# Title and Subtitle

**Heuristic Methods in Applied Probability**

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## Abstract

The purpose of this research program is the development of heuristic and algorithmic approaches to various problems of engineering and applied mathematical interest. This research program was initiated under the guidance of Professor Marcel F. Neuts. Unfortunately, a substantial revision of the project budget required his resignation from the project. Thus, in this report, we will summarize the work of Dr's Julia L. Higle, who investigates problems of stochastic optimization and develops non-accident based measures of vehicular traffic hazards, and Jeffery B. Goldberg, who investigates problems of design for reliability and manufacturability, decision making in Just-In-Time manufacturing systems, and approximation models for spatially distributed queueing systems. These investigators and the students supported during the final year of this grant work in quite diverse areas, but share a strong interest in algorithmic methodology.
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1. GENERAL SUMMARY

The purpose of this research program is the development of heuristic and algorithmic approaches to various problems of engineering and applied mathematical interest. This research program was initiated under the guidance of Professor Marcel F. Neuts. Unfortunately, a substantial revision of the project budget required his resignation from the project. Thus, in this report, we will summarize the work of Dr.'s Julia L. Higle, who investigates problems of stochastic optimization and develops non-accident based measures of vehicular traffic hazards, and Jeffrey B. Goldberg, who investigates problems of design for reliability and manufacturability, decision making in Just-In-Time manufacturing systems, and approximation models for spatially distributed queueing systems. These investigators and the students supported during the final year of this grant work in quite diverse areas, but share a strong interest in algorithmic methodology.

This report includes a list of all Journal articles and Technical Reports prepared during the final year of funding.

2. DISCUSSION OF THE PAST YEAR'S ACCOMPLISHMENTS

Dr. Julia Higle: In the past year, we have continued our investigations in two primary areas: further development of Stochastic Decomposition, and development of methods for analyzing non-accident based measures of vehicular traffic hazards.

During the past year, the Stochastic Decomposition algorithm has undergone developments in two directions. To alleviate the potential computational burden associated with the method, we have been able to include a slight alteration of the algorithmic statement that allows a predetermined bound on the number of cutting planes required by the method. In previous versions of the algorithm, we have (in theory) required a potential proliferation of cutting planes in order to verify the asymptotic properties of the method. By including a regularizing term in the master program, this proliferation can be avoided without sacrificing the theoretical properties of the method. Our computational results reflect the obvious savings that result from this change. We have also investigated the viability of a subgradient optimization technique based on the type of statistically motivated approximations derived by an SD algorithm. Along another line, we have also investigated a variation of the basic SD method that can be construed as providing a more direct algorithmic interface between simulation output and mathematical programming techniques.
Dr. Diana Yakowitz, a Ph.D. candidate whose research has been supported by the grant, has completed her degree program and is currently employed by the University of Arizona, Department of Hydrology.

Dr. Steven J. Oakley has completed his dissertation, which involved a study of orthogonal polynomials in the approximation of probability distributions. The techniques that he developed have provided a computationally tractable method for investigating non-accident based measures of vehicular traffic safety. Following a one year visiting position at the University of Tennessee, Dr. Oakley has decided to join Decision Technologies at American Airlines.

Dr. Higle and her students have reported on their ongoing research in the following presentations:


Dr. Jeffrey Goldberg: During the past year, the research of Professor Goldberg has continued along three paths; models and algorithms for product design for manufacturability, decision models for Just-In-Time systems and approximation models for geographically distributed queueing networks.

The research in product design centers around the development of algorithms to solve models to aid in design decisions. In this research we have empirically evaluated stochastic neighborhood search algorithms (simulated annealing). We have found that the neighborhood structure (size and connectivity) in these algorithms are crucial for successful application. A paper containing the results of this work, including a large computational study, has been accepted for publication in *Computers and Operations Research* and in the Masters thesis of Kah Mun Cheh - *The Effect of Neighborhood Structure on Simulated Annealing*
Also, we have considered decision models for simultaneously designing standard modules and selecting part type reliabilities within the framework of modular design. Initial solution attempts based on monotonicity look promising in that they greatly improve starting solutions and tend to be robust over a variety of starting solutions. This work is contained in a chapter in the dissertation of Gamage Viriththamulla (completed 4/15/91) and will be rewritten into a paper during the summer of 1991.

The research in decision problems in Just-In-Time (or Kanban) manufacturing systems focuses on the fundamental issue of determining the inventory level (or number of Kanban) between two production centers. A model was developed to consider the trade-offs between excess inventory and machine downtime due to insufficient material in a multi-item two stage system. Simulation results show that the model has a high degree of validity when the average queuelength can be accurately estimated. The results of this study are contained in a forthcoming publication in IIE Transactions.

The research in distributed queueing models has been applied mainly to the emergency vehicle location problem. The most significant results of this research were an algorithm with guaranteed convergence properties for the basic model where servers are assumed to operate independently, an algorithm with guaranteed convergence properties for the basic model corrected for server dependence (but requiring assumptions of equal server utilization), and an extension of a basic model to include the possibility of multiple servers per call and multiple servers per server base. We have found that when the server independence assumption is used, the basic model generates estimates of server utilization generally within 10% of the actual server utilization (as predicted by a simulation model) in a wide variety of test cases. We have developed an alternate model and solution method that does not require the server independence assumption and hence predicts system performance more accurately. The work concerning the independence assumption, model validity and the alternate solution process is contained in the thesis of Ricardo Benitez (supported by the grant) - 'Evaluating Bias in Models for Predicting Emergency Vehicle Busy Probabilities'.

Dr. Goldberg has reported on his ongoing research in the following presentations:


'Determining the Number of Kanban in Multi-Item Just-in-Time Systems', Material Handling Research Conference, June 1990, Cincinnati, Oh.

'Evaluating Performance in EMS Systems: An Example of the link between Mathematics and OR', Mathematical Association of America, National Meeting,
August 1990, Columbus, Oh.

JOURNAL ARTICLES

The following journal articles, written with the partial support of the Grant, have now been published or accepted for publication:


Higle, J.L. and M.B. Hecht, 'A Comparison of Techniques for the Identification of Hazardous Locations', *Transportation Research Record, #1238, Application and Management of Accident Data, pp. 10-19*.


3. RECENT PREPRINTS

The following are Technical Reports prepared with the support of the current Grant:


Higle, J.L. and S. Sanchez, ‘Observational Studies of Rare Events: A Selection Approach’, submitted to JASA.