Inventory System Modeling: A case of an Automotive Battery Manufacturer

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ABSTRACT

Production systems necessarily feature both detail complexity, the effect of having many variables, and dynamic complexity, the effect of time and spatial separation, non-linearity, and counter-intuitive relationships between cause and effect. This paper presents a system dynamics modeling of a Nigerian automotive battery production organisation. Policy runs of the system simulation were done to evaluate the impact of the size and pattern of demand, initial conditions, facility capacities, scrap rates, and material delays on raw material usage rates, production, and unfilled orders. This was with a view to meeting demands, highlighting the potential benefits of alternative policies, and engendering team consensus among decision makers through the generation of a shared vision.

Keywords: [Inventory system, System Dynamics, Feedback loops]

INTRODUCTION

Inventory management plays a critical role in ensuring smooth production operations. However, while there are many analytical approaches to inventory management, the applications of these techniques mostly cater for only one of the many interacting variables at a time.

Real-life inventory problems are usually simultaneously strategic, dynamic, multi-objective, and partly subjective, and stochastic. Inventory decision systems feature detail complexity in the form of their many interacting variables and dynamic complexity in having accumulation, time delays, non-linearities and multiple feedback loops.

All these call for a systems analysis approach that model the inventory decision situation as a feedback system with dynamic feedback interactions among its many variables, incorporating time delays, and non-linearities. A systems approach is usually recommended when the behaviour of the system is dependent on a feedback structure.

Sumer (1974) reviewed several analytical inventory techniques and classified them with a focus on the variables, parameters and set objectives. The effect of multiple feedback loops was missing in these models. Sterman (1989) and Diehl et al. (1995) also found that the system performance deteriorated with increasing time delays and feedback effects. Roberts et al. (1983) have shown that the process of implementing the system dynamics modeling procedure is iterative.

We consider the case of a battery manufacturer’s inventory system of raw materials, in-process and finished products with a view to meeting the product demands. The company operates in competition with importers of battery units. However, it has the advantage of giving a 3-months guarantee to its customers, which is not available from the competing battery importers. The guarantee offer is designed to earn goodwill and increase market share.

THE MODEL AND EXPERIMENTAL PROCEDURE

In this paper we examine two scenarios (pessimistic and optimistic) alongside the base run. Amongst others, we assume a 25% reduction/increment in the various production capacities for the pessimistic/optimistic run relative to the base run. For some of the other parameters, we assumed the worst/best case values for the pessimistic/optimistic runs respectively. We note that these runs are mainly exploratory and that various other combinations of the factors and parameters are possible.

Based on a pilot study of the battery manufacturer's operations, a systems dynamics model of about 50 variables and 100 system equations was constructed. The DYNAMO software was used for the simulation. The system equations related the usage and transfer rates of material as well as capacities of the machinery in respect of the key sections involved in the production of the battery units. Table 1 highlights the main features.

Table1: Main Production sections and some key features influencing system equations

Section	Feature
Oxide Mill	• Pure lead ingots used to produce lead (grey) oxide. • Incoming lead from smelter and outflow of ingots for oxide production. • Constraints include storage capacity for oxide and availability of the Mill
Casting	• Casting of grids from GSM lead alloy ingots. • Incoming lead from smelter and outflow of ingots for casting of the grids. • Constraints include machine capacities and availability.
Pasting/Curing	• Pasting of grids and curing in cubicles. • Constraints include the curing capacity of the cubicle, which determines the mixing rate and lead oxide availability.
Formation/Assembly	• Cured plates are sent to formation tanks. • Assembly rate limited by the demand for battery units and availability of formed plates. • Constraints include formation rate and capacity of formation tank.
Finished Goods Inventory/Filling orders	• Orders increase level of unfilled orders while deliveries reduce the level of unfilled orders. • Demand is based on forecasts by the Marketing department. • Delivery rate depends on finished goods in store and unfilled orders.
Antimony Lead	• Antimony lead is a raw material used at the assembly stage. • Inventory level is increased by smelt shop transfers and decreased by usage in the assemblies.

A base run of the model simulation was obtained with the set of values for the initial conditions, facility capacities, scrap rates, and material delay lengths. Table 2 shows the parametric values for the base, optimistic and pessimistic runs. The appendix shows the influence diagram of the system.

Table 2: Parametric Values for Simulation Runs

Parameter	**Description (units)**	**Base Run**	**Optimistic Run**	**Pessimistic Run**
FOTOCAP	Formation tank capacity(kg)	126720	158400	95040
MIXCAP	Mix capacity (kg)	1189.6	1487	892.2
MILCAP	Mill capacity (kg)	10608	13300	7956
CUBCAP	Cubicle capacity (plates)	80000	100000	60000
NUMACH	Number of machines	3	6	2
SCRAP2	Scrap rate, grid plates	Random; μ=0.135; σ=0.04	0.12	0.3
SCRAP3	Scrap rate, assembly	0.05	0.03	0.1
DEMAND	Demand (units/day)	Random; μ=1092.5 σ =167.5	1200	Random; μ =870.0 σ =465.3
DEL	Delay (days) to cure plates	3	2	4
DEL4	Delay (days) to form plates	1	0.75	1.5

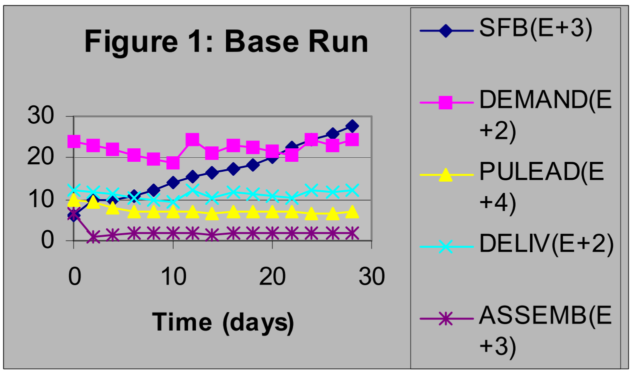
System outputs of interest in the simulation experiment were PULEAD (inventory of pure lead), SFB (stock of finished batteries), ASSEMB (battery assembly rate per day), UNFORD (unfilled orders of batteries), and DELIV (number of batteries delivered per day). The dynamic behaviour of these output variables from one simulation to the other was observed and for a length of 28 periods (one month).

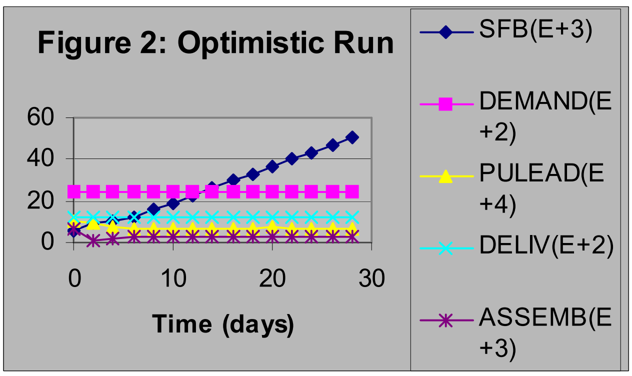
DISCUSSION OF RESULTS

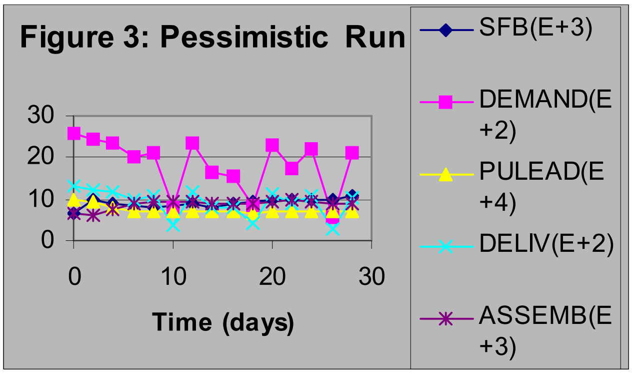
Figures 1, 2 and 3 highlight the behaviour of the system in the respective simulation runs. The stock of pure lead rises with time in the first 8 periods for the optimistic and pessimistic runs, while reducing in a fluctuating manner in the base run. This is followed by a duration when the stock fluctuates gently around 68,000 kg for both the optimistic and pessimistic runs while the base run continues its fluctuating decline to around 67,000 kg at the end of the run.

The unfilled deliveries are always short of the demand. On the average only about 50% of the demand levels are being met. This is inspite of the assembly and stock rates. This points to a weakness in the delivery system.

These observations suggest the preference of the optimistic structure when the criterion of maximum steady assembly rate is desired and a preference for the pessimistic policy otherwise. However, the continuous rise of the stock of finished batteries should be examined with a view to its significant reduction. An immediate cue is the low level of deliveries in all cases: an achievement of much higher deliveries should appreciably reduce the rate of additions to the stock of finished batteries. The personnel and facilities component of the delivery system should be improved upon to decongest the finished stock levels and get the products to the market as soon as possible.







CONCLUSIONS

The inventory system of a selected battery manufacturer has been modeled as a dynamic system. The behaviour over time of the system was obtained in a base run. Optimistic and pessimistic policy runs were obtained by increasing or decreasing facility capacities by 25% among other parametric changes. It was observed that both the alternate policies have potential benefits: the optimistic policy is preferred to satisfy an objective of maximised steady assembly rate while the pessimistic policy is preferred towards minimising the stock of finished batteries. Other policy packages can be evaluated by an informed combination of parameter and/or structural changes. The study illustrates the valuable feature of system dynamics modeling namely, the generation of trade-off analysis required for a satisficing solution in a complex managerial decision process. Equally importantly, the modeling process enables all stakeholders to have a shared vision of how selected policies work, thus enhancing the process of consensus building. The model could also be extended to cover other organisational functions as major subsystems of an aggregate corporate system for strategic decision making.

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Appendix: Influence diagram