

RESEARCH REPORTS

EXECUTIVE SUMMARIES OF CURRENT STUDIES

EDITED BY MARK S. DASKIN

Reliability is an increasing concern in industry. This edition of Research Reports highlights three papers that focus on different aspects of the reliability problem, including the choice between standby and active redundancy, the method of allocating limited resources to redundant components to maximize reliability, and the impact of delayed versus scheduled maintenance on job tardiness.

Each of the research studies summarized below can be found in the June issue of *IIE Transactions* (Vol. 35, No. 6).

STANDBY OR ACTIVE REDUNDANCY?

System design optimization approaches are determined to maximize reliability when either active or cold-standby redundancy can be selectively chosen for individual subsystems within an overall design. There are many engineering system design projects that require the use of redundancy to meet very high reliability expectations. For some of these, the choice of redundancy type becomes

an additional design variable.

Active redundancy involves the use of fully activated components that can continue to provide needed design functions in the event of failure, while standby redundancy involves the use of non-activated components that can be activated in response to failure. For example, the computer servers, routers, bridges, and links required to operate an e-business successfully must provide computer systems that are extremely reliable. Redundancy at several levels is a necessity for the systems to achieve the required reliability.

Designers can use active redundancy, like RAID (redundant array of inexpensive disk) or disk mirroring, or they can use additional computers and hardware for standby. Often, systems are designed with both types of redundancy in different parts of the system. Additionally, the switches used to detect failure and activate redundant units have become quite sophisticated and must be considered. There are many other examples in which the redundancy type is a design variable, including highly reliable telecommuni-

cation systems using fiber optic cable.

In "Maximization of System Reliability with a Choice of Redundancy Strategies," David Coit presents a new method to determine optimal system design configurations when there is a choice of redundancy strategies. Formulation of the problem in this way is more realistic and provides a better tool for designers and reliability analysts. Optimal solutions to the problem are found by an equivalent problem formulation and integer programming considering imperfect switching of standby redundant components. The optimal system design is distinctly different from the corresponding design obtained with only active redundancy.

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ALLOCATING REDUNDANT RESOURCES

In competitive markets, developing reliable and cost-effective systems is imperative. To achieve the very high levels of reliability demanded by consumers, the system design must use redundancy so that it can provide full functionality even in the presence of individual component failures.

Consider the design of a telecommunications satellite: The system must be highly reliable because it is difficult or impossible to repair, yet the design is also highly constrained, limiting the amount of redundant circuits and components that can be included. There are numerous other application areas of the redundancy allocation problem, including those in medicine, aerospace, and communications, where the desire for system reliability



David Coit devised a method to determine whether active or standby redundancy is a better strategy.



Sadan Kulturel-Konak and other researchers are examining the problem of allocating redundant resources.

is extremely high and the system design is constrained by cost as well as space, weight, or power.

While there are many forms of the redundancy allocation problem, it generally involves the selection of components and redundancy levels to maximize system reliability given various system-level constraints, such as cost and weight. This has been extensively studied with mathematical approaches such as dynamic programming, integer programming, and nonlinear optimization. Due to the nature of these exact mathematical approaches, the design problem often only considered a restricted set of possible solutions, usually limiting each functional component to a single type.

In "Efficiently Solving the Redundancy Allocation Problem Using Tabu Search," Sadan Kulturel-Konak, Alice E. Smith, and David W. Coit apply tabu to a relaxed problem domain that is more reflective of the actual design problem. The authors show that tabu search, coupled with an innovative adaptive penalty function, is a computationally tractable methodology for redundancy allocation problems.

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INTEGRATING MAINTENANCE AND SCHEDULING

Most manufacturers are challenged by problems related to production scheduling and preventive maintenance planning. Preventive maintenance may consume time that could be used for production, but delaying preventive maintenance in order to expedite production may increase the risk of machine failure and additional machine downtime. Despite this relationship between the two areas, production scheduling and preventive maintenance planning typically are treated independently in the research literature and in practice.

In "Minimizing Job Tardiness Using Integrated Preventive Maintenance Planning and Production Scheduling," Richard Cassady and Erhan Kutanoglu present an optimization model that integrates production scheduling and preventive maintenance planning decision making by minimizing average job tardiness. Designed for a single machine, the model considers the machine's production requirements (job processing times, due dates, and importance weights) and reliability and maintainability characteristics (failure rate, repair time, and preventive maintenance time) in developing a production schedule supplemented with preventive maintenance actions.

An extensive set of numerical examples provide insight into the implications and benefits of integrating the two decision-making processes. In the majority of the examples studied, the integrated solution is different from the production schedule and preventive maintenance plan that result from solving the two problems



The optimization model Richard Cassady worked on presents integrated solutions to balancing preventive maintenance with production scheduling.

independently. Furthermore, the integrated solution yields an overall reduction in average job tardiness of approximately 30 percent.

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