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U.S. Army Research, Development and Engineering Command

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Maintenance Analyses Using IMPRINT

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Motivation

ARL

- The Joint Light Tactical Vehicle (JLTV) will replace the High Mobility Multipurpose Wheeled Vehicle (HMMWV) in a variety of military environments

- Maintenance requirements are a key concern
- **Want to**:
  - Accurately estimate the maintenance requirements of a proposed system design, and
  - Understand the modeling biases
- Fair comparison between system designs

Research Question, IMPRINT

- **Research Aim:** Develop a modeling methodology that allows accurate estimation of key maintenance metrics given a specific system design
- **Research Tool**: IMPRINT (Improved Performance Research Integration Tool) maintenance module is a discrete event simulation tool

- IMPRINT maintenance module (Equipment Analysis): allows user to model a system and determine maintenance needs under different operating environments through simulation

Maintenance Performance Metrics

- Potential maintenance analysis focus areas:
  - Maintenance Ratio
  - Inventory/ Sparing Issues
  - Operational Availability
  - Mission Reliability
  - Maintainer Utilization
  - Maintenance Patterns
  - Maintainer Staffing/ Scheduling
- Key performance metric of interest: Maintenance Ratio (MR)
- Maintenance Ratio: The ratio between maintainer man hours and operating miles (units of maintainer man hours per operating mile)

Building the Model

Building the Model:

i. Inputting the parts data

ii. Defining the simulation scenarios/ segments

Inputting Parts Data

1. Determine which parts to use (Essentiality Codes [ECs])
2. System → sub-systems → parts (use Tech. Manuals)
3. Enter corrective (and preventive) maintenance data for each part
4. Enter reliability data for each part

Building the Model, cont.

- Essentiality Code: Indicates if an item is essential or not. "Essentiality is the degree of military worth of an item of supply or how its failure, if a replacement is not immediately available, would affect the ability of the weapon system, end item, or organization, to perform its intended functions or missions."
  SOURCE: http://www.usamma.army.mil/assets/apps/qbca_medsils/WebHelp/MedsilsEssentiality_Code.htm
- For Repair Parts:
  - C: part is essential for end item operation
  - D: part is not essential for end item operation, but is needed for crew safety
  - E: part is not essential to end item operation or crew safety, needed for legal purposes
- ECs: One way to define the list of parts modeled

Building the Model, cont.

Defining Scenarios/ Segments

- Scenarios (containing 1 or more segments) determine usage “experienced” by the system during the simulation
- Can be generated using:
  - Historical data and Subject Matter Expert (SME) input
  - System documents (e.g., Operation Mode Summary & Mission Profile)
- Segment definition includes:
  - Length of segment
  - Usage rate (distance, rounds fired, time)
  - Repeating?
  - Combat damage

Building the Model, cont.

Defining Scenarios/ Segments, cont.

- Usage accrues whenever a system is sent out on a segment
- Usage of all types ***only*** accrues if the system is out on a segment
- This form of modeling makes it impossible* to model preventive maintenance occurring a fixed time interval apart
- Workaround needed to model preventive maintenance occurring before/ after a segment

* I have not been able to find a way, if someone knows how please let me know.

Building the Model, cont.

Challenges

- Obtaining a parts list for the system
- Best way to refine parts list (using ECs?)
- Obtaining parts data:
  - MOUBF (Mean Operational Units Between Failure), and
  - MTTR (Mean Time to Repair)
  - Existence of data and accuracy of data is unclear – large numbers of parts have the same MOUBF and MTTR values
  - Example:
    - 70 parts
    - 9 different MOUBF values
    - 35 have the same MOUBF *x*, and 20 have the same MOUBF *y*

Building the Model, cont.

Challenges, cont.

- Obtaining accurate time estimates for preventive maintenance
  - The Maintenance Allocation Chart (MAC) for the HMMWV uses 0.1hrs as the smallest 'Inspect' time value
  - Example:
    - Inspect Tailgate – check that tailgate latches securely and operates properly
    - Time needed: 0.1hrs (6 minutes)
- Dealing with the biases introduced by inaccurate data
  - Having to account for biases when analyzing data and interpreting results
  - Garbage in = garbage out

Running the Simulation

- Running the simulation:
  - Specify the length of simulation
  - Specify a few other basic parameters (e.g., random seed value)
- Reports with summary statistics are automatically generated from the simulation replication
- All maintenance actions are performed after a segment is either aborted or completed
- Hierarchy of maintenance:
  - Crew Chief → Contact Team → Org → DS-On → DS-Off → GS
- Two-level Army maintenance concept:
  - Field Level and Sustainment Level

Running the Simulation, cont.

Challenges

- Each simulation replication must be performed manually, one at a time:
  - Multiple replications necessary for point estimates of maintenance metrics with confidence bounds around these estimates
- 'Daily reports': assumed that a segment would never start on day *n* and finish on day *n+1* – the reports of daily statistics can be misleading
- Reports only provide summary statistics – if the metric you need is not reported, there might be no way for you to calculate it with the summary data provided

Running the Simulation, cont.

Challenges, cont.

- Must consider what results are required:
  - Transient: initial conditions matter
  - Steady-state: initial conditions ***should not*** matter
  - Maintenance modeling of this type requires a steady-state simulation
  - Currently: no option to have a ‘warm-up’ period to provide steady state results in the reports
  - If the simulation length is not long enough, the point estimates can be highly skewed

Unresolved Modeling Questions

- Based on the data and information provided, each design will have:
  - A different percentage of maintenance modeled
  - Different types of maintenance modeled
- How to ensure a fair comparison, i.e., that:
  - Model biases apply to each design in the same way
  - The differences outlined above are accounted for in the modeling process
- Ensuring that point estimates are derived from steady-state data
- Ensuring that both corrective and preventive maintenance can be accurately modeled

New Guy Questions

- What databases/ Points of Contact (POCs) would have:
  - Parts list for a given system
  - Essentiality codes for a given system
  - Reliability information
  - Maintenance information (e.g., MTTR, Maximum Time to Repair [MaxTTR])
  - Preventive maintenance information (i.e., what PMCS are done to the system, and time estimates)
- Is preventive maintenance (i.e., PMCS) normally modeled, or does it form a negligible part of maintenance?
  - Does this depend on the operating environment?
- What other tools are used (by the Army) to perform maintenance analyses?

Questions?

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Technical Manuals/ Documents Used

- **Preventive Maintenance Checks & Services (PMCS):** TM 9-2320-387-10 (HMMWV Operators Manual)
- **Maintenance Allocation Chart (MAC):** TM 9-2320-387-24-2
- **Subsystem/ Part Hierarchy:** TM 9-2320-387-24-1, TM 9-2320-387-24-2, and TM 9-2320-387-24P
- **Essentiality Codes (ECs):** AR 700-18
- **Scenarios/ Segments:** JLTV Operation Mode Summary & Mission Profile (OMS/MP) v3.1