Design and Operation of Manufacturing Systems

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November 5, 2005

1 Research Objectives

DESIGN AND OPERATION OF MANUFACTURING SYSTEMS is the name and focus of the research group headed by Stan Gershwin in the Laboratory for Manufacturing and Productivity of the Massachusetts Institute of Technology. The group's objective is to develop methods for the analysis, synthesis, and real-time operation of factories based on a fundamental, first-principles understanding of the dynamics of such systems. The role of random events is predominant, and the mathematical description of the response of the system to such events as machine failures, quality deterioration, stochastic demand, uncertain supplies, and inaccuracy in inventory estimates form an essential part of this research. The long term goal is to develop a coherent, comprehensive theory of manufacturing systems, and a set of practical computational tools to aid factory designers and operators, as well as related professionals such as product designers.

Current and past research support has come from Peugeot, Xerox, Hewlett Packard, Boeing, General Motors, Polaroid, Johnson & Johnson, United Technologies, the Semiconductor Research Corporation, the National Science Foundation, the Department of Energy, the Singapore–MIT Alliance, and other industry and government sources.

2 Prior Accomplishments

The group's past accomplishments include the following.

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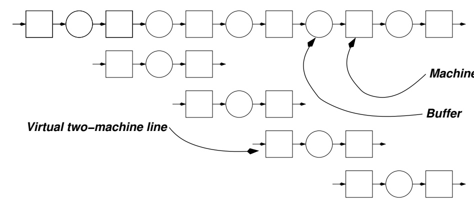
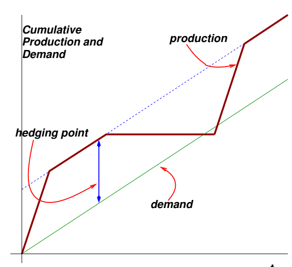


- The invention of decomposition methods for flow lines and tree-structured assembly/disassembly networks with unreliable machines and finite buffers (Gershwin 1987; Gershwin 1991). These methods permit the calculation of production rate and average inventory for systems that are being designed. Previous work in queuing systems treated in-process storage space as infinite. This assumption made the mathematics tractable, but it is not appropriate in a production environment where steps are taken to reduce inventory. This approach has been extended and has been quoted and used very widely.

- The application of the decomposition method to a Hewlett-Packard printer production line. This was worth hundreds of millions of dollars and was a finalist in the INFORMS Edeleman Competition. This experience is documented in Burman, Gershwin, and Suyematsu (1998).

- The invention of a new, rapid method for the optimization of in-process inventory space in flow lines (Gershwin and Schor 2000). This was the first use of a gradient method for this problem.



- The invention of the hedging point strategy and the hedging point concept for control of small production systems. This came from a fundamental dynamic programming analysis of the real-time scheduling of production in a manufacturing system with unreliable machines (Kimemia and Gershwin 1983). This concept has been quoted very widely.

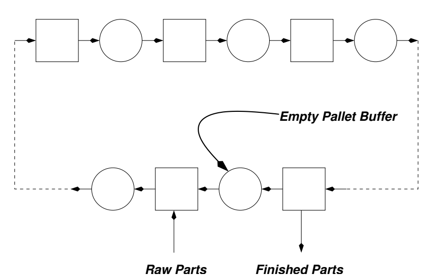
- The book *Manufacturing Systems Engineering* (Gershwin 1994) and numerous papers in international journals.

- The invention of the control point policy, which is an extension of the hedging point policy to multiple-stage production systems (Gershwin 2000). A unification of surplus-based, time-based, and token-based policies followed from the same analysis.

- Two awards by the Institute of Industrial Engineers were given to the paper "Design and Operation of Manufacturing Systems — The Control-Point Policy," (Gershwin 2000):

  ⋆ the **Best Paper Award** for the *IIE Transactions* focus issues on Design and Manufacturing for 2000-2001, and

  ⋆ the **Outstanding IIE Publication Award** for 2000-2001.



- A new analysis method for production systems with single loop (Gershwin and Werner 2003). This is useful for evaluating production systems with captive pallets or fixtures as well as systems controlled by the CONWIP (constant work-in-process) scheduling policy.

- A new analysis method for production system with multiple loops (Levantesi 2001). This extends our evaluation methods to a very large class of systems, including systems controlled by a wide variety of policies.

- The recent initiation of research into the relationship among quality, quantity, and inspection (Kim 2004, Kim and Gershwin 2005, Gershwin, Kim, and Schick 2005). More frequent inspection is one way of increasing the yield of a system, because when defects are discovered sooner, the cause of the defects can be repaired sooner. Defects waste material (or require expensive rework), and defective parts that are not detected early waste the time of all the machines and workers that are devoted to them. (Defects that are never detected in the factory are the worst of all.) However, frequent inspection adds to production costs. This is well known, but there has been no quantitative analysis in this relationship. This has generated considerable interest, and researchers elsewhere are beginning to contribute to this analysis.

- The recent initiation of research into information inaccuracy in inventory systems (Kang and Gershwin 2005). Virtually every research document ever written on inventory theory has assumed that managers have a perfect knowledge of their inventory. Managers know that this is far from true, and there are major ongoing technological efforts (eg, RFID tags) to improve inventory accuracy. Our work investigates the value of such technology, and proposes alternative methods using existing technology to improve such estimates.

3 Current Research

The group's current work extends and improves our earlier work, and also opens new research directions. Our activities include:

- Extension of decomposition methods to multiple-part type systems. This is an important step in expanding the set of production systems we can analyze.

- Improvement of our analysis method for systems with multiple loops. The method already developed is a proof of concept, but it is too slow for practical use. We are investigating improvements that will accelerate its performance.

- Continuation of our work relating quantity and quality in production systems. Earlier work on inspection strategies focused only on the quality of the parts; we consider the impact of the inspection policy on the maintenance of machines, and the resultant impact on production rate an production costs.

4 Future Research Goals

With the same long term research objective always in mind, we plan to continue extending and improving our results, and to continue exploring related new directions. We will maintain and increase our ties to industry (which provides specific problems, guidance, data, experimental sites, as well as support). We are considering the following future activities:

- Optimization of control point policy parameters. We will extend our rapid optimization methods to the choice of buffer sizes, hedging points and other parameters of the control point policy.
- Investigation of MRP nervousness. The widely used MRP policy was designed in a world of slow computers, which meant that its schedules were revised infrequently. The speed of modern computers tempts managers to recalculate their schedules whenever a change occurs in demand, factory resources, etc. Unfortunately, this frequent changing can lead to chaotic changes in the schedules, which leads to reduced performance and friction between suppliers and customers. We will investigate this phenomenon and seek ways of mitigating it.
- Integration of the design of lines, operating policies, and inspection strategies. At present, these issues are treated separately, and this may cause the loss of some performance or economy. We plan to integrate our results in a single optimization model, and apply the special purpose optimization methods that we have developed to treat all these issues in a single, coherent approach.

5 Research Personnel

Because this research group is based at a university, the composition of the group changes from year to year. What remains constant is the high quality of the members of the group. It consists predominantly of MIT students pursuing Master's and Doctoral degrees. They are joined by visiting scientists and professors, post-doctoral researchers, some of the best Master's and Doctoral students from other universities, and sometimes MIT undergraduates. Stan Gershwin is the leader of the group; he is a Senior Research Scientist at MIT and he holds a BS degree from Columbia University and Master's and PhD degrees from Harvard University. Irvin C. Schick is a Research Scientist who holds BS, Master's and PhD degrees from MIT.

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