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THE NEXT GENERATION LORA MODEL

by

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ABSTRACT

This paper reviews the shortcomings of the current level-of-repair-analysis (LORA) model in LOGAN and identifies the required actions needed to develop a next generation model. The paper suggests a network optimization approach and discusses some of the problem areas of its implementation and integration with a multi-echelon, multi-indenture sparing model and a special user interface.

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A NEXT GENERATION LEVEL-OF-REPAIR-ANALYSIS MODEL

I. INTRODUCTION

1. In the late eighties, the Directorate of Logistics Analysis developed three independent logistics models. These models provide sparing analysis, life-cycle-costing, and level-of-repair analysis (LORA). In the early nineties, due to the commonalities of data requirements, efforts were made by D Log A to integrate these three models. The result of this integration process is a software product called LOGAN, which is now supported by Omega Logistics of Canada. There is a continuous effort in broadening the capability of LOGAN and keeping it current with the changes of the user community.

2. Over the last few years it has been recognized that LOGAN (LORA) [2] has not satisfactorily addressed the issues and concerns of the users in the area of maintenance plans development resulting in considerable customization of LOGAN(LORA) or using other means all together [3]. This paper focuses on the key ingredients required to develop a more capable level-of-repair-analysis model than LOGAN (LORA). As a first step in this renewal process a contract was let to investigate the theoretical underpinnings of solving combinatorially complex problems such as is found in LORA type scenarios [1]. A general knowledge of the references [1], [2], and [3] is needed for this paper, as the latter uses them as a basis to discuss the next steps to be taken in the development of a new LORA model. This paper is not an exact road map for this development but will attempt to under score the issues and problem areas that will have to be addressed in identifying better solutions.

II. RATIONALE FOR A NEXT GENERATION LORA

3. LOGAN (LORA) does not use a system approach to level-of-repair-analysis. Instead, LOGAN (LORA) performs a level-of-repair-analysis of each multi-indentured item independently. This is a serious deficiency in the model because many maintenance scenarios require resources, such as labour, test equipment, and facility costs, that are shared among many different items in the system. The accuracy in calculating the cost of common resources is compromised with an item-by-item approach. This cost is important because it affects the overall repair decision.

4. The concept of repair fraction (percentage of repairs of an item performed at a site) in LOGAN(LORA) poses some difficulties. A repair fraction reflects the functional capability of a line of maintenance that relates to the level of people skills and sophistication of equipment required at that site, usually being higher at higher echelon levels. Users of the model have encountered difficulties with estimating this parameter, which has a value in the range between zero and unity. Ideally a LORA model would identify at what levels the higher cost skills and support resources should be placed to minimize costs from which repair fractions could be computed. In particular, repair fractions are a required output for use in LOGAN(Sparing). Further study of this concept is needed to identify to what extent their creation can be automated as opposed to having the user estimate them . If this latter is not possible, it will be important in the design of a new LORA model to ensure that there is understanding and consistency of the use of the concept of repair fraction.

5. The next generation model must be able to model preventative maintenance. This is highly desirable in level-of-repair-analysis. Users of LOGAN (LORA) have often inquired about the capability of assessing the location of a preventative maintenance site for a system.

6. Another area of weakness is the way the model handles the sparing of repairable items. LOGAN (LORA) has a built-in sparing model, which does not take a system approach in computing the required number of spares. Rather than this approach it spares each item separately at a fixed service level . Optimally a strategy to overcome this deficiency should be to integrate the LOGAN multi-indenture, multi-echelon sparing model LOGAN(Sparing) into the level-of-repair analysis. This will require designing an iterative approach as initially LOGAN(Sparing) requires the specification of a maintenance plan and specifically the repair fractions. Thus a first cut could be done using the item by item approach selecting

heuristically a some appropriate set of service level targets which would be subsequently transferred to LOGAN (Sparing) using a PE system level availability target. In any event further research into an appropriate scheme to accurately reflect the sparing component of costs is required.

7. A system approach is required to develop the next generation LORA which would enable decision makers to resolve important management issues with near optimal solutions from a system level perspective. For example, the model must be able to determine the most economical maintenance plan for a fleet of aircraft with a specified aircraft availability. The solution methodology must be flexible so as to be able to model a wide variety of situations while minimizing the intervention of modelling specialists. Because LORA must be done at the earliest inception of a project when little data exists the model must be able to be run with very little rudimentary data. On the other hand when more information about the environment that the PE will be operating in becomes known the combinatorial complexity required to integrate this data grows exponentially. Thus the evolution of a maintenance concept through modelling will be iterative and may require more than one model to meet the requirements at different stages. In any event it appears that, because of the mutual interdependence of the LORA and the Sparing processes an iterative process will be required as mentioned above.

III. THE NEXT GENERATION LORA MODEL

8. Multi-echelon, multi-location, and multi-indenture features of any LORA model offers flexibility, and allows decision makers to address key maintenance issues. The next generation LORA should contain some or all of those features. This section focuses on some of the key elements required to develop the next generation LORA.

9. In level-of-repair analysis, each line of maintenance is called an echelon, and each repair facility is called a location, (see Figure 1). LOGAN (LORA) does not select the best location within an echelon. Instead, it aggregates all the locations in each echelon. In the same fashion LOGAN(Sparing) treats all sites at each echelon level as functionally homogeneous. This eliminates the multi-location aspect of the problem. The aggregation of the facilities in each echelon reduces the number of different repair plans. Aggregation of the facilities works well in some military applications because the choice of facilities in each

echelon can be determined by alternative information. For example, second-line maintenance for the Canadian Forces Hercules aircraft (see, Reference 3) could be located in Trenton because a large percentage of the aircraft fleet resides at Trenton. Care must be exercised in treating multi-location problems when integrating LOGAN(Sparing), as the latter was not designed for this problem. Also, though the study in [3] successfully integrated multi-location, it was very limited in scope as it involved only one LRU, two echelons and no type II failures, a situation that does not generate non-homogeneous repair functions at second line. Some research will be needed to see if and how this situation can be handled.

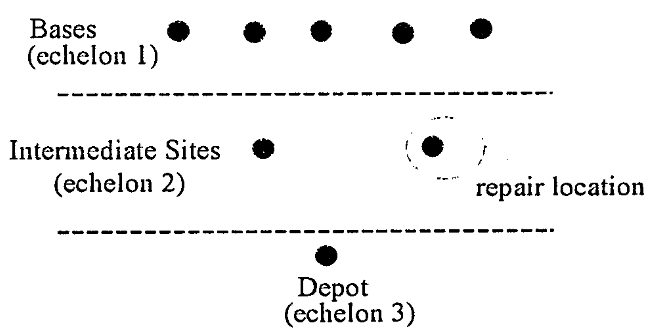

Figure 1: A Maintenance Scenario

Network Optimization Approach

10. Reference [1] developed a general purpose model for level-of-repair-analysis. The model described in pages 12-19 of Reference [1] is a multi-echelon, multi-indenture, multi-location model for level-of-repair-analysis. The author develops a network formulation of a linear programing(LP) problem which takes advantage of a sparse activity matrix. This model, using a shareware LP solver, has produced solutions with a small number of repair locations. However, in scenarios with a large number of repair locations, the efficiency of this approach is still unknown. The increased combinatorial complexity of the multi-location feature poses a challenging problem.

11. In [5] a number of commercial LP packages with specialized network algorithms for solving the linear programming problem can be found (e.g. LINDO or CPLEX) and most packages claim unlimited restrictions on the number of rows, columns and non-zero entries. On the other hand extremely large problems will cause other problems such hardware (discussed below) and time requirements that could reduce the useability of the model. Thus the requirement for the multi-location capability should be thoroughly substantiated before being implemented. Certainly development time for the next generation LORA can be reduced substantially if the multi-location capability is not modelled. Other capabilities of existing LP packages should be investigated as well, for instance, parametric programming would be a great advantage for sensitivity analysis.

12. Models for the coefficients of the linear program provided in Reference [1], pages 14-15, have not been developed. There should be no difficulties in developing models for these coefficients though the formulation of the indexing in [1] will not be easily transferable to a programing language, as it is structured primarily for comprehension. Some of the cost models in the LOGAN (LORA) could be used to compute these coefficients. A large database is required for the linear program formulation under conditions where the number of different items and locations are large. Models representing the coefficients must reflect the way costs are actually charged. For example, transportation costs charged to the Department of National Defence are based on break-points in mileage and weight, see Reference [4]. This suggests that a step-function model is more appropriate than the linear function in the current LOGAN(LORA).

13. One advantage of the network approach is that it can model the lateral transfer of supplies and parts from one repair facility to another. Though this could be an important feature when various units in a line of maintenance share spare parts, it would cause inconsistencies with LOGAN(Sparing) which does not permit lateral transfers as it is currently set up. Further research into integrating this feature into LOGAN(Sparing) would be required.

14. The network approach also offers an intuitive process for level-of-repair-analysis. Several graphical concepts were introduced in [1] to demonstrate the network approach. Reference [1] supplied a software tool for level-of-repair-analysis in a network environment. The tool provided with Reference [1] demonstrated some of the drawbacks of a network approach. A user of this model requires an understanding of network analysis and concepts in order to apply this tool. This would limit the number of users because most users do not

possess a background in network analysis. Furthermore, in problems with many levels of indenture and many locations, the density of the graph is high, thus making it difficult to set up the network visually. For these reasons it will be important to be able to set up the network problem from within the existing LOGAN framework. Failing this, a review of the methodology presented in [1] as well as existing commercial modelling languages [5] would be required to determine the most appropriate course of action.

IV. DATA AND DATA PROCESSING REQUIREMENTS

15. The burden of data preparation and collection is enormous in any level-of-repair-analysis, particularly with systems comprised of many parts. LOGAN(LORA) provides simple screens for the user to input data. Currently the input screens to all models are being integrated into a common set of input screens for LOGAN which can be used with some minor modifications in the next generation LORA. This will allow current users to migrate to the new LORA model effortlessly. The modifications required will depend on the extent of new data elements required by the new LORA model but it is not anticipated that, at this point, there are any technical difficulties to this integration. There is however the potential of substantial hardware requirements caused by problems of even medium size. The LP matrices of activity data can become very large. For instance in the formulation in [1], a problem with 10 bases, 2 depots and one contractor site servicing a PE system with 10 LRUs and 300 SRUs using 10 support equipment would generate a matrix of about 135K by 4K. The ability to model such situations depends on the number of non-zero entries. For instance in the survey of [5] the MPL modelling system requires about 1 MB of RAM per 50K of non-zero entires. Thus in this example of network analysis where matrices are generally very sparse, if we assume about 1% of the matrix is formed of non-zero entires which would amount to about 5,400 K, there would be a requirement for a PC with more than 100MB of RAM. Such a need represents the upper reaches of expansion for today's PCS. Though this provides a very rough assessment of requirements, it indicates that further study of the situation and caution are required.

V. CONCLUDING REMARKS

16. Based on References [1], [2], and [3], a network formulation of a LP approach appears be a good choice for the next generation LORA. However, several key areas must be researched before pursuing the network approach. Because the combinatorial complexity grows rapidly with the inclusion of more and more decision variables, these must be chosen judiciously. As a first step towards a new LORA model clear objectives must be reviewed with the user community and trade-offs must be identified against what is achievable. In particular the decision to include the multi-location feature into the model needs to be determined. If the choice is to include that feature, then a robust solution technique is required for the model as well as compatibility with the way sparing analysis is done. Including the current sparing model directly into the linear program formulation will create a non-linear model. Therefore the integration of sparing into a level-of-repair-analysis framework also requires further research.

17. The question of how the new LORA model is to be implemented is one that should be addressed concomitantly with the scope, as the computational complexity is directly dependent on the scope of the application. The development time and the required resources for developing the final model will of course depend on the approach. The inclusion of the multi-location capability in the model adds tremendous complexity to the development of the next generation LORA. It may be necessary, in fact, to develop two models, one which would be very simple for use early in a project life with sparing roughed in as it is today and a second model capable of substantially more detail which would run iteratively with LOGAN(Sparing). Again moderation may be forced on the situation by a special hardware requirements.

18. The network optimization approach formulates the problem into a graph of nodes and arcs, which becomes very dense with many different indenture levels and locations. This makes it difficult for a user to construct the network visually. Reference [1] suggests some ideas to reduce the density of the network graph but ultimately the solution should be framed in the LOGAN data capture modelling language.

19. Developing the next generation LORA poses a serious challenge to the project leader because he/she is inevitably faced with a delicate balance between the amount of data required, amount of support resources and the capability of the model. A strong commitment from senior management to provide the required resources to develop a marketable product is necessary. A team with specific skills is required to develop the next generation LORA. A full

complement of logistics engineering knowledge, mathematical modelling skills and computer programming are central to the development of the next generation LORA which must have the flexibility to involve various equipment types in different support scenarios to ensure that the capability of the model is broad.

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