PRELIMINARY ANALYSIS OF THE FUNCTIONAL MODEL OF A DSS FOR MAINTENANCE PLANNING OF TRANSIT SYSTEMS

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INTRODUCTION

The first step in the operational planning cycle which produces the maintenance schedules for each item of a transit system is the development of maintenance plans.

Here it is intended with the term "maintenance plans" the definition of all the aspects of the maintenance task plan except the date in which the task is performed, which is assigned to the particular item by the maintenance scheduling.

Maintenance planning is performed by decision makers on the basis of maintenance policy and guidelines previously formulated by top management, and on the basis of information obtained by raw data processing.

The decision process connected to maintenance planning is very complex, it involves a large number of aspects and discipline s such as safety and technical standards, reliability and maintainability, cost evaluation and optimization, etc... Therefore in rec ent years information systems structured in form of decision support systems (DSS) were proposed to support maintenance planners dec isions [1] [2]. However, proposed DSS's have been focused more on the scheduling then on the basic planning aspects.

In this paper a general functional model of a DSS supporting decisions in the development of reliability centered maintenanc e plans is proposed. A reliability approach, which starts from system reliability analysis and considers as the major objective of m aintenance to assure high operative reliability, is followed. Therefore in the following more attention will be given to the descrip tion of functions relative to reliability aspects.

Moreover, only the first two components of the most commonly defined structure of a DSS will be analysed, i.e. the function s relative to data base and model base management system will be described, whereas the whole user interface will not be considered.

1. THE MAINTENANCE PLANNING MODEL

The basic components of the functional model of a DSS for maintenance planning decision process is presented in the following. The functions of the system model are graphically presented in the figures by a set of box-diagrams.

The so called parent module is a function which transforms the input raw data into maintenance plans having policy and guidelines as controls (figure 1).

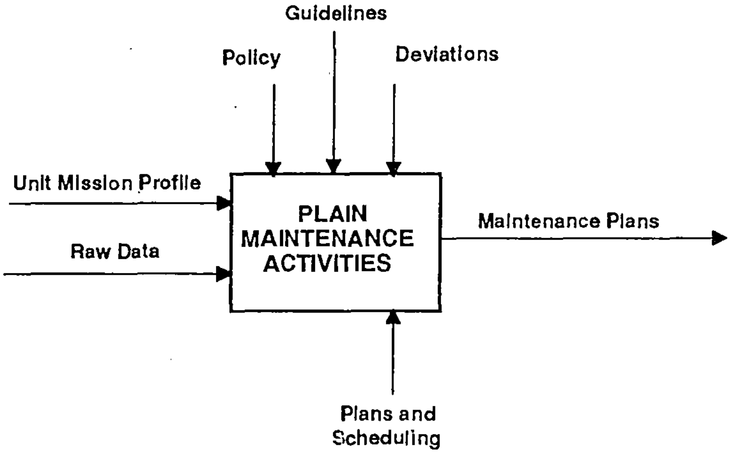

Fig. 1 - Plan maintenance A - 0

The decision process of planning maintenance, assuming maintenance policy and guidelines fixed by top management, involves to collect and organize data and to follow the planning cycle (figure 2).

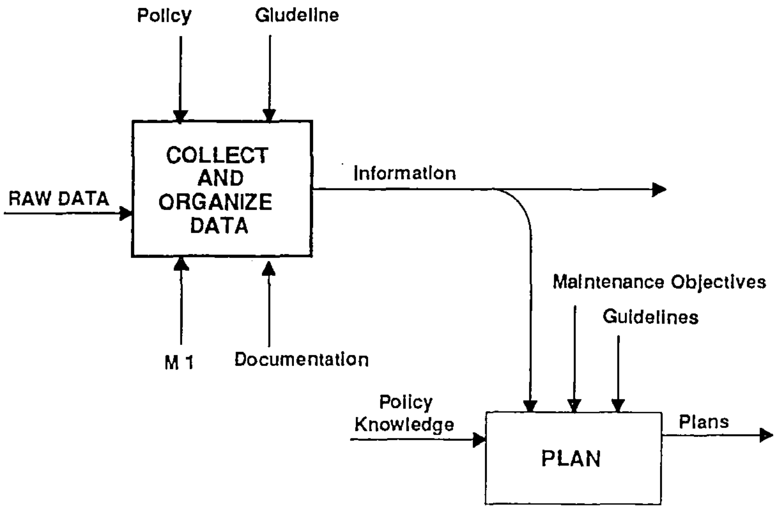

Fig. 2 - Plan maintenance A0

1.1 Collect and organize data

The collect and organize data function is performed by the data base management system of DSS, which, essentially, creates and manages the following data bases:

- Part number item database
- Serial number item data base
- System breakdown structure (vehicle) data base

Some functions of the model base system are called to process raw data and prepare input information to models utilized in the planning cycle.

Part number item data base refers to information relative to all items entering the transit system. Serial number item data base refers to each identified copy of items more relevant to maintenance, and singularly followed by information system from the entrance to system up to scrapping.

System breakdown structure (SBS) data base contains information on the hierarchy structure of the transit system, starting from zero level, which is the fleet level, up to the maximum analysis level relative to the smallest unit level considered in the decision process. Typical levels of indenture considered in the SBS of transport systems make reference to Line Repairable Units (LRU) and Lowest Level Repairaible Units (LLRU).

The most relevant data base is the serial number item data base, whose information components are the following ones:

- Forecast data current and hystorical
- Reliability and Maintainability data
- Regulations
- Costs.

Reliability data are obtained by processing raw data by means of two distinguishable functions:

- **FMECA**
- **STATISTICS.**

FMECA function is based on the well known Failure Mode Effect and Criticalty Analysis methodology which is the foundamental step in the reliability analysis of complex systems, such as transit systems. FMECA is a sort of dynamic hierarchical data base associating to each item in the hierarchical structure of transit system the following information:

- effect of failures on uppermost system and lower level items performance
- mode of failure-failure statistics
- maintenance task to be performed to improve failure resistance and failure detectability.

In a new system, or in the design phase of a new part of an existing system, data input to FMECA are supplied by vendors and/or obtained by similar experienced items, whereas during operating phase input data are enlarged and updated by maintenance actions records and by STATISTICS output data.

The function here called STATISTICS is a very complex function whose basic task is to obtain point and trend estimates of Reliability, Availability and Maintainability (RAM) characteristics (figure 3).

On the basis of RAM estimates, comparing actual versus reference RAM data, STATISTICS should also produce alerts for deteriorating, improving trend of RAM performance or deviations from RAM reference thresholds values.

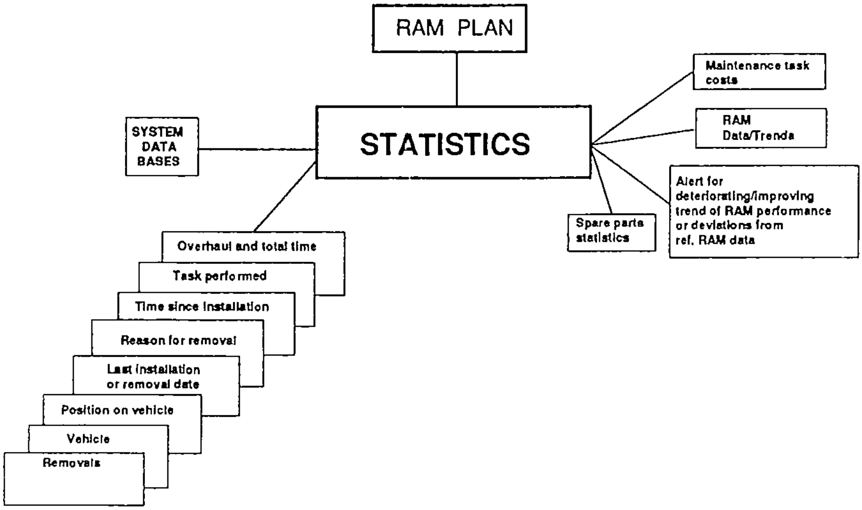

Fig. 3 - The statistics function

The COST function evaluates costs relative to scheduled and unscheduled maintenance actions on the basis of information prepared by FMECA and STATISTICS functions. In a transit system the evaluation of costs relative to revenue loss due to maintenance actions is very hard and necessitates of system dependability models [3].

System dependability models assess the impact of downtimes on system effectiveness, relating system dependability to reliability and maintainability characteristics of subsystems.

It is to point out that a DSS for maintenance planning shall utilize the results of transport system reliability studies performed since the design phase [7]. Thus, the data base management system of DSS shall interface with (or incorporate) the information system utilized during the design/development phase of transport system.

2. MAINTENANCE PLANNING CYCLE

The maintenance planning cycle is accomplished by defining the maintenance task, building the decision model and setting limits (figure 4).

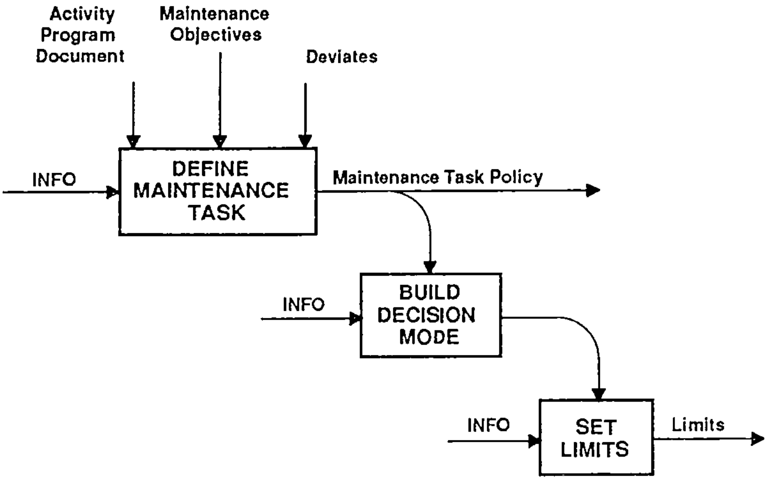

Fig. 4 - Plan A 1

To define maintenance task it is necessary to make decisions on maintenance task policy. This requires to make two levels of decisions on:

- foundamental aspects
- detailed features.

of task maintenance policy.

The foundamental aspects of policy are the following:

- type of maintenance
- preventive maintenance policy
- limit setting criteria.

In figure 5 primary decisions connected to the definition of policy foundamental aspects are described. To this end a basic tool has been developed in the early 70's by commercial airlines: the Reliability Centered Maintenance (RCM) method, also known as MSG3.

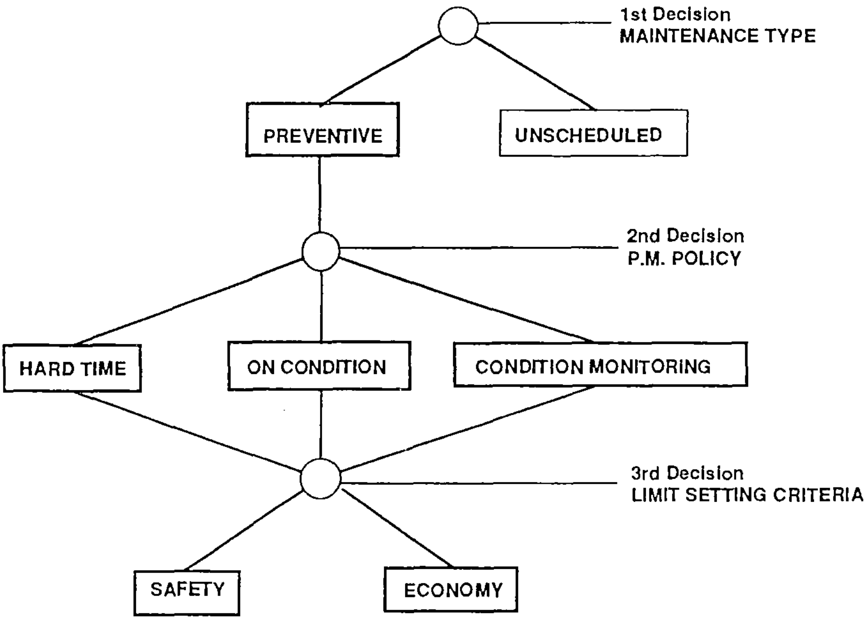

Fig. 5 - RCM decision - tree

The basic RCM process involves the following major activities [4] [5]:

1) Determine maintenance important items
2) Acquire failure data
3) Develop fault-tree analysis data
4) Apply decision logic to critical failure modes
5) Compile/Record maintenance classification
6) Implement RCM decisions
7) Apply sustaining engineering based on experience data.

The heart of decision logic consists in a tree sequence of successive questions on failure modes, effects, criticalty and detectability. The path individuated by answers ends with the definition of the foundamental aspects of policy.

Once the primary aspects of task policy are determined by the use of RCM methodology, it is necessary to completely define the detailed features of task policy, making decisions on detailed aspects of maintenance task. These decisions are made on the basis of information collected by RCM and on engineering experience.

An example of detailed features of maintenance task is reported in table 1.

The maintenance task is defined by a set of listed options.

Table I Maintenance task definition. Options:

- not repairable item
  - replacement after failure
  - preventive replacement at age T

- repairable item
  - minimal repair
  - simple preventive maintenance
  - overhaul
  - removal
  - inspecting
  - monitoring
  - ......

2.1 Build the decision model

The RCM determines the decision basic criteria to set limits among the following two:

- safety and regulations
- economy.

For items subjected to safety or particular technical standards, limits are determined applying relative regulations. For economy based criteria, limits are set through a cost optimization process.To this end a cost model shall be built for the particular maintenance task policy individuated for each item [6].

The construction of cost models involves the following steps:

- assumption of a stochastic process to model the pattern of system failures, incorporating also the effect of maintenance on system failure pattern.
- assessment of preventive maintenance costs
- evaluation of expected corrective maintenance costs
- evaluation of expected indirect failure costs (damages, impact on transit service etc.)
- definition of optimization criterion.

The most diffused criterion in the literature is the minimization of the limiting cost lim E [C(i)] where E[C(i)] is the expected total cost relative to the policy I.

2.2 Set limits

According to the policy adopted for maintenance task relative to a particular item, limits must be set for each action listed in the maintenance plan of the item (removal, check, scheduled maintenance,...).

Limits are determined by the implementation of decision models. They constitute a primary information in the data base management system, and are the basic input to the limits analysis function of the information system for the maintenance management which periodically prepares the maintenance checks list and the serialized items removal list.

CONCLUSIONS

The part of the basic structure of the functional model of a DSS for maintenance planning more strictly connected to reliability aspects has been presented. The matter involved in each function of the DSS is very complex. Methods which are to be implemented in the information system depend strictly on the particular system for which the DSS is to be implemented. In particular, the next research activity will be focused on the development of DSS's for the maintenance planning of engine powered transport means like buses and ships.

In the development of this family of DSS's the research groups of Statistics and Reliability Div. and Standards, Quality and Reliability Div. of Istituto Motori are going to exploit the experience and the results achieved in this year in the following topics:

- Statistical methods (classical and bayesian) for the estimation of reliability and reliability characteristics;
- Statistical methods for reliability trend analysis of repairable systems;
- Dependability models of transit systems
- Monitoring of service quality of transit systems
- Failure, repair and delay data management

In this preliminary analysis the complexity of DSS development emerged. Thus, it is seemed more feasible to start with the d evelopment of parts, or modules, of presented DSS than to consider it as a whole system. In particular, decision support systems are being designed for the decisions connected to:

- Choice of mantenance policy (hard time, on condition, condition monitoring) for each item of a transport mean.
- Management of maintenance policy (maintenance effectiveness monitoring, policy/limit criticism, etc.).

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