# IFAC/IFORS/IIASA/TIMS

The International Federation of Automatic Control
The International Federation of Operational Research Societies
The International Institute for Applied Systems Analysis
The Institute of Management Sciences

# SUPPORT SYSTEMS FOR DECISION AND NEGOTIATION PROCESSES

*Preprints of the IFAC/IFORS/IIASA/TIMS Workshop*
*Warsaw, Poland*
*June 24-26, 1992*

**Editors:**
*Roman Kulikowski*
*Zbigniew Nahorski*
*Jan W. Owsiński*
*Andrzej Straszak*

Systems Research Institute
Polish Academy of Sciences
Warsaw, Poland

**VOLUME 2:**

Names of first authors: **L-Z**

SYSTEMS RESEARCH INSTITUTE, POLISH ACADEMY OF SCIENCES

**SUPPORT SYSTEMS FOR DECISION AND NEGOTIATION PROCESSES**
Preprints, IFAC/IFORS/IIASA/TIMS Workshop, June 24-26, 1992, Warsaw, Poland

# A GENERALIZED MODEL FOR SERIES PRODUCTION LINES (SPL)

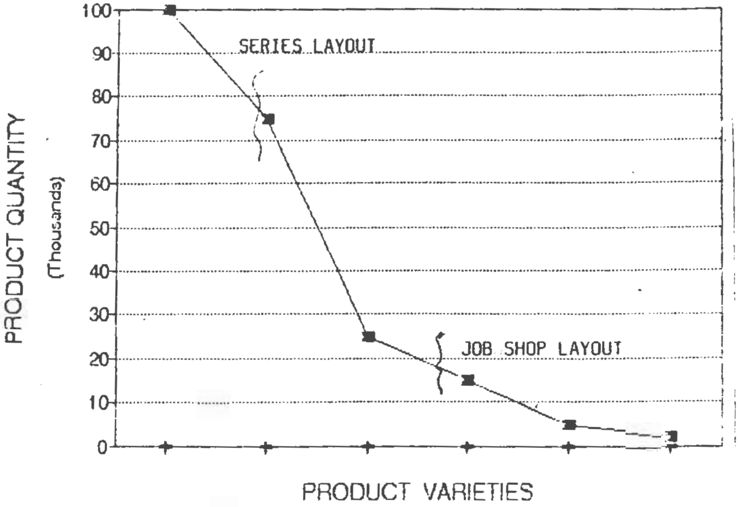
By: Prof. S. M. Seyed-Hosseini, Ph.D., P.E.
Department of Industrial Engineering,
Iran University of Science & Technology,
Narmak 16, Tehran/Iran

The problem of series production lines have been analyzed by many researchers during the last two decades. Because of the large expense of operating series production lines, it is necessary for management to know the reliabity, efficiency, and the effectiveness of the production layout arranged as series that may be obtained prior to implementation. The behavior of a series production line can be expressed as a Markov Chain. Markov Chain analysis is then used to derive equations that relate the efficiency, reliability, and the effectiveness of the series line with respect to the buffer capacity can be determined. The results can be evaluated with the simulation technique.

## INTRODUCTION

A Series Production Layout (SPL) is an arrangment of machines, operators, and operations to perform the production process. As the structural function of series layout indicates, each component can be assumed to be an unreliable part in which may contribute to the overall system breakdown. In order to increase the reliability of the system, the buffer storage can be used. So the series production components can be separated by buffer storages between them for finite production capacity.

One of the characteristics of the series production layout is its lower transportation cost, production time, easy control, and etc. in which almost is caused to be recommended to be implemented for high production process . Figure (1) represents the P-Q chart for various plant production layouts.




Figure(1) / The application of P-Q chart in layout planning

MODEL DESCRIPTION

In this paper a generalized model has been developed under certain assumptions. It is assumed that each SPL component may break down at random times and remain inoperable for random periods while they may be repaired. This is the most common feature of series production lines and it is the case that will be examined in this papar. Then the line or system efficiency of a SPL can be formulated and simulated under different assumptions.

## BUFFER STORAGE

The use of buffer storage certainly improves SPL efficiency by diminishing the forced down effect caused by any component breakdown. As long as the the buffers are not full or empty component in SPL are not forced down when one component breaks down unless it takes a long time to repair the broken down component. But if that repair time is longe enough, the upstream buffer can be full and/or the downstream buffer can be empty so that all other components in the line efficiency is increased when the capacities of buffers are increased.

As it mentioned, SPL may composed of differnt machines, operators, or operations that in this article all are called "components". So, if the buffer storage is used, according to our definition in SPL, the modification for underestanding should be made when the word of " component" is applied (to make sense).

However, the buffer storage may require high costs of floor space, material handling equipment, or according to our definition of components using it in any means of planning, the cost or "unwanted things" will be increased. So, for the planner, it is necessary to find optimum level of buffer storage (according to our definition of component) that can optimize the planner objective function.

## GENERAL MODEL ASSUMPTIONS

For the purpose of general model development, the following assumptions has been made:

(1) The supply of raw materials should always be available for the first component. So the first component is never to be starved.

(2) The last component should never be blocked, in the other word, a storage of infinite capacity should be provided for the last component.

(3) The probabilities of component breakdown and thier repairs are assumed to be constant.

(4) Series line operation policy stated by Buzacott is considered here again:

(a) No component is stopped when it is in the operating state unless it is forced down,

(b) The buffer stock is not increased or decreased except when a component broken down,

(c) Maintenance is only performed on a broken down component.

(5) The probability of zero buffer breakdown is assumed.

(6) Operaion dependent breakdowns, it means that a component can only breakdown in a cycle if it is in the working state at the bigininig of the cycle. So, a component can not breakdown if it is blocked or starved, and the probability of an operation dependent breakdown occuring in a cycle, does not depend on time but depends only on the mechanism of the related component.

(7) The probability of a time dependent breakdown does not depend on the mechanism of the component but depends on the time.

(8) The probability of more than one event occuring in a cycle is zero.

(9) For an N-component line the maximum number of events is N, that means that in a cycle each component can experince either a breakdown or a completion of repair.

Instantaneus transfer between component j and j+1, i.e., component j+1 recieves a workpiece in the same instant component j discharge a workpiece.

Following of this assumption, the next assumption also deals with instantaneous transfer with specific transfer steps as follow:

(11) In the two-step transfer model component j+1 does not recieve a workpiece in the same instant machine j discharge a workpiece. There are five types of two step transfer:

Type(1): Type 1 two step transfer is used by several authors. Steps 1 and 2 conditions are quoted from Soyster and Toof,

Step 1 conditions:

a. component j+1 must be in the operating state

b. It must be able to place an additional workpiece in buffer j+1. That is, the buffer contents are less than Zj+1

c. There must be a workpiece available in buffer j.

If three conditins a,b, and c are satisfied, component j+1 is able to process a workpiece. After component j+1 has processed its workpiece , then Step 2 can proceed,

Step 2 Conditions:

d. component j must be in the operating state.

e. It must be able to place an additional workpiece in buffer j. That is the buffer contents are less than Zj-1.

f. There must be a workpiece in buffer j-1.

If all three conditions d, e and e are satisfied, component j is able to process the workpiece.

Type 2: The same as type 1 except step 2 occures before step 1.

Type 3: For each step of transfer to occure all three conditions of step 1 and 2 must be satisfied:

a. Component j+1 must be in the operating state,

b. Component j+1 must be able to pick up a workpiece from buffer j.

If all two conditions a, b are satisfied, component j+1 is able to process the workpiece and proceed to the next condition c,

c. The workpiece is discharged from component j+1 and then the workpiece is recieved by buffer j+1.

If condition c is satisfied, the processed workpiece is discharged.

Step 2 Conditions:

d. Component j must be in the operating state.

e. Component j must be able to pick up a workpiece from buffer j-1

If all two conditions d and e are satisfied, component j is able to process the workpiece and proceed to the next condition f.

f. The workpiece is discharged from component j and then the workpiece is recieved by buffer j.

If condition f is satisfied, the processed workpiece is discharged to buffer j.

Type 4: The same as type 3 except step 2 occure before step 1

Type 5: There are two conditions in this type:

a. Buffer j-1 must have at least one workpiece.

b. Buffer j must not be full.

If all conditions a and b are satisfied, component j is able to process the workpiece successfully.

When a component break down while another is under repair, SPL requires another kind of assumptions as follows:

(12) The probability of one component breaking down during the repair of another component is assumed to be zero. For an N component line where Aj is the probabity that a component j is broken down, so by the mathematical notaion:

Aj=0 if any component k is in the broken down state,

where k=1,2,...,N

For example, for the three component series line two component cannot be broken down in the same cycle i.e.,

Prob.(NWW,i,j)=0

Prob.(NWN,i,j)=0

Prob.(WNN,i,j)=0

Where: $0 \leq i \leq Z1$,

$0 \leq j \leq Z2$

According to the notations used Z1 and Z2 are the buffer capacities for components ( Z1 buffer capacity between components 1 and 2, and Z2 buffer capacity between components 2 and 3).

(13) Two components may be broken down in the same cycle, as you may be noticed this assupmption is the converse of assumption 10. For example, for a three component SPL two compnent can be broken down in the same cycle.

(14) Three component may be broken down in the same cycle, i.e.,

Prob.(NNN,i,j) is not zero
Prob.(NWN,i,j) is not zero
Prob.(WNN,i,j) is not zero

Still some other assumptions should also be made in order to be able to develope a generalized SPL model. In this regards, there are three more assumptions required to treatment of semi-processed units during repair of a broken down components as follows:

(15) When a component breaks down, the workpiece it was processing is rejected or scrapped. Then,the workpiece is not returned to the upstream buffer or remain in the component. So based on this

assumption, the workpiece is scrapped during component breakdown.

(16) When a component breaks down, the workpiece it was processing is removed and returned to the upstream buffer. Therefore a repaired component can start to process a workpiece after repair is completed, as there is always at least one workpiece in the upstream buffer. So, the workpiece should be returned to the upstream buffer during component breakdown.

(17) When a component breakdown, the workpiece it was processing remains in the component during repair. If the repair is completed the component restarts its processing of the workpiece. Therefore a repaired component discharges the workpiece in the same cycle that repair is completed.

In order to develop a generalized model for SPL , the concept of MARKOVE CHAIN MODEL has been vastely used and the transition probabilities for all possible combinitions according to the indicated assumptions has been calculated. The method of solution consists of three steps:

(1) Find all possible transient states and construct system state transition table,

(2) Derive transition matrix from the system state transition table and derive a set of system transition equations,

(3) Solve the system state transition equation in terms of

breakdown and repair probabilities with respect to their buffer capacities.

SPL EFFECTIVENESS AND EFFICIENCY MEASURES

In order to calculate the effectiveness and efficiency of the SPL with different buffer capacity levels, a computer softeware is developed and under different assumptions the sensitivity analysis has been done. To have a different alternatives plan, a simulation technique also is applied and the results is compared. The SPL efficiency is calculated based on the equation bellow:

$$\text{SPL EFF.} = \frac{\text{THE NUMBER OF FINISHED WORKPIECES PRODUCED OVER SOME LONG TIME INTERVAL}}{\text{NUMBER OF FINISHED WORKPIECES THAT COULD HAVE BEEN PRODUCED IN THE SAME INTERVAL}}$$

Where:

$$0. \leq \text{SPL EFF.} \leq 1.$$

As you may be noticed, the use of buffer storage improves SPL efficiency by diminishing the forced down effect caused by a component breakdown. So, as far as the buffers are not full or empty, the SPL are not forced down and for the breakdown a good and suitable maitenance plan may prevent the long stopping experince.

MODEL APPLICATION

As it was mentioned, the application of SPL in assembly industries, production, office layout managment, service industries, plant layout managment and many other situations have been used and with the help of developed model, the reliability and the system effectiveness can be determined. In a new application of the model, the modified SPL is successfully applied for service industries and the results show the greate saving in the operating expense and the increasment of managemet capabiliy to control the process and evalute the amount of percieved saving using the simulation technique.

In Tables (1) through (3) the system state transition table for a general SPL model for a three components as an example, is shown.

ENTER MAXIMUM BUFFER LIMITS =)
10

| INIT. State | AFTER State | MACHINE1 fail | MACHINE1 fix | MACHINE2 fail | MACHINE2 fix | MACHINE3 fail | MACHINE3 fix | NO EVENT occured |
|---|---|---|---|---|---|---|---|---|
| WWWOO | WWWOO | NSWOO | | WNS10 | | WBN10 | | WWWOO |
| WWW10 | WWW10 | NWWOO | | BNS10 | | BBN10 | | WWW10 |
| WWNOO | WBN10 | NBN10 | | BNN10 | | | WWW10 | BBN10 |
| WWN10 | BBN10 | NBN10 | | BNN10 | | | WWW10 | BBN10 |
| WWSOO | WWWOO | NSWOO | | WNS10 | | WBN10 | | WWWOO |
| WWS10 | WWW10 | NWWOO | | BNS10 | | BBN10 | | WWW10 |
| WNWOO | WNS10 | NNS10 | | | WWW10 | BNN10 | | BNS10 |
| WNW10 | BNS10 | NNS10 | | | WWW10 | BNN10 | | BNS10 |
| WNNOO | WNN10 | NNN10 | | | BBN10 | | BNS10 | BNN10 |
| WNN10 | BNN10 | NNN10 | | | BBN10 | | BNS10 | BNN10 |
| WNSOO | WNS10 | NNS10 | | | WWW10 | BNN10 | | BNS10 |
| WNS10 | BNS10 | NNS10 | | | WWW10 | BNN10 | | BNS10 |
| WBWOO | WWWOO | NSWOO | | WNS10 | | WBN10 | | WWWOO |
| WBW10 | WWW10 | NWWOO | | BNS10 | | BBN10 | | WWW10 |
| WBNOO | WBN10 | NBN10 | | BNN10 | | | WWW10 | BBN10 |
| WBN10 | BBN10 | NBN10 | | BNN10 | | | WWW10 | BBN10 |
| WSWOO | WWSOO | NSWOO | | WNS10 | | WBN10 | | WWWOO |
| WSWOO | WWSOO | NSWOO | | WNS10 | | WBN10 | | WWWOO |
| WSNOO | WBNOO | NBNOO | | WNN10 | | | WWWOO | WBN10 |
| WSNOO | WBNOO | NBNOO | | WNN10 | | | WWWOO | WBN10 |
| WSSOO | WWSOO | NSWOO | | WNS10 | | WBN10 | | WWWOO |
| WSSOO | WWSOO | NSWOO | | WNS10 | | WBN10 | | WWWOO |
| NWWOO | NSWOO | | WWSOO | NNSOO | | NSNOO | | NSSOO |
| NWW10 | NWWOO | | WWWOO | NNSOO | | NBNOO | | NSWOO |
| NWNOO | NBNOO | | WBN10 | NNNOO | | | NSWOO | NBNOO |
| NWN10 | NBN10 | | BBN10 | NNN10 | | | NWWOO | NBN10 |
| NWSOO | NSWOO | | WWSOO | NNSOO | | NSNOO | | NSSOO |
| NWS10 | NWWOO | | WWWOO | NNSOO | | NBNOO | | NSWOO |
| NNWOO | NNSOO | | WNS10 | | NSWOO | NNNOO | | NNSOO |
| NNW10 | NNS10 | | BNS10 | | NWWOO | NNN10 | | NNS10 |
| NNNOO | NNNOO | | WNN10 | | NBNOO | | NNSOO | NNNOO |
| NNN10 | NNN10 | | BNN10 | | NBN10 | | NNS10 | NNN10 |
| NNSOO | NNSOO | | WNS10 | | NSWOO | NNNOO | | NNSOO |
| NNS10 | NNS10 | | BNS10 | | NWWOO | NNN10 | | NNS10 |
| NBWOO | NSWOO | | WWSOO | NNSOO | | NSNOO | | NSSOO |
| NBW10 | NWWOO | | WWWOO | NNSOO | | NBNOO | | NSWOO |
| NBNOO | NBNOO | | WBN10 | NNNOO | | | NSWOO | NBNOO |
| NBN10 | NBN10 | | BBN10 | NNN10 | | | NWWOO | NBN10 |
| NSWOO | NSSOO | | WWSOO | NNSOO | | NSNOO | | NSSOO |
| NSWOO | NSSOO | | WWSOO | NNSOO | | NSNOO | | NSSOO |
| NSNOO | NSNOO | | WBNOO | NNNOO | | | NSSOO | NSNOO |
| NSNOO | NSNOO | | WBNOO | NNNOO | | | NSSOO | NSNOO |
| NSSOO | NSSOO | | WWSOO | NNSOO | | NSNOO | | NSSOO |
| NSSOO | NSSOO | | WWSOO | NNSOO | | NSNOO | | NSSOO |
| BWW10 | WWW10 | NWWOO | | BNS10 | | BBN10 | | WWW10 |
| BWW10 | WWW10 | NWWOO | | BNS10 | | BBN10 | | WWW10 |
| BWN10 | BBN10 | NBN10 | | BNN10 | | | WWW10 | BBN10 |
| BWN10 | BBN10 | NBN10 | | BNN10 | | | WWW10 | BBN10 |
| BWS10 | WWW10 | NWWOO | | BNS10 | | BBN10 | | WWW10 |
| BWS10 | WWW10 | NWWOO | | BNS10 | | BBN10 | | WWW10 |
| BNW10 | BNS10 | NNS10 | | | WWW10 | BNN10 | | BNS10 |
| BNW10 | BNS10 | NNS10 | | | WWW10 | BNN10 | | BNS10 |
| BNN10 | BNN10 | NNN10 | | | BBN10 | | BNS10 | BNN10 |
| BNN10 | BNN10 | NNN10 | | | BBN10 | | BNS10 | BNN10 |
| BNS10 | BNS10 | NNS10 | | | WWW10 | BNN10 | | BNS10 |
| BNS10 | BNS10 | NNS10 | | | WWW10 | BNN10 | | BNS10 |
| BBW10 | WWW10 | NWWOO | | BNS10 | | BBN10 | | WWW10 |
| BBW10 | WWW10 | NWWOO | | BNS10 | | BBN10 | | WWW10 |
| BBN10 | BBN10 | NBN10 | | BNN10 | | | WWW10 | BBN10 |
| BBN10 | BBN10 | NBN10 | | BNN10 | | | WWW10 | BBN10 |

END OF SYSTEM STATE TRANSITION TABLE

TABLE (1) A SAMPLE OF COMPUTER PRINT-OUT FOR A THREE COMPONENTS STATE'S COMBINATIONS.

---

NOTE: EACH ENTRY IN THE TABLE COMPOSED OF 5 PLACES, 3 FOR COMPONENT'S STATE SPECIFICATIONS, AND THE OTHER TWO, FOR BUFFER CAPACITIES, N=NOT WORKING COMPONENT, W=WORKING COMPONENT, AND THE FOURTH AND FIFTH NUMBERS REPRESENT THE BUFFER CAPACITIES.

| State Before Inter Change | State After Inter. Change | 1 COMPONENT | | 2 COMPONENT , | | 3 COMPONENT | | No Event per Cycle |
|---|---|---|---|---|---|---|---|---|
| | | Fail | Repair | Fail | Repair | Fail | Repair | |
| WWW,0,0 | WWW,0,0 | $D_1$ NSW,0,0 | – | $D_2$ WNS,1,0 | – | $D_3$ WWN,0,1 | – | $D_4$ WWW,0,0 |
| WWW,1,0 | WWW,1,0 | $D_1$ NWW,0,0 | – | $D_2$ WNS,2,0 | – | $D_3$ WWN,1,1 | – | $D_4$ WWW,1,0 |
| : | : | : | | : | | : | | : |
| WWW,i,0 | WWW,i,0 | $D_1$ NWW,j–1,0 | – | $D_2$ WNS,i+1,0 | – | $D_3$ WWN,i,1 | – | $D_4$ WWW,i,0 |
| : | : | : | | : | | : | | : |
| WWW,Z,0 | WWW,Z,0 | $D_1$ NWW,Z–1,0 | – | $D_2$ BNS,Z,0 | – | $D_3$ WWN,Z,1 | – | $D_4$ WWW,Z,0 |
| WWW,Z,1 | WWW,Z,1 | $D_1$ NWW,Z–1,1 | – | $D_2$ BNW,Z,0 | – | $D_3$ WWN,Z,2 | – | $D_4$ WWW,Z,1 |
| WWW,Z,2 | WWW,Z,2 | $D_1$ NWW,Z–1,2 | – | $D_2$ BNW,Z,1 | – | $D_3$ WWN,Z,3 | – | $D_4$ WWW,Z,2 |
| : | : | : | | : | | : | | : |
| WWW,Z,j | WWW,Z,j | $D_1$ NWW,Z–1,j | – | $D_2$ BNW,Z,j–1 | – | $D_3$ WWN,Z,j+1 | – | $D_4$ WWW,Z,j |
| : | : | : | | : | | : | | : |
| WWW,Z,Z | WWW,Z,Z | $D_1$ NWW,Z–1,Z | – | $D_2$ BNW,Z,Z–1. | – | $D_3$ BBN,Z,Z | – | $D_4$ WWW,Z,Z |
| WWW,0,Z | WWW,0,Z | $D_1$ NSW,0,Z | – | $D_2$ WNW,1,Z–1 | – | $D_3$ WBN,1,Z | – | $D_4$ WWW,0,Z |
| WWW,1,Z | WWW,1,Z | $D_1$ NWW,0,Z | – | $D_2$ WNW,2,Z–1 | – | $D_3$ WBN,2,Z | – | $D_4$ WWW,1,Z |
| : | : | : | | : | | : | | : |
| WWW,i,Z | WWW,i,Z | $D_1$ NWW,i–1,Z | – | $D_2$ WNW,i+1,Z–1 | – | $D_3$ WBN,i+1,Z | – | $D_4$ WWW,i,Z |
| : | : | : | | : | | : | | : |
| WWW,Z-1,Z | WWW,Z-1,Z | $D_1$ NWW,Z–2,Z | – | $D_2$ WNW,Z,Z–1 | – | $D_3$ WBN,Z,Z | – | $D_4$ WWW,Z-1,Z |
| WWW,0,1 | WWW,0,1 | $D_1$ NSW,0,1 | – | $D_2$ WNW,1,0 | – | $D_3$ WWN,0,2 | – | $D_4$ WWW,0,1 |
| WWW,0,2 | WWW,0,2 | $D_1$ NSW,0,2 | – | $D_2$ WNW,1,1 | – | $D_3$ WWN,0,3 | – | $D_4$ WWW,0,2 |
| : | : | : | | : | | : | | : |
| WWW,0,j | WWW,0,j | $D_1$ NSW,0,j | – | $D_2$ WNW,1,j–1 | – | $D_3$ WWN,0,j+1 | – | $D_4$ WWW,0,j |
| : | : | : | | : | | : | | : |
| WWW,0,Z–1 | WWW,0,Z–1 | $D_1$ NSW,0,Z–1 | – | $D_2$ WNW,1,Z–2 | – | $D_3$ WWN,0,Z | – | $D_4$ WWW,0,Z–1 |

TABLE (2) DEVELOPED A SYSTEM STATE TRANSITION MATRIX FOR A GENERAL 3 COMPONENTS SPL, AS AN EXAMPLE.

---

NOTE: THE D'S IN TABLE WITH DIFFERENT ANDICES REPRESENT THE CALCULATED EQUATIONS OF PROBABILITIES FOR STATE TRANSITIONS.

| | WWW,0,0 | BBN,0,0 | BNS,0,0 | BNN,0,0 | NSS,0,0 | NNS,0,0 | NNN,0,0 | NSW,0,0 | NBN,0,0 | NSN,0,0 | WBN,0,0 | WWS,0,0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WWW,0,0 | $D_4$ | $D_3$ | $D_2$ | | | | | $D_1$ | | | | |
| BBN,0,0 | $V_3$ | $V_4$ | | $V_2$ | | | | | $V_1$ | | | |
| BNS,0,0 | $G_6$ | | $G_8$ | $G_7$ | | $G_5$ | | | | | | |
| BNN,0,0 | | | $H_7$ | $H_8$ | | | $H_5$ | | | | $H_6$ | |
| WWS,0,0 | $U_4$ | $U_3$ | $U_2$ | | | | | $U_1$ | | | | |
| WBN,0,0 | $Q_3$ | $Q_4$ | | $Q_2$ | | | | | $Q_1$ | | | |
| NSW,0,0 | | | | | $N_4$ | $N_2$ | | | | $N_3$ | | $N_1$ |
| NNS,0,0 | | | $K_1$ | | | $K_4$ | $K_3$ | $K_2$ | | | | |
| NNN,0,0 | | | | $L_1$ | | $L_3$ | $L_4$ | | $L_2$ | | | |
| NBN,0,0 | | $O_9$ | | | | | $O_{10}$ | | $O_{12}$ | | | |
| NSS,0,0 | | | | | $Y_4$ | $Y_2$ | | | | $Y_3$ | | $Y_1$ |
| NSN,0,0 | | | | | $O_3$ | | $O_2$ | | | $O_4$ | $O_1$ | |

TABLE (3) A SAMPLE OF TRANSITION MATRIX FOR A GENERAL SPL MODEL WITH A THREE-COMPONENT, THE PROBABILITY OF EACH EVENT IS SHOWN IN THE MATRIX.

# CONCLUSION

In this paper the seventeen required assumptions that are particularly desirable for a good modeling SPL has been argued. What is important to the aim of this research abridgment is that a reader would think about many current approaches that may come to his mind and to see to what extent and assumptions each model can be operational. The confirmation of this is a greate number of models proposed, the use of which though is not always economically convenient.

As a matter of fact the evalution of possible burdens concerning the development of SPL, specially when the number of components is more than three cannot be undervalued, particularly as far as the burdens deriving from the determination of SPL effectiveness, efficiency, availability and the reliability in any sector of its application, with respect to the different level of buffer capacities, various component's distribution breakdown, complexity of the SPL, complex production sequences, and specially unbalanced SPL, in which make this task to be a very difficult and time consumming pocedures. In this regards, having the suitable and logical assumptions is going to be onl; a practical tool to attack to research SPL.

For the purpose of demonstarion, a compuer program has been develope to produce all possible transient states and construct a system state transition table for different buffer storage levels. It goes without saying that, according to the assumptions mentioned in this paper, a full system state transition table is introduced and the equations of probability has been defined in which for a three component SPL, it came up with more than 78 equations. This indicates that if the number of component increases, under different level of buffer capacity, the number of calculations growth rapidly. In this regards, the special case (when the maximum buffer storage of 0, 1, and 2) was ran and all possible transient state were found and a system state transition table and equations was constructed for this special case in which some of these tables has been shown in this paper.

BIBLIOGRAPHY


(1) Buzacott J.A., " Automatic Lines With Buffer Stocks", Ind.J. Prod. Res., Vol. 5, pp. 183-200, 1976.

(2) Buzacott, J. A. " Prediction of the Efficiency of Systems Without Internal Storage", Int. J. Prod. Res., Vol.6,pp.173-188.

(3) Buzacott, J.A., "Markove Approach to finding Failure Times of Repairable Systems",IEEE Transactions on Reliability", Vol.19, pp.128-123, 1970.

(4) Buzacott, J. A., " The Role of Inventory Banks In Flow-Line Production System", Int. J. Prod. Res., Vol. 9, pp.425-436, 1971.

(5) Buzacott, J. A., " Models Of Automatic Transfer Lines With Inventory Banks ", AIIE Transactions, Vol. 10, pp.197-207, 1978.

(6) Elsayed, E. A. and Turley, R. E., "Reliability Analysis of Production Systems With Buffer Storage", Int. J. Prod. Res., Vol. 15, pp. 637-645, 1980.

(7) Gershwin, S. B., and Ammar, M., "Reliability in Flexible Manufacturing Systems", Proceeding of IEEE Conference On Decision and Control, Vol. 1, pp. 540-545, 1978.

(8) Gershwin, S. B. and Schick, I. C., " Modelling and Analysis of Three Stage Transfer Lines With Unrelibale Machines and Finite Buffers", Opra. Res. Vol. 31, pp. 354-380, 1983.

(9) Oh, Y. M., Efficiency of Series Production Line, The University of New South Wales, 1987.

(10) Ohmi, T, " an Approximation for the Production Efficiency Of Automatic Transfer Line with In-Process Storages", AIIE Transactions, Vol. 13, pp. 22-28, 1981.

(11) Okamura, K. and Yamashina, H., " Analysis of the Effect of Buffer Storage Capacity in Transfer Line Systems", AIIE Transaction, Vol. 9, PP. 127-135, 1977.

(12) Okamura, K. and Yamashina, H., " Justification for Installing Buffer Stocks In Unbalanced Two-Stage Automatic Transfer Lines ", AIIE Transactions, Vol. 11, pp. 308-312, 1979.

(13) Seyed-Hosseini, S. M., Availability Analysis of a System with N-Production Components Arranged as Product Layout, a paper submitted and presented at 12th Triennial Conference on Operations Research, Athens, Greece, 1990.

(15) Soyster, A. L., Schmidt and Rohrer, "Allocation of Buffer Capacities for a Class of Fixed Cycle Production Lines", AIIE Transaction, Vol. 11, pp.140-146, 1979.

(16) Soyster, A. L. and Toof, D. I., " Some Comparative and Design Aspects of Fixed Cycle Productions Systems", Naval Res. Logistics, Vol. 23, pp. 437-454, 1976.

(17) Wignaard, j., " The effect of Interstage Buffer Storage of Two Unrelibale Production Units in Series, With Different Production Rates", AIIE Transactions, Vol. 11, pp. 42-47, 1979.

(18) Yeralan, S. and Muth, E. J., " A general Model of aproduction Line with Intermediate Buffer and Station Breakdown", AIIE Transaction, Vol. 19, pp.130-139, 1987.