ORLA - Optimum Repair Level Analysis

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1. Summary

Level of repair analysis is the most important to minimize system life cycle cost. In this article we describe ORLA program which analyzes and optimizes the level of repair of complex systems. It makes the following economic decisions:
1. Which assembly should be repaired and which should be discarded?
2. What is the best repair level and site for each assembly?
3. What is the optimal maintenance cost, actual and relative values of elements?

Key words: Life Cycle Cost, Computer Aided Reliability Engineering (CARE), Concurrent Engineering, Integrated Logistic Support, Corrective Maintenance, Preventive Maintenance, Optimization.

ORLA is useful for complex Hi-Tech systems to optimize the maintenance cost. A considered system is a hierarchy of different assemblies (blocks). Maintenance includes corrective actions to replace ***randomly failed*** blocks, which may be also complicated multilevel sub systems, and periodically preventive actions to replace some blocks or components ***before failure***, to check and, if necessary and possible, to repair them.

ORLA provides cost estimations for the following problems:
- Maintenance Array
- System Design

Maintenance Array:

- Which block (including its sub blocks and components) should be discarded after replacement and which should be repaired;
- At which repair level and site each failed block should be repaired, according to the detected failure mode;
- What is the optimal system maintenance cost;
- Support System requirements in each site according to the number and types of blocks that will be repaired, including spares, personnel, man-hours, material handling, facilities, utilities, package, technical data, training, etc.;
- Where should be installed new Shared Support Equipment (SSE), if necessary, used simultaneously by different block repairs.

System Design:

- Which elements of the considered project or maintenance system must be changed to decrease maintenance cost?
This decision may be obtained considering some alternatives of the project design or maintenance organization and comparing their optimal maintenance cost with ORLA.

2. Data Flow

Assumptions:

- One or several considered systems operate at different sites, which may be simultaneously repair sites.
- The systems must be defined using System Tree Editor.

Input Data

The following repair expenses are defined by the user as input data for each block:
- Manpower
- Material handling
- Training
- Maintenance documents
- Technical data and records
- Test and support equipment
- Facilities
- Utilities
- Transportation
- Packaging

Preliminary Calculation

Before optimization ORLA calculates the following total costs using the above input data and inflation or discount rates during the maintenance life cycle:
- Discard costs for each block,
- Repair cost for each block related to each possible repair site,
- The cost of transportation, packaging and additional spares for each block and sub block pair at all possible repair site combinations (Relative Cost).

Optimization Process

Optimization task is to provide minimal Life Cycle Cost for considered system making the following decisions for each block:
- Should it be repaired after replacement and at which site?
- Or should it be discarded at its Parent block repair site?
- Should new Shared Support Equipment or other Shared Resources be used?
- At which sites they should be installed?

ORLA Results:

- The optimal maintenance cost of the system including the cost of repairing each block and sub block.
- The optimal Maintenance array.

3. ORLA Benefits

-. Many different projects may be selected together for common optimization. It may be useful, if they have common physical blocks and spares or shared support resources, or similar projects operate at different operational sites.
- ORLA calculates optimal cost for system level and also for any other block as a sub system for all its possible repair sites.
- ORLA can consider Failure Mode (FM) for each block, and this will make the analysis more accurate because we can assign different repair sites for different FM of the same failed block.
- The user can define Permissions for block repair sites and maintenance levels for each block and its sub blocks.

For example, he can define that, if in the optimal solution a certain block will be repaired at Intermediate level, its sub block may be repaired only either at Intermediate or at Depot level.

4. ORLA algorithm

Consists of the following steps:
- Preliminary calculation,
- Optimum repair location for blocks not depended on shared resources,
- Optimum repair location for blocks which depend on shared resources and in which location shared resources should be installed.

4.1 Preliminary calculation

Consists of:
- **Discard costs for each block**. This cost contains the block purchase cost and all cost related to discard activities after the block replacement and removing from its Parent block, multiplied by number of yearly failures.
- **Repair cost for each block related to each possible repair site**. This cost includes for each block maintenance personnel and support cost, test and support equipment maintenance cost, spare part cost, maintenance facility cost, technical data cost, multiplied by discount and inflation coefficient, and new individual support equipment cost.
- **Relative Cost**. This cost contains transportation and packaging cost, multiplied by discount and inflation coefficient and for the repairable blocks the cost of spares needed to fill up the pipe line between one maintenance site to another related to the Turn Around Time.

4.2 Optimal repair location for blocks not depending on shared resources.

This process starts from leaf blocks (blocks not having sub blocks) through all sub levels to the system level and uses dynamic programming techniques.
The following steps are repeated for every leaf block:

- The minimal sum of Repair and Relative (or Discard) Cost of each block is selected from the preliminary calculations over all possible repair sites defined for this block for each considered Father repair site.
- The optimal repair site of the considered block (or discard decision) is stored and the above cost is added to the Father block repair cost at considered repair site.
- This leaf block is excluded from next process.

The process stops when all blocks, that do not need Shared Resources, are excluded (except root). If there are not other blocks in the system, the minimal cost for root block (main system) repair site is obtained.
If there are blocks that need shared resources the process continue to the next step.

4.3 Optimal repair location for blocks which depend on shared resources and in which location shared resources should be installed.

This process starts only if there are blocks that need shared resources.
It uses "Branch and Bound" optimization technique applied to this special case.
Branch, is determined by assuming what locations of considered shared resource are permitted. Lower and upper optimal cost estimation are built for all branches.
Lower estimation is obtained by assuming, that shared resource cost may be divided between a few blocks that need them, if they are optimally located not at the same site.
Upper estimation assumes that undivided shared resource must be located at one site and all blocks, which need it for repair, must be repaired at this site.
On each step the best branch is divided into 2 new branches, so that the number of possible location sites of shared resource decreases. The process is finished when the lower and upper estimation are for the best branch and it takes a limited number of steps.

5. Example.

The example describes an Israel company that provides maintenance support for IBM Personal Computers and compatibles. The company headquarters and the Central Lab (Depot Level) is located at Tel-Aviv, See picture 1.
There are also other 4 Intermediate sites (I Levels) Located at Haifa, Beer-Sheva, Jerusalem and Tel-Aviv. Each one supports 200, 100, 200 and 500 customers respectively.
For description of the IBM-PC product tree, see picture 2.
For ORLA input data see picture 3. For ORLA reports see picture 4.

6. References:

- MIL-STD-1390C Level of Repair.
- AFLCM/AFSCM 800-4 Optimum Repair-Level Analysis
- CARE - Computer Aided Reliability Engineering, a Software Package
- ORLA - User Manual

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