17th European Symposium on Computer Aided Process Engineering – ESCAPE17
V. Plesu and P.S. Agachi (Editors)

Generic Modelling and Simulation of Stock Levels in Supply Chains

Edric Margono, Nouri Samsatli and Nilay Shah[a]

[a] *Centre for Process Systems Engineering, Department of Chemical Engineering, Imperial College London, Longon SW7 2AZ, UK, n.shah@imperial.ac.uk*

Abstract

Stock levels of raw materials, intermediates and final products are a key performance measure of supply chains. Computer aided tools have helped in trying to understand the movement of stock levels and aid in making decisions that will improve these measures. This work aims to create a tool to help in the analysis and planning of existing systems via a robust planning mechanism and a simulator that incorporates stochastic elements.

The tool is based on three main components: a data generator that generates, from historical data, demand forecasts scenarios; a robust planner that generates a plan from a selection of data scenarios; a simulator that puts the robust plan into action with the introduction of random events and a simple form of online scheduling (as a form of feedback control on the system) to examine how the system behaves under such conditions.

Keywords: Chain, Robust Planning, Stochastic Elements, Stock Levels

1. Introduction

Supply chain management is a field that has been attracting the interests of individuals working in the field of process engineering for two reasons, firstly, that it is an attempt to unify the optimization problem that is posed by a system from all levels, in terms of details, and in terms of field work. The second is that a lot of the optimization mechanisms and modeling and simulation techniques

that have been used by process engineers are now being used more extensively in supply chain management modeling [1].
Simulation and modelling tools have more increasingly being employed to solve supply chain problems in the form of increased production capcity, reduction of production lead times, reduction of stock levels and/or the increase of the profit margin. With the implementation of Supply Chain overview software, industries now have rapid access to amne

2. Problem Statement, background

Simulation and modeling work typically aims to achieve two aims. The first is to gain, from the computer based model, an indication of how to begin to improve the system (optimization models) and the second is to give a realistic indication how the system would react to potential new changes in policy, structure and mechanisms of the system.
Supply Chain Simulation and modeling work several key common difficulties that need to be overcome. The first is achieving a realistic model that gives a realistic indication of the behavior of the system, thus allowing obtaining insight into the system, without requiring no extensive computational time or effort to establish the model [2]. The other key problem is the lacking of a huge volume of data that is useful for running a model.
Another problem that exists is that while, given enough time and effort, create a model that is both realistic and useful can be made, but there is often the need in industry to rapidly get a first approximation results to help guide decisions on how much effort is to be put into a problem. Thus a generic tool that is easily employed from one system to another and can preferably be used by people who do not posses specialized knowledge of the field is desirable.

3. Supply Chain Tool Overview

This work involves the creation a tool of three distinct parts which interacts with each other (see figure 1)

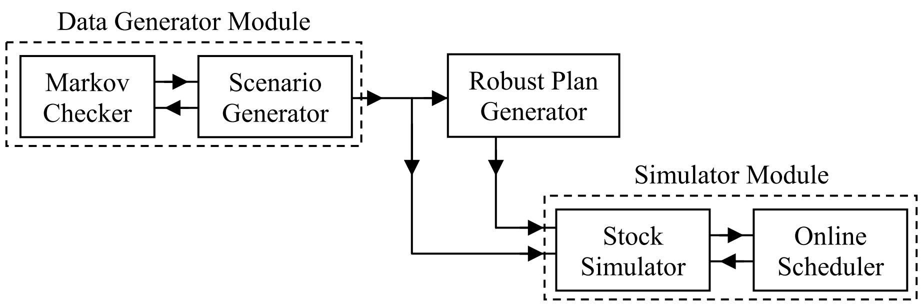

Figure 1: Overview of structure of Supply Chain Tool

The first part is a data generator module which uses one set of demand data to generate various demand and forecast scenarios, minimizing the need for tremendous volumes of data to be used in the system.
The second component is a robust plan generator that takes these demand scenarios to give out a robust plan that meets a stipulated condition, typically a given On Time in Full (OTIF) value, for a minimal average cost across the scenarios that are used in the data generation.
The third component is a simulator system that uses simple protocols tied to a simple online scheduler called SimpleSched, and a stochastic disturbance generator to attempt to try and test and see how the robust plan performs in light of additional disturbances.

3.1. Data Generator Module

The data generator works on the observation of the principle that the distribution of errors between demand forecast and actual demand data does not tend to change too much. Figure 2 illustrates this by showing a comparison graph of how the cumulative error function of demand data of flavors does not change by much from year to year. Thus a cummulative error function (CEF) can then be created.

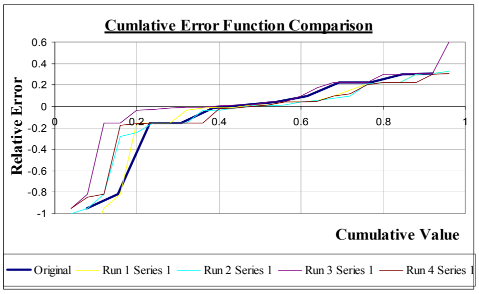

Figure 2: Comparison of CEFs generated from using 3, 4 and 5 years amount of data from the same demand data source.

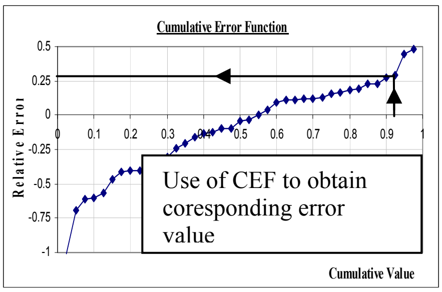

Figure 3: A simple illustration on how the CEF is used to obtain the corresponding error value for a given random number

The way the demand scenarios are created is by using a random number generator to generate a set of random numbers between zero and 1. After that, the corresponding relative error value for each of those random numbers can be obtained from the CEF (see Figure 3). The current method is to use linear interpotlation to approximate the region between two data points. Then already having the forecasts, we can create the demand scenarios.

In order to improve the accuracy of this mechanism, to ensure that the demand profiles that are generated are realistic, a markov checking process is used. Figure 4 illustrates how this works.

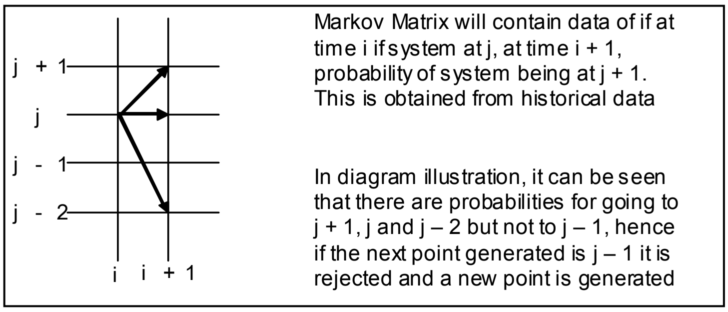

Figure 4: Illustration and explanation as to how to how the Markov Matrix is generated and used to check the demand scenarios that are created

However, in the face of restricted amounts of data that is available, and in the interest of reducing the computational time without comprimising on the quality of the demand scenarios that are being generated, exception rules are used to allow for more points to be acceptable from the checker.

3.2. Robust Planner

Robust plans are created based on a set of given demand scenarios along with the details of factories, and cost under a stipulated condition, for which is the OTIF value must be at least higher than the stipulated value of α. The key set of equations that the system has to optimize is written below:

Minimize $\overline{C}$ (1)

Under the conditions $\overline{OTIF} \geq \alpha$ (2)

Where: $$\overline{C} = \frac{\sum_x C_x}{x} \quad (3)$$

$$C_x = \sum_j \sum_i \left(S_{i,j,x} \times S_j^c\right) + \left(Pc_{i,j,x} \times Pc_j^c\right) + \left(Pen_{i,j,x} \times Pen_j^c\right) \quad (4)$$

$$OTIFj,x = \frac{i - \sum_i Pen_{i,j,x}}{i} \quad (5)$$

Nomenclature S = Stock of j at time i in scenario x,
Pc = No. of purchase orders arriving at time i
Pen = Binary variable indicating whether a stock out occurs
C = Total Cost $OTIF$ = On Time in Full Measure
Subscripts: i = Time; j = Product No.; x = Scenario Number
Superscript: c = Cost of

In order to simplify the mathematics as well as reduce the computational time required, a simple campaigning version of the scheduling algorithm is used and a more fine resolution to be used [3].

3.3. Stock simulator

The stock simulator functions as a means by which the robust plan that is generated in the earlier section of the tool to be tested. The stock simulator will function on a more fine time resolution allowing the factoring of stochastic disturbances to see how the robust plan performs.
The basic protocol by which stock levels are simulated in the tool are illustrated in figure 5. There are two material classes which are used in the simulator component, raw materials and product materials. The simple case with raw materials, is that they cannot be manufactured on site and orders must be placed for them

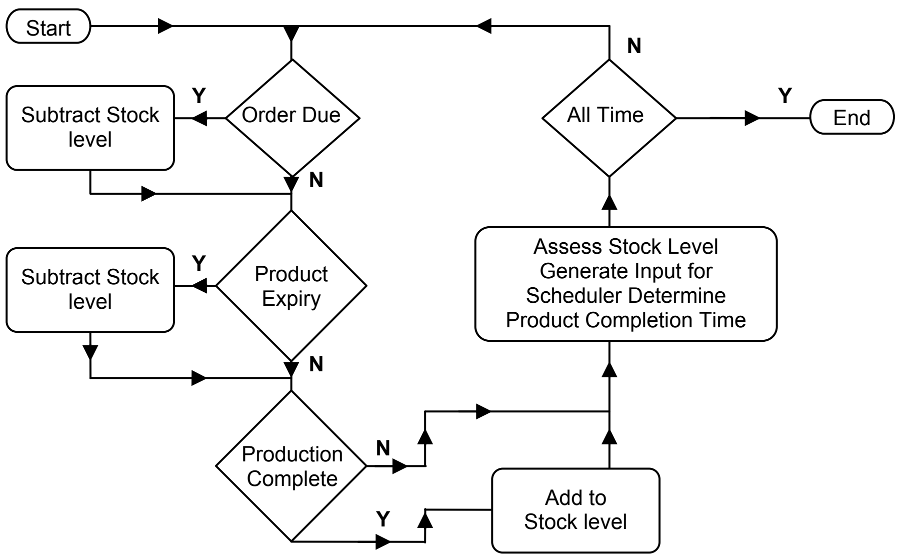

Figure 5: Program flow for the stock simulator. Note that the interface io the online scheduler is not fully shown here.

A simple online scheduler called SimpleSched [4] is used to better simulate the behaviour of the system.
The stochastic elements which are then added to test the suitability of the plan is currently done by introducing delays into the arrival of materials that are ordered, failure of the quality control step and machine unavailability. This is to test to see how truly robust the generated plan is.
The stochastic element modelling is not included in the robust planning section in order to reduce the complexity of the mathematics and thus reduce the computational time that is required.

4. Remarks

The work done thus far has proven insightful and interesting, although many more in-depth studies into each of the sections can be done. The tool does accomplish, albeit on a basic level, the aims and objectives that are stated earlier.
Future studies on the data generator in the form of sensitivity analysis and a more detailed and complex looking into how the original amount of data used impacts the quality of the demand scenarios created as well as the kind of exception rules that are used in the Markov Process.
Also, for the stock simulator to see how the online schedule can perhaps be improved and whether improving the amount of detail captured by the tool has any impact on its usefulness.

Acknowledgements

The financial support of the Overseas Research Scholarship (UK) and of ICI Strategic Technology group is gratefully acknowledged.

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