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Abstract

In initial System Development & Demonstration phase, it is possible Total Lifecycle Cost (LCC) estimation using Reliability, Maintainability (RM) analysis result. RM analysis data are following applicable to LCC estimation. Reliability metric is System/Equipment MTBF and Maintenance Task Frequency Maintainability metric is LRU/SRU MTTR Reliability and Maintainability metric are Interval for Planned Maintenance

1 Introduction

1.1 RM Analysis

RM(Reliability and Maintainability) is metric of system/equipment failure frequency and war readiness. Also RM is numerical metric of ILS development and tool for optimization of customer requirement.[9] Through RM prediction and analysis activity, design/evaluation/logistics is supported.



Fig.1 DOD 5000 Defense Acquisition Management Framework[2][4][5][6]

Reliability is the probability that an item will perform its intended function for specified interval under stated conditions.[1][7]

MTBF = Total Operation Time / Number of Failures (1) Annual Maintenance Frequency = Annual Operation Time / MTBF (2)

Maintainability is a measure of the ability of an item to be retained in, or restored to, specified condition when maintenance is performed using prescribed procedures and technical skill levels.[1][8]

Principal Metric of Maintainability is the MTTR(Mean Time To Repair). Calculation of MTTR is sum of Task Frequency multiply Elapsed Time divided by sum of Task Frequency.

1.2 LCC Analysis

LCCA is Life Cycle Cost Analysis. The objective of LCC Analysis should choose the most effective approach for utilizing available resources over entire product life cycle. LCC is composed Acquisition cost plus Operation & Support cost or Development plus Investment plus O&S plus Disposal Cost. 60 to 80% of LCC is Operation & Support Cost. So in initial development, it is important to decide Life Cycle Cost.[3]



Fig.2 General Life Cycle Cost

LCCA process is following.[3]Define Cost Analysis Goals

- Identify Guidelines and Constraints
- Identify Feasible Alternatives
- Develop Cost Breakdown Structure
- Select or Develop Cost Model
- Development Cost Estimating Relationships
- Develop Life Cycle Profile
- Perform Sensitivity Analysis
- Select Best Value Alternative

1.3 TLCSM Metric

TLCSM(Total Life Cycle Systems Management) Metrics are for evaluation and management through total life cycle and quantitative criteria of PBL(Performance Based Logistics). Operational Availability and Cost per Unit Usage metric is available metric in the Research and Development phase. And those metrics are associated with Reliability and Maintainability. Mission Reliability, Logistics Footprint, Logistics Response Time is available metric in the other phase.[4]





2 LCC Estimation Method and Case Study

2.1 RM Analysis vs. LCCA

RM Analysis is able to analyze at the system development inception and LCCA is able only to analyze when operation and support data or similar system operation data is available. But in the development, LCCA could be performed by RM Analysis result. Then general fact about LCCA is following.

- As MTBF increase, Maintenance Requirements decrease
- Rough LCC Estimation Formula

 $LCC = (Annual Operating Time) \times (Life Time) \times (Acquisition Cost) / MTBF$ (3)

2.2 Case Study using RM and LCCA

2.2.1 General

This case study objectives are Verification of outside depot maintenance through LCCA of System and Decision making of depot maintenance through decision of Depot interval. Analysis method is Alternatives Analysis and Comparison through RM and Logistics Support Analysis of System. And constraints are following.

- Uncertain Value of Unplanned depot maintenance required
- Uncertain Manhours of Organization/Intermediate/Depot Level
- Uncertain Cost of Organization/ Intermediate/Depot Level

2.2.2 CBS(Cost Breakdown Structure) and CER(Cost Estimating Relationship)

CBS is composed of Research & Development cost, Investment cost, Operation and Support cost, Disposal cost. Research & Development cost is composed of prototype development and test & evaluation cost. Investment(Acquisition) cost is composed of production and government and depot maintenance development cost. Operation and Support cost is composed of operation, organization maintenance. intermediate maintenance, depot maintenance, sustaining support, indirect support cost. CBS and CER are the following.

Level		CBS (Cost Breakdown Structure)	CER (Cost Estimating Relationship)			
1		Research and Development	Development Budget			
	1	Prototype Development	-			
	2	Test and Evaluation	-			
2		Investment (Acquisition)	Production Budget			
	1	Production	-			
	2	Government	-			
	3	Depot Maintenance Development	-			
3		Operation and Support	-			
	1	Operation	Operation Cost			
	2	Organizational Maintenance	LRU Maintenance Frequency × MTTR (Frequency = AOT / MTBF)			
	3	Intermediate Maintenance	SRU Maintenance Frequency \times MTTR			
	4	Depot Maintenance	Depot Maintenance Frequency \times Overhaul Time			
	5	Sustainment Support	(O/I/D) × ○%			
	6	Indirect Support	(O/I/D + Sustainment) × 0%			
4		Disposal	System Price × 0%			

Fig4. Total Lifecycle Cost CBS and CER

Maintenance of Operation and Support CER are following.

- Organizational Maintenance = LRU Maintenance Frequency × MTTR (Frequency = AOT / MTBF)
- Intermediate Maintenance = SRU Maintenance Frequency × MTTR
- Depot Maintenance = Depot Maintenance Frequency × Overhaul Time
- Sustainment Support = (O/I/D) × sustaining assumption percentage

2.2.3 Applied Data

For LCCA, applied data are following.

Cost Element	Applied Data	Calculation		
Price of Main Equipment	3.62B	Production Contract Cost		
MTBF(hrs)	200	Design MTBF		
Annual Operating Time(hrs)	50	00hr × 00sortie		
Organizational Maintenance (Unplanned)	0.52	Organization MTTR		
Organizational Maintenance (Planned)	119	$\texttt{Daily(214)} \times 0.52 + \texttt{Monthly(12)} \times \texttt{1hr}$		
Intermediate Maintenance (Unplanned)	4	Intermediate MTTR		
Intermediate Maintenance (Planned)	36	$Quarterly(4) \times 4hrs + Haif \underline{vealy}(2) \times 6hrs + Yearly \times 8hrs$		
Depot Maintenance (Unplanned)	80	10days		

Cost Element	Applied Data	Calculation		
Annual LRU Maintenance Freq.	0.25	Annual Operation Time / MTBF		
Annual SRU Maintenance Freq.	0.12	50% of LRU Maintenance Freq.		
Unplanned Depot Freq.	0.02	10% of LRU Maintenance Freq.		
Maintenance Increasing Rate	10.0%	Predicted Maintenance Freq. Increasing rate after 5 years		
Labor Cost of Organization	20,000	'2008		
Labor Cost of Intermediate	30,000	'2008		
Labor Cost of Depot	43,000	'2008		
Increasing Rate of Labor	5.6%	Predicted		
Increasing Rate of Material	4.0%	Price Increasing rate		
Discount Rate	3%	Predicted		
Organizational Material Rate	2%			
Intermediate Material Rate	15%	Against Main Equipment Price		
Unplanned Depot Material Rate	5%	· · ·		

Fig5. Applied Data

2.2.4 Analysis results

Alternative analysis result between unplanned overhaul and planned overhaul shows us it is economic efficiency to perform planned depot maintenance(overhaul).

	OD9	Unplanned	l Overhaul	Planned Overhaul	
	600	Account Value	Present Value	Account Value	Present Value
1	Research and Development	64.7B	72.8B	64.7B	72.8B
2	Investment (Acquisition)	176.7B	173.9B	183.2B	179.9B
3	Operation and Support	368.2B	231.5B	254.6B	175.5B
	Disposal	4.9B	4.7B	4.9B	4.7B
	Total LCC Estimation	614.5B	482.9B	507.4B	433.0B

Fig6. Case study 1

Alternative analysis result each yearly overhaul shows us it is economic efficiency to perform 6y-cyclic depot maintenance(overhaul).

CBS		5 yearly Overhaul		6 yearly Overhaul		7 yearly Overhaul	
		Account Value	Present Value	Account Value	Present Value	Account Value	Present Value
1	Research and Development	647	728	647	728	647	728
2	Investment (Acquisition)	1,832	1,799	1,832	1,799	1,832	1,799
3	Operation and Support	2,671	1,851	2,483	1,745	2,546	1,755
4	Disposal	49	47	49	47	49	47
Total LCC Estimation		5,199	4,426	5,011	4,320	5,074	4,330

Fig7. Case study 2

3 Conclusion

Stakeholders knew decision making base data alike operation and maintenance concept through LCCA using RM Analysis result in the Development Inception phase.

Available decision making issues are following

- Maintenance Level (Organization/Intermediate/Depot) Decision
- Responsible Maintenance (Organization/Intermediate/Depot) Decision
- Economic Depot Maintenance Interval Decision through Comparison of unplanned vs. planned maintenance

RM Analysis Data are applicable to LCCA

- Reliability metric : System/ Equipment MTBF Maintenance Task Frequency
- Maintainability metric : LRU/ SRU MTTR
- Reliability and Maintainability metric : Interval for Planned Maintenance

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