PERFORMANCE ANALYSIS OF PRODUCTION LINE WITH BERNOULLI’S MACHINES

Soumen Paul¹, Somnath Ganguly²

¹Assistant Professor, Mechanical Engineering, ²Assistant Professor, Electrical Engineering, Bankura Unnayani Inst. of Engg, West Bengal, India
sou_indicom@rediffmail.com, somnath_aec82@yahoo.co.in

Abstract

In flexible manufacturing environments, the performance of a production system is often affected by the sequence of operation. While performance evaluation, improvement and lean design of production system have been studied extensively, the joint effect of productivity and quality parameters on operation sequencing remains practically unexplored. Indeed, determining the optimal operation sequence has significant implication from both theoretical and practical perspectives. In this work the framework of Bernoulli reliability and quality models, we develop effective indicator that area simple and easy to implement in practice to determine the optimal operation sequence that maximize the system production rate.

1. INTRODUCTION

Performance evaluation, continuous improvement, lean design, and bottleneck identification of production systems have been studied extensively during the last 50 years. In this studies, it is often assumed that all parts are posed according to predetermined sequence of operations. The effect of the operation sequence (OS) on the performance of production systems, however, has not been systematically investigated. Indeed in flexible manufacturing environments, one type of final product can be produced by several sequence of operations. Thus, determining the optimal sequence of operations to be performed by all parts is of importance for the entire production processes. Practical example of operation sequencing can be widely found in product assembly [(3)], as well as in machining processes [(4)].

The development based on a recently developed improvement methodology for production system with quality quantity couple operation where by increasing the probability to complete a job during a cycle time leads to decreasing job quality. Production lines with unreliable machines usually contain finite capacity buffers intended to attenuate mutual perturbations of the machines due to breakdowns. It is well known that the capacity of the buffers should be as small as possible, that is, lean.

In the present work the production machine considered are unreliable machine and have non perfect quality. The buffers used between machines have finite capacity. In the several production lines the machines follow Bernoulli reliability and quality model.

The production system with unreliable machines, non perfect quality and finite buffer are considered. The serial production lines With M machines having Bernoulli reliability and quality models. According to these models, machine $m_i$, $i \in \{1, \ldots, M\}$, when neither blocked nor starved, produces a part during a cycle time with probability $p_i$ and fails to do so with probability $(1 - p_i)$; in addition, for each part produced by this machine, it is of good quality with probability $g_i$ and is defective with probability $(1 - g_i)$. Parameters $p_i$ and $g_i$ are referred to as the efficiency and quality of machine $m_i$, respectively. The Bernoulli reliability model is applicable to manufacturing operations where the unscheduled downtime is comparable to the cycle time (e.g., assembly and painting operations, conveyor pallet jams, etc.). The Bernoulli quality model is applicable when the defects are due to random and uncorrelated events (e.g., dust and scratches, etc.).

2. MODELING OF PRODUCTION LINE

![Image 1.1](image1.png)

Fig: 1.1 sequence $m_1 - m_2$

![Image 1.2](image2.png)

Fig: 1.2 Serial production line.

The following assumptions are consider for a production system with M machine shown in Fig. (i) The system consists
of M machines arranged serially, and M−1 buffers separating each consecutive pair of machines. (ii) The machines have identical cycle time Tc. The time axis is slotted with the slot duration Tc. Machines begin operating at the beginning of each time slot. (iii) Each buffer is characterized by its capacity, Ni ≤ 1 ≤ i ≤ M−1. (iv) Machine i is starved during a time slot if buffer i−1 is empty at the beginning of the time slot, and machine i+1 fails to take a part during the time slot. Machine M is never starved for parts. (v) Machine i + 1 fails to take a part during the time slot if buffer i has Ni parts at the beginning of the time slot, and machine i+1 fails to take a part during the time slot. Machine M is never blocked by ready goods buffer. (vi) Machines obey the Bernoulli reliability model, that is, machine i, i = 1, . . . , M, being neither blocked nor buffer.

(iii) Each buffer is characterized by its capacity, Ni ≤ 1 ≤ i ≤ M−1. Each machine takes a part during a time slot if buffer i−1 is empty at the beginning of the time slot, and machine i+1 fails to take a part during the time slot, and machine M is never starved for parts. (v) Machine i + 1 fails to take a part during the time slot if buffer i has Ni parts at the beginning of the time slot, and machine i+1 fails to take a part during the time slot. Machine M is never blocked by ready goods buffer. (vi) Machines obey the Bernoulli reliability model, that is, machine i, i = 1, . . . , M, being neither blocked nor starved during a time slot, and machine M is never starved for parts.

### 3. MATHEMATICAL EXPRESSION FOR PERFORMANCE MEASURES

**Production Rate (PR):** The production rate of a flexible manufacturing system may be defined as the average number of parts produced by the downstream machine per cycle time.

**Consumption Rate (CR):** It is defined as the average number of raw material consumed by the upstream machine per cycle time.

**Scrap Rate (SR):** Scrap rate means the average number of parts scrap by the machines per cycle time.

**Work-in-process (WIP):** work-in-process defined as the average number of parts produced by the downstream machine per cycle time.

### 3.1 SCRAP RATE

Scrap rate means the average number of parts scrap by the machines per cycle time.

\[
\text{SR} = \frac{\text{Production Rate}}{\text{Consumption Rate}}
\]

### 3.2 WORK-IN-PROCESS (WIP)

Work-in-process (WIP): work-in-process defined as the average number of parts produced by the downstream machine per cycle time.

\[
\text{WIP} = \frac{1 - \alpha^N (p_1 g_1 p_2)}{1 - \alpha (p_1 g_1 p_2)}
\]

Where \( p \) is the probability of failure of a machine.

### 3.3 PERFORMANCE MEASURES

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Blockages and starvations: Since these probabilities must evaluate blockages and starvations of the real, rather than aggregated, machines, taking into account expressions, the estimates of these performance measures, BLi and STi, are introduced as follows:

\[ BL_i = p Q(p_{b_i+1}^b; p_i^f; N_i); i = 1, \ldots, M - 1; \]

\[ ST_i = p Q(p_{i-1}^f; p_i^b; N_{i-1}); i = 2, \ldots, M; \]

4. RESULT AND ANALYSIS OF PERFORMANCE MEASUREMENT:

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CONCLUSIONS AND FUTURE WORK:

When the machine have different efficiency but quality does not exits the higher efficiency machine should be placed upstream to achieved higher production rate. In the same sense the results obtain from previous chapter when the machines have efficiency and quality parameter both, the lower quality machine placed upstream to achieved higher production rate. If the machine efficiency same it is shown that selecting the optimal operation sequence increased the production rate by 6% with typically reduction of work-in-processes by 15% 

The future of the system theoretic properties of production system includes: (1) Extension of the results obtained to production system with machines having other reliability and quality model e.g., exponential, Weibull, Gamma, Lognormal etc.(2) Generalization of the results for production system with different topologies, e.g., assembly system, closed line, re-entrant line etc.(3) Investigation of the effect of operation sequencing on the trade off among deferent performance measures.(4) Generalization of the results for small volume job-shop production environment with high product varity.

ACKNOWLEDGMENTS

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REFERENCES

[6]. A.B. Hu and S.M. Meerkov,” Lean Buffering in serial production line with Bernoulli machines , April 07.