influential parameters in finished castings. One product, i.e. transmission case is taken for the purpose of study. The model is studied starting from the purchase department-(purchase of raw material and indirect materials) production departments (core shop, moulding shop, melting shop, and fettling shop) then to sales department. The processing time, customer orders, rejections rates are taken. The data is collected for 25 days and simulated. Graphs are plotted for purchase of core sand, moulding sand, steel scrap, and inventory of steel scrap, assembling of moulds etc. Model validation is done on the basis of statistical tests. The validity of the test is done by heuristic method, judged by its usefulness. In this case previous year procurements of sands are taken and compared with the simulated results and also the castings produced. In this case strike periods, abnormal cases are eliminated. Fettling stock, finished castings and also the delivery rate of the castings to the customers.

Figure 2: Purchase of Core Sand (no. of Months vs Tons of Sand)

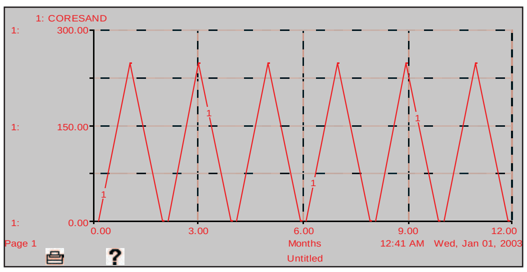


Figure 3: Purchase of Moulding Sand (no. of Months Vs Tons of Sand)

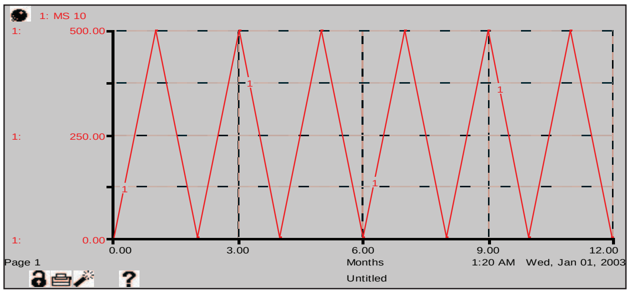


Figure 4: Procurement of SS (no. Months Vs Tons Steel Scrap)

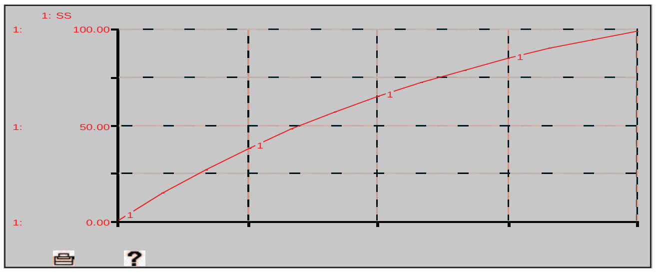


Figure 5: Casting Production Rate (no. Months Vs Tons of Castings)

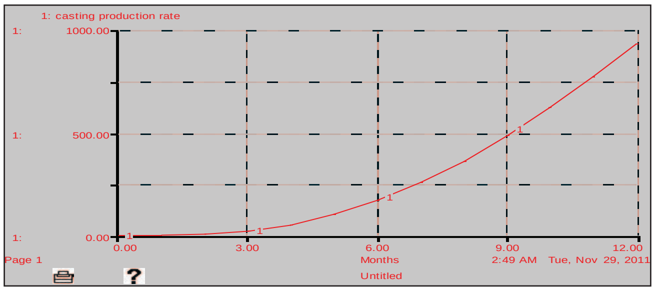
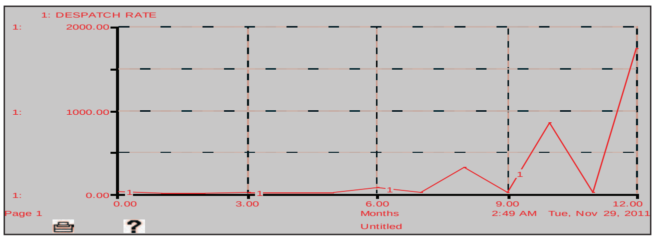


Figure 6: Dispatch Rate (no. of Months Vs Tons of Dispatch)



Results and Discussions

This paper has considered simple deterministic model. The demand of the product (transmission case) is taken.

The simulation results/ graphs show how much sand should be procured, at what time/month. It also gives very good validated results to procurement of scrap, plan for dispatch. Figure 3, 4, 5, 6, 7 are the simulated graphs. In these graphs one can generate the policies also, i.e. when to procure, how much to procure. Inventory planning can also be done by these simulation results.

Conclusions

This work has made it possible to understand and explain the complex behaviour of a moulding sand, core sand effect to the production of iron castings and its rejections. In this paper, we considered a simple system dynamic model based on the supply chain, relationships for identified various parameters. The simulation has been carried out for one year. The model is tested by using secondary data. System dynamic model presented here helps the organisation to understand its supply chain variables, procurement of steel scrap, sand and other materials, process planning, and also maintaining inventory, thereby reducing cost of inventory. By maintaining vendor relations, it is also helpful to reduce the lead time, and improvement in its quality of services, customer satisfaction and improving the supply chain efficiency. It is useful to take the decisions by studying the graphs such as when to purchase the raw material, when to start production and also one can know the situation of the products. It is useful to make inventory policies such as how much to produce, how much to keep the core stock, castings stock, one can be able to know the requirements of core production taking care of core rejection, mold rejections. By taking the yearly demand one can be able to estimate the rejections castings, required sand level, core stock level and also rate production.

Further research for different aspects of this method is still possible and necessary. The aggregation step and the generation of new decision rules is an open field. One possibility is to interpret the solution of the optimisation model only as a target strategy and use adaptive decision rules to approximate this target strategy in an uncertain environment. The use of sensitivity results of the optimisation model might lead to improved decision rules. Further investigations are possible for the boundaries between the simulation and the optimisation model. The question, which aspects should be included in the optimisation model, is not completely answered yet. If more complex models are used, other fast solution methods (e.g., heuristics, mathematics, etc.) should be taken into consideration.

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