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NORTHWESTERN UNIV EVANSTON ILL DEPT OF INDUSTRIAL E--ETC F/G 15/5  
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Final Report

on

Contract N00014-75-C-0797

Task NR -42-322

entitled

MAINTAINABILITY

Report No. 1

May, 1977

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JUN 3 1977  
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Summary of all Work under Task NR 042-322

There were five major technical reports produced as a result of research on this Task Order. Reports #1, 2, 3, and 5 deal directly with the subject of Maintainability. Report #4 deals only indirectly with maintainability but does assess optimal stocking quantities for items which are subject to deterioration over time.

Although the contract has terminated, there is still some ongoing research and writing in this and related areas. It is anticipated that much of this work will be published in the near future.

Technical Report #1 (W. P. Pierskalla and J. A. Voelker)

"A Survey of Maintenance Models: The Control and Surveillance of Deteriorating Systems," Naval Research Logistics Quarterly, vol. 23, no. 3 (September, 1976), pp. 353-386.

Abstract

The literature on maintenance models is surveyed. The focus is on work appearing since the 1965 survey, "Maintenance Policies for Stochastically Failing Equipment: A Survey" by John McCall and the 1965 book, The Mathematical Theory of Reliability, by Richard Barlow and Frank Proschan. The survey includes models which involve an optimal decision to procure, inspect, and repair and/or replace a unit subject to deterioration in service.

Technical Report #2 (J. A. Voelker)

"Contributions to the Theory of Mass Screening," Ph.D. dissertation, Department of Industrial Engineering and Management Sciences, Northwestern University, Evanston, Illinois 60201, June, 1976, pp. 1-111.

Abstract

This thesis develops and analyzes two analytical models of a mass screening program. In both models, the defect arrival process is Poisson and the ability of the test to recognize a defect is not, in general, assumed perfect.

The first model represents the evolution of the defect, once it occurs, as a semi-Markov process. Both the test reliability and the detection payoff are dependent upon the state of that process.

The second model is structurally simpler, focusing on the time since incidence of a defect as the factor which determines the reliability of a test administration and the value of a detection. There is no concept of defect state. In this model, various subproblems and special cases are considered including the following: the allocation of a screening budget among subpopulations characterized by different susceptibilities to the defect and different testing costs; decision rules for the choice of type of tests when two different types differ with respect to cost and reliability; and an empirical, ethically acceptable procedure for estimating the shape of the function relating detection delay disutility to detection.

Technical Report #3 (W. P. Pierskalla and J. A. Voelker)

"A Model for Optimal Mass Screening and the Case of Perfect Test Reliability," Department of Industrial Engineering and Management Sciences, Northwestern University, Evanston, Illinois 60201, December, 1976, pp. 1-37.

Abstract

This paper considers a population (composed, for example, of people, machines, or livestock) subject to a randomly occurring defect or disease. If there exist testing procedures capable of detecting the defect before it would otherwise become known, and if such early detection provides benefit, the periodic administration of such a test procedure to the members of the population, i.e., a mass screening program, may be advisable. An analytical model of a mass screening program is developed and analyzed. In the development of the model, the defect arrival process is Poisson and the ability of the test to recognize a defect is not, in general, assumed perfect.

The model focuses on the time since incidence of a defect as the factor which determines the reliability of a test administration and the value of a detection. The objective is to minimize an arbitrary increasing function of the detection delay which represents the disutility from the occurrence of the defect and its detection. This disutility is also represented as a function of the type of test applied, the probability of success of the test, the testing intervals and the arrival rates of the defects over  $Q$  subpopulations. A relatively simple expression is derived for the objective function and a comprehensive mathematical program is presented. The case of perfect test reliability is then considered and,

from the class of "cyclic" schedules, the optimum schedules are shown to be equally spaced. For a polynomial disutility function, properties of the optimal schedules are presented. Finally, a method for determining the disutility function from experimental data is suggested.

Technical Report #4 (B. L. Deurmeyer and W. P. Pierskalla)

"A By-Product Production System with an Alternative," Department of Industrial Engineering and Management Sciences, Northwestern University, Evanston, Illinois 60201, January, 1977, pp. 1-25, submitted to Management Science.

#### Abstract

This paper considers the optimal control of a production system which is composed of two distinct production processes, called type A and type B. These production processes are used to produce two different products called I and II. It is assumed that the demands for these products are sequences of continuous, nonnegative and independent random variables with known distributions. Production type A is used to produce both products, but they are related as by-products of each other by a fixed set of production coefficients, while type B can only be used to produce product II. At the beginning of each period, the level of production of each production type must be determined, given the amounts of each product already in stock. The criterion used to make these decisions is based on the minimum expected discounted total cost over the finite horizon. Results presented show that the decision plane is partitioned into four distinct regions, and the boundaries between these regions are characterized in terms of a particular sequence of points which are independent of the on-hand stock levels each period.

Technical Report #5 (W. P. Pierskalla and J. A. Voelker)

"Optimal Mass Screening under Constant and Threshold Test Reliabilities,"  
Department of Industrial Engineering and Management Sciences, Northwestern  
University, Evanston, Illinois 60201, March, 1977, pp. 1-38.

Abstract

This paper develops and analyzes two important cases of a general model of a mass screening program. In both cases, the defect arrival process is Poisson.

In the first case, the reliability of the test, i.e., the probability that the test will detect the disease, is dependent only on the type of test being administered and is constant over all values of elapsed time since the incidence of the defect. The long-run expected disutility per unit time is derived and variations of the disutility with regard to test reliability and testing frequency are presented. In addition, explicit solutions are provided for various special forms of the disutility function.

In the second case, the test will detect the defect if and only if the elapsed time since incidence exceeds a critical threshold  $T$  which characterizes the test. An expression for the long-run expected disutility per unit time is derived and decision rules to select between two alternative test types and costs are presented.

As mentioned previously, there is still some work started in the previous year which is ongoing. This work will culminate in several papers and will be submitted for publication. Some of it centers on mass screening modelling and others on the control of deteriorating stocks.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Final Report No. 1	2. GOVT ACCESSION NO. (9) Rept. no. 1 (Final)	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (16) Maintainability,	5. TYPE OF REPORT & PERIOD COVERED Final Report 1 Jan 75 - 3 Sep 76 1/1/75 - 9/30/76	
7. AUTHOR(s) (10) William P. Pierskalla	6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Industrial Engineering and Management Sciences Northwestern University Evanston, Illinois 60201	8. CONTRACT OR GRANT NUMBER(s) (15) N00014-75-C-0797	
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Statistics and Probability Program Code 436 Arlington, Virginia 22217	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 042-322	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	12. REPORT DATE (11) May 1977	
	13. NUMBER OF PAGES (12) 70.	
	15. SECURITY CLASS (for this report) Unclassified	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		