(2)

AD-A238 229

MENTATION PAGE

Form Approved
OMB No. 0704-0188



| 1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE | 3. REPORT TYPE AND DATES COVERED |
|---|---|---|
| | | FINAL 01 Dec 89 to 30 May 90 |

4. TITLE AND SUBTITLE

HEURISTIC METHODS IN APPLIED PROBABILITY

5. FUNDING NUMBERS

AFOSR-88-0076
61102F 2304/A5

6. AUTHOR(S)

JULIA L. HIGLE

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

UNIVERISRTY OF ARIZONA
ARIZONA BOARD OF REGENTS
TUCSON AZ 85721

8. PERFORMING ORGANIZATION REPORT NUMBER

AFOSR-TR- 91 0615

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

AFOSR/NM
Bldg 410
Bolling AFB DC 20332-6448

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

AFOSR-88-0076

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release;
distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

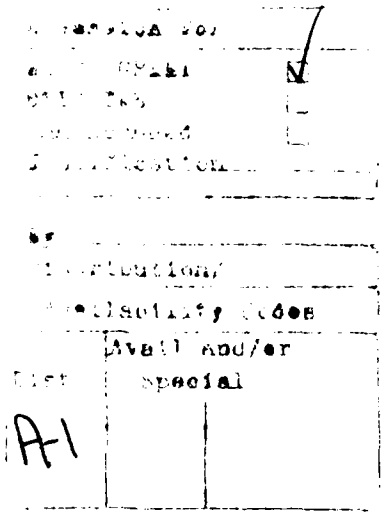
The purpose of this researh program is the development of heuristic and algorithmic approaches to various problems of engineering and applied mathematical interest. This research program was initiated under the guidance of Professor Marcel F. Neuts. Unfortunately, a substantial revision of the project 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.

| 14. SUBJECT TERMS | | | 15. NUMBER OF PAGES |
|---|---|---|---|
| | | | 16. PRICE CODE |
| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
| unclassified | unclassified | unclassified | ul |

PROGRESS REPORT ON RESEARCH SUPPORTED BY

Grant Nr: AFOSR-88-0076

AT THE UNIVERSITY OF ARIZONA




Submitted by:

Julia L. HIGLE

Assistant Professor and Principal Investigator

Co-Investigator:

Jeffrey GOLDBERG, Assistant Professor

Department of Systems and
Industrial Engineering
University of Arizona
Tucson Arizona 85721

(602) 621-2525

Title: Heuristic Methods in Applied Probability

Period of Award: 12/01/89-5/30/91

Amount of Award: $90.000

Date submitted: May 30, 1991

## 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 Decompostion, 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 astotic 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 progamming 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:

'A Primal-Dual Method for the Determination of Step Lengths in Subgradient Optimization', ORSA/TIMS Joint National Conference, May 1990, Las Vegas NE.

'Orthogonal Polynomials in the Approximation of Probability Distributions', ORSA/TIMS Joint National Conference, May 1990, Las Vegas NE.

'Conditional Stochastic Decomposition (CSD) for Stochastic Linear Programs with Recourse', ORSA/TIMS Joint National Conference, October 1990, Philadelpha, PA.

'Two Stage Stochastic Programs with Constrained Recourse Values', ORSA/TIMS Joint National Conference, October 1990, Philadelpha, PA.

'Stochastic Decomposition Approach for Convex Stochastic Programs', TIMS Special Interest Conference on Applied Probability in the Engineering, Information, and Natural Sciences, January 1991. Monterey, CA.

**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 promissing 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 assmption, model validity and the alternate solution process is contained in the thesis of Ricardo Benitez (suppported 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:

'Solving Nonlinear Equations Used in EMS Location Models', ORSA/TIMS Joint National Meeting, May 1990, Las Vegas, Ne.

'A General Model and Convergence Results for Vehicle Utilization in EMS Systems', ORSA/TIMS Joint National Meeting, May 1990, Las Vegas, Ne.

'Evaluating the Independence Assumption in EMS Location Models', ORSA/TIMS Joint National Meeting, May 1990, Las Vegas, Ne.

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

'Evaluating Performance in EMS Systems', PTO Department Seminar Series, College of Business, Arizona State University, October 1990, Tempe, Az.

'Estimating Emergency Vehicle Busy Probabilities When Multiple Vehicles are Co-Located or Calls Require Multiple Vehicles', ORSA/TIMS Joint National Meeting. October 1990, Philadelphia, Pa.

'Estimating Emergency Vehicle Busy Probabilities Under and Infinite Queue and Location Dependent Service Times', ORSA/TIMS Joint National Meeting, October 1990, Philadelphia, Pa.

'Modeling and Computational Extensions, and Computer Implementation of EMS System Research', SIE Department Seminar Series, January 1991, Tucson, Az.

'Modeling Performence in Emergency Vehicle Systems', District XII, IIE Student Conference, January 1991, Tucson Az.

JOURNAL ARTICLES

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

Askin, R., M.G. Mitwasi, and J. Goldberg, 'Determining the Number of Kanban in Multi-item Just-in-Time Systems', to appear in *IIE Transactions*.

Corrado, C. and J.L. Higle, 'Economic Investment Times for Capacity Expansion Problems', to appear in *European Journal of Operational Research*.

Goldberg, J., R. Dietrich, J. Chen, M.G. Mitwasi, T. Valenzuela, and E. Criss, 'A Simulation Model for Evaluating a Set of Emergency Vehicle Locations: Development, Validation, and Usage', *Socio-Economic Planning Sciences*, vol. 24, pp. 125-141.

Goldberg, J., R. Dietrich, J. Chen, M.G. Mitwasi, T. Valenzuela, and E. Criss, 'Validating and Applying a Model for Locating Emergency Medical Vehicles in Tucson, Arizona', *European Journal of Operational Research*, vol. 49, pp. 308-324.

Goldberg, J., and L. Paz, 'Locating Emergency Vehicle Bases When Service Time Depends on Call Location', to appear in *Transportation Science*.

Goldberg, J., and E. Smith, 'Repair Policies for Additively Degrading Machines', *International Journal of Production Research*, vol. 28, pp. 1955-1976.

Goldberg, J., and F. Szidarovszky, 'A General Model and Convergence Results for Determining Vehicle Utilization in Emergency Service Systems', to appear in *Stochastic Models*.

Goldberg, J., and F. Szidarovszky, 'Methods for Solving Nonlinear Equations used in Evaluating Emergency Vehicle Busy Probabilities', to appear in *Operations Research*.

Higle, J.L., 'Production Planning with Discounting and Stochastic Demands', *European Journal of Operational Research*, vol. 50, no. 3, pp. 257-265.

Higle, J.L., J.C. Bean, and R.L. Smith, 'Deterministic Equivalence in Stochastic Infinite Horizon Optimization', *Mathematics of Operations Research*, vol. 15, no. 3, pp. 396-407.

Higle, J.L. and S. Sen, 'Statistical Verification of Optimality Conditions', to appear in *Annals of Operations Research*.

Higle, J.L. and S. Sen, 'Stochastic Decomposition: An Algorithm for Two Stage Linear Programs with Recourse', to appear in *Mathematics of Operations Research*.

Higle, J.L. and S. Sen, 'On the Convergence of Algorithms, with Applications to Stochastic and Nondifferentiable Optimization', to appear in *Mathematics of Operations Research*.

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.

Cheh, K., J. Goldberg, and R. Askin, 'A Note on the Effect of Neighborhood Structure in Simulated Annealing', to appear in *Computers and Operations Research*,

Valenzuela, T., J. Goldberg, K. Keeley, and E. Criss, 'Computer Modeling of Emergency Medical System Performance.' *The Annals of Emergency Medicine*, vol. 19, pp. 898-901.

## 3. RECENT PREPRINTS

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

Au, K.T., J.L. Higle, and S. Sen, 'Inexact Subgradient Methods with Applications in Stochastic Programming', submitted to *Math. Programming*.

Goldberg, J., and F. Szidarovszky, 'A Model for Determining Vehicle Utilization Under Location Dependent Service Time, and Multiple Vehicles per Call or Multiple Vehicles per Base', submitted to *Operations Research.*

Goldberg, J., and R. Benitez, 'Evaluating Bias in Models for Estimating Busy Probabilities in Emergency Vehcile Systems', submitted to *Transportation Science.*

Higle, J.L. and S.J. Oakley, 'An Approximation Scheme for Traffic Safety Evaluation Using Traffic Conflicts', submitted to *Operations Research.*

Higle, J.L., W.W. Lowe, and R. Odio, 'Conditional Stochastic Decomposition: An Algorithmic Interface for Simulation and Optimization', submitted to *Operations Research.*

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

Higle, J.L., Sen, and D. Yakowitz, 'Finite Master Programs in Stochastic Decomposition', submitted to *Math. Programming*.