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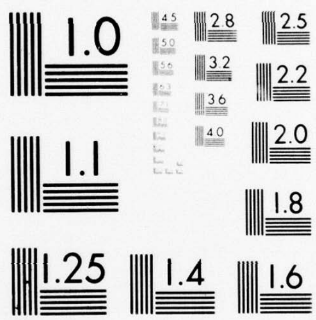

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LIFE EXPECTANCY OF U.S. ARMY COMMERCIAL DESIGN ADMINISTRATIVE VEHICLES

JUN 1978

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INTRODUCTION: At the request of the Tank-Automotive Readiness Command (TARCOM), the Army Materiel Systems Analysis Activity (AMSAA) has initiated a study to reassess the useful life (years/miles) of the Army's commercial type administrative vehicles. Specifically, 122 different types of vehicles will be studied. Included among these commercial type vehicles are buses, sedans, panel trucks, dump trucks, ambulances, etc. In addition, it has been requested that the maintenance man-hour standards for these vehicles also be re-evaluated.

In this paper, a description of the study plan will be presented along with a discussion of the data base and methodology to be employed. In this connection, it will be shown how the existing Administrative Vehicle Management System (AVMS) data base will be used in developing maintenance cost models for the various vehicles under study. Further, in describing the methodology, it will be shown that the determination of the life expectancy of these administrative vehicles will be arrived at through an evaluation of the economic life of these vehicles supplemented by a Reliability, Availability and Maintainability (RAM) analysis of the vehicles.

STUDY REQUIREMENTS: In tasking AMSAA to carry out the administrative vehicle life expectancy study, TARCOM specifically requested that AMSAA update the life expectancies and maintenance man-hour standards contained in two Department of Defense Instruction (DODI) documents. DODI 4150.4 "Replacement and Repair Guidance, and Life Expectancies For Commercial Design Vehicles" contains a list of the life expectancies (year/miles) for 14 types of vehicles (see Table I). It is pointed out that the last update of these life expectancies occurred in 1963 and thus an update of these lives was deemed necessary. In discussing these 14 types of vehicles, it was learned that 92 separate types of vehicles actually comprised the 14 vehicles listed in DODI 4150.4 (Table I) and that a life expectancy analysis was in fact required for each of the 92 vehicles. As an example of the division of the 14 vehicles listed in Table I into the 92 vehicles mentioned, the "Sedans, All" divides into five types: subcompacts, compacts, intermediate, regular and executive. In addition to the 92 vehicles to be studied, TARCOM requested that an additional 30 maintenance and service vehicles also be evaluated from a life expectancy viewpoint (see Table II).

An additional requirement that was included in the study was to evaluate the maintenance man-hour standards for commercial design vehicles contained in DODI 4151.10 "Maintenance Man-Hour Input Standards For Commercial (Transport) Design Motor Vehicles." This particular requirement was included in the study not only because the Department of Army (DA) requested an update of the values contained in DODI 4151.10 (see Table III) but because maintenance man-hour data will be accumulated during the course of the study.

STUDY PLAN: In order to accomplish the goals of this study (life expectancy determinations and updated maintenance man-hour standards), it is planned to determine the economic life of each of the vehicles being studied supplemented by a RAM analysis of these vehicles over the economic life span in order to determine if the life expectancy should be less than the economic life because of RAM considerations. The primary data requirement for this effort is maintenance data as a function of accumulated vehicle mileage for each of the 122 vehicles under study. Specifically, the types of maintenance data required are maintenance costs, man-hours utilized, mileage at which maintenance occurred, parts consumed, header data (vehicle type, line item number, description), date maintenance occurred and whether maintenance was of a scheduled or unscheduled variety. This type information will permit the generation of maintenance cost models as well as provide data for a RAM analysis. The maintenance cost models when combined with the present value (in FY 78 dollars) and the salvage values of the vehicles will thus provide all the data necessary for the economic life determination of the vehicles.

In order to obtain the primary data requirement (maintenance data as a function of accumulated mileage), AMSAA plans on accumulating this data through the currently existing Administrative Vehicle Management System (AVMS). AVMS data will be collected at six different sites (Fts. Benning, Lewis, Shafter, and Knox; Aberdeen Proving Ground (APG) and White Sands Missile Range (WSMR) beginning 1 October

1977 for one year. These sites were selected because they contain the largest quantities and have the widest diversification of types of administrative vehicles. It is anticipated that data will be collected on a total of approximately 6,000 vehicles at these sites.

DATA BASE: From past experience in the conduct of life expectancies studies for tactical vehicles, AMSAA immediately began a search for a data base from which maintenance data for administrative vehicles could be obtained. It was AMSAA's concept to obtain this data, if possible, from an existing data base rather than launching into an expensive data collection effort. In discussing the data requirements with Training and Doctrine Command (TRADOC) personnel, it was learned that the existing AVMS data base basically accumulates the desired data although not in the form required for the study. In the AVMS, each reporting installation compiles maintenance data on each of their administrative vehicles on a monthly basis but utilizes this data to supply an accumulated summary of the particular data element (man-hours, maintenance cost, etc.) since the beginning of the fiscal year to higher headquarters for review. There is no requirement in the AVMS to provide any of the data elements as a function of vehicle mileage as is required for a life expectancy study. It is also noted that in the current system the raw monthly maintenance data is disposed of after 90 days and further the mileage on the vehicle at the time of the maintenance action is not recorded.

Despite the shortcomings of the AVMS, from a life expectancy analysis standpoint, this data base was considered suitable for the study. To utilize the data base, each installation included in the study was requested to record the vehicle mileage at each maintenance action and rather than disposing of the monthly data, the study installations were requested to forward the data to the Materiel Readiness Support Activity (MRSA), Lexington, KY for computerizing. Since past data at these installations had been disposed of, except for the last 90 days which did not contain mileage entries, it was decided to initiate the life expectancy study with a new data collection effort beginning 1 October 1977. Another problem that had to be dealt with was that four of the installations (Fts. Benning, Knox, Lewis and Shafter) had their monthly maintenance data transcribed on magnetic tape while the other two installations (APG and WSMR) could only supply MRSA hand-written copies of the maintenance actions. Each of these two installations have been compiling about 800 maintenance actions a month.

MRSA acting as the central data receiving point not only has the large task of computerizing the hand-written APG and WSMR data but has to translate the tapes received from the other four installations so that they could be used on their computer. It should be pointed out that each installation initially forwarded to MRSA an inventory tape of all administrative vehicles at each post so that the current mileages, ages, etc., of each vehicle (as of 1 October 1977) could be determined. During the course of the one year data collection period, MRSA will further review the data received from each installation for accuracy and completeness, assemble data by individual vehicles, sort maintenance actions into proper date and mileage sequences and consolidate data on magnetic tape.

Upon completion of the one year data collection effort, MRSA will forward the data to AMSAA for a determination if in fact, sufficient data has been collected for the life expectancy study. Assuming one year of data collection is sufficient, the data collected will form the basis of the determination of commercial administrative vehicle life expectancies and maintenance man-hour standards.

STUDY METHODOLOGY: The life expectancy of the vehicles being studied will be assessed by determining the mileage at which the average system cost per mile (costs associated with the acquisition, shipping and maintenance of the vehicle) is minimized (economic life). This cost analysis will be supplemented by an evaluation of the vehicle's Reliability, Availability and Maintainability (RAM) characteristics over the economic life span to establish if the vehicles life expectancy should be less than the economic life because of RAM considerations. In exercising this methodology, the procedure that will be employed will be to analyze the maintenance costs (scheduled and unscheduled) to determine how the costs are changing as the vehicles increase in mileage. This will result in the development of a maintenance cost function which will be combined with the vehicle investment costs to establish an average system cost function. The RAM characteristics will also be analyzed to determine how they are changing as the vehicles increase in mileage.

COST ANALYSIS: As noted above, the object of the cost analysis was to determine how the maintenance costs were varying as the vehicle mileage was increasing in order that the average system cost could be minimized. Thus, all the maintenance actions occurring with these vehicles will be costed in constant dollars (parts and labor) as a function of mileage. The analysis of this data will involve determining a continuous instantaneous maintenance cost curve (the instantaneous maintenance cost refers to the maintenance cost at a specific mileage). This curve will then be used to obtain the average system cost curve (the system cost refers to all costs associated with the procurement, shipment, and maintenance of a vehicle including such costs as the vehicle's acquisition price, administrative expenses sustained, tooling costs, first and second destination charges, if any and maintenance costs). From the average system cost curve, the mileage at which the average system cost is at a minimum can be determined which represents the point where the overall average cost to the Army to procure, ship, and maintain the vehicle fleet is at a minimum. An example of the results of this type analysis is presented on Figure 1. As observed on the figure, the average system cost for the 2-1/2 ton truck was indicated to reach a minimum at 60,600 miles.

RAM ANALYSIS:

Unscheduled Maintenance Action Analysis. As noted above, data on maintenance actions (scheduled and unscheduled) is being collected during this study effort. This data is not being separated into those unscheduled maintenance actions resulting from a failure versus those actions not associated with a reliability failure. As a result, a reliability analysis based on the occurrence of unscheduled maintenance actions will be carried out rather than the usual reliability analysis based on failures. It should be noted, however, that a reliability analysis based on unscheduled maintenance actions provides a lower limit on a reliability failure analysis because if all unscheduled maintenance actions were in fact failures then the two analyses would be the same.

In analyzing the unscheduled maintenance actions, it is planned to develop a system Weibull failure rate function, i.e.,

$$r(t) = \lambda\beta t^{\beta-1} \quad t > 0,\ \lambda > 0,\ \beta > 0$$

where t = mileage on vehicle
λ = scale parameter
β = shape parameter

This function assumes that the probability that a vehicle will have an unscheduled maintenance action at mileage t is proportional to r(t) and independent of the unscheduled maintenance action history of the system prior to t. This definition differs from the usual definition which states that the probability of an unscheduled maintenance action at mileage t is also proportional to r(t) but conditioned on no unscheduled maintenance actions prior to t. The former definition applies to repairable systems whereas the latter definition does not. From this function, the probability that a vehicle with mileage t will complete an additional s miles without undergoing an unscheduled maintenance action (as determined by a non-homogeneous Poisson process) is

$$P(s/t) = e^{-\lambda(t+s)^{\beta} + \lambda t^{\beta}}$$

From this analysis, the probability of completing 75 miles without an unscheduled maintenance action as a vehicle is increasing in mileage through its economic life indication will be determined. An example of the results of this type analysis is shown on Figure 2.

Inherent Readiness Analysis. As with a reliability failure analysis, the determination of availability is normally based on failure data. For example, Inherent Availability (A_i) is normally defined as:

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

where MTBF is the mean-time-between-failures and MTTR is the mean-time-to-repair.

As noted above, unscheduled maintenance actions rather than failure data will be available. Further, the data will provide information on the mean-man-hours-to-repair rather than the mean-time-to-repair. The mean-time-to-repair for a particular maintenance action could be less than the man-hours involved if two or more mechanics worked on a particular maintenance action. To utilize this data, however, to obtain an estimate of an availability statistic, one can determine the probability of a vehicle not undergoing active repair due to any unscheduled maintenance action when called upon to operate at a random point in time (Inherent Readiness) and this is given by the following expression:

$$R_i = \frac{MTBUMA}{MTBUMA + MMHTR}$$

where MTBUMA is the mean-time-between-unscheduled-maintenance-actions and MMHTR is the mean-man-hours-to-repair. It should be noted that the Inherent Readiness parameter is a lower bound on an Inherent Availability value, i.e., if all unscheduled maintenance actions were reliability failures and if no more than one mechanic ever worked on a maintenance action then the mean-man-hours-to-repair would be equivalent to the mean-time-to-repair and $R_i = A_i$. The results of this analysis will thus be used to determine if any degradation is occurring in the Inherent Readiness parameter as the vehicles are increasing in mileage through the economic life indication.

Maintainability Analysis. The object of this analysis will be to determine if the man-hours required for maintenance is changing as the vehicles increased in mileage and to provide data for a review of the current maintenance man-hour standards. In addition, a parts replacement analysis will consist of the following: (1) major component replacements as a function of mileage (engine, axles, differential and transfer case), (2) high cost parts (in excess of $100) replacements, (3) ten most frequently replaced parts and (4) determination of the frequency of replacements for all vehicle parts.

Study Milestones. The conduct of this study is expected to take nearly two years. The study was formally initiated in August 1977 and is expected to be completed in June 1979. The study is essentially divided into three phases: (1) study feasibility phase (August 1977 - September 1977), (2) data collection phase (October 1977 - October 1978) and (3) analysis phase (November 1977 - June 1979). A detailed milestone schedule is indicated below.

MILESTONES:

Aug 77	Initial In-Process Review of Study Plan
Aug/Sep 77	Discuss Content of Installation Monthly Maintenance Report and Feasibility of Transferring Data to MRSA with Fts. Knox and Benning.
Sep/Oct 77	Visit Additional Data Collection Sites (APG, WSMR and Fts. Lewis and Shafter) to Discuss Implementation of Data Collection Effort.
Oct 77	Initiate Data Collection Effort.
Apr 78	Review Initial 6 Months of Data Collection.
May/Jun 78	Revise Existing Computer Programs on Basis of Initial Data Review.
Jun/Jul 78	Visit Data Collection Sites to Review Data Collection Effort.
Sep 78	Complete Data Collection.
Oct 78	Receive Data Tapes from MRSA.
Nov 78	Initiate Analysis of Data.
Apr 79	Complete Analysis of Data
May/Jun 79	Prepare Interim Report on Study Findings and Provide Briefings as Required.

TABLE I

COMMERCIAL VEHICLES
(LIFE EXPECTANCY YEARS AND MILES*)

Description	Years	Miles
Ambulance, All	8	60,000
Sedans, All	6	72,000
Station Wagon	6	72,000
Bus, Body on Chassis (BOC) (up to 37 passengers)	8	84,000
Bus, Body on Chassis (over 37 passengers)	10	150,000
Bus, Integral	12	300,000
Truck, 1/4 thru 3/4 ton (under 7,000 GVW)	6	72,000
Truck and Truck Tractor 1 thru 2 ton (7,000 thru 18,999 GVW)	7	84,000
Truck and Truck Tractor 2-1/2 thru 4 ton (19,000 thru 23,999 GVW)	8	84,000
Truck and Truck Tractor 5 thru 10 ton (24,000 thru 39,999 GVW)	10	150,000
Truck and Truck Tractor 11 ton and over (40,000 GVW and up)	12	300,000
Trailers and Semi Trailers	15	--
Motorcycle	5	30,000
Scooter 3W - Package Del	5	15,000

*Years or miles indicated whichever occurs first.

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TABLE II

MAINTENANCE AND SERVICE VEHICLES

NOMENCLATURE	LIN
Ser Pltf Trk Mtd 4 x 2	S80048
Ser Pltf Trk Mtd 24,000 GVW	S80068
Ser Pltf Trk Mtd 4 x 4 28,000 GVW	S80070
Ser Pltf Trk Mtd 34,500 GVW	S80078
Ser Pltf Trk Mtd 4 x 2 28,000 GVW	S80088
Ser Pltf Trk Mtd 6 x 4 30 Ft. H	S80108
Trk, FB Tilt Frame	X45187
Trk, Hopper Coal	X48792
Trk, Hopper Coal 10 Ton	X48799
Trk, Maint LC 4 x 4 14/21,000 GVW	X53366
Trk, Maint LC 4 x 2 28/36,000	X53371
Trk, Maint LC 4 x 4 28/36,000	X53376
Trk, Maint LC 4 x 4 24/26,000	X53400
Trk, Maint LC 6 x 6	X53402
Trk, Maint 6 x 4 34,500	X53406
Trk, Maint Tele 3/4 Ton	X53572
Trk, Maint 4 x 4 5/9000 GVW	X53790
Trk, Maint Utility Panel	X53848
Trk, Maint Utility 7/10,000	X53851
Trk, Maint Utility 14/21,000	X53856
Trk, Mat'l Hdlg 21,000 GVW	X54428
Trk, Mat'l Hdlg 24,000 GVW	X54433
Trk, Mat'l Hdlg 4 x 2 32,000 GVW	X54445
Trk, Mat'l Hdlg Hi Lift	X54448
Trk, Ref Col R/H	X55820
Trk, Ref Col 4 x 2 24,000	X55832
Trk, Ref Col 4 x 2 28,000	X55837
Trk, Ref Col Comp 6 x 4	X55839
Trk, Ref Col 6 x 4 39,500 GVW	X55842
Trk, Ref Col 6 x 4 51,000 GVW	X55847

TABLE III

MAINTENANCE MAN-HOUR STANDARDS FOR COMMERCIAL DESIGN VEHICLES

	Identification Vehicle Group	Direct Man-Hour Input Standards Per 1000 Miles	Average Annual Mileage
A.	Sedans.	2.0	14,000
B.	Bus, Body on Chassis (BOC) (Up to & Including 29 Passengers).	7.0	12,000
C.	Bus, Body on Chassis (BOC) (30-37) Passengers)	9.0	12,000
D.	Bus, All 38 Passengers and Up	10.0	12,000
E.	Station Wagon	2.2	16,000
F.	Ambulances.	6.0	8,000
G.	Truck, 1/2 Ton Pickup	3.5	10,000
H.	Truck, Carryall: Truck, Sedan or Panel Delivery Trucks, Other 1/4 Ton Through 3/4 Ton	3.5	10,000
I.	Truck and Truck Tractor, 1 Ton. . . .	3.0	9,000
J.	Truck and Truck Tractor, 1-1/2 Tons: Truck and Truck Tractor, 2 Tons . . .	8.0	7,000
K.	Truck and Truck Tractor, 2-1/2 Tons.	7.5	7,000
L.	Truck and Truck Tractor, 3 Tons - 4 Tons.	6.5	7,000
M.	Truck and Truck Tractor, 5 Tons - 10 Tons	10.0	7,000
N.	Truck and Truck Tractor, 11 Tons and Over.	12.5	9,000

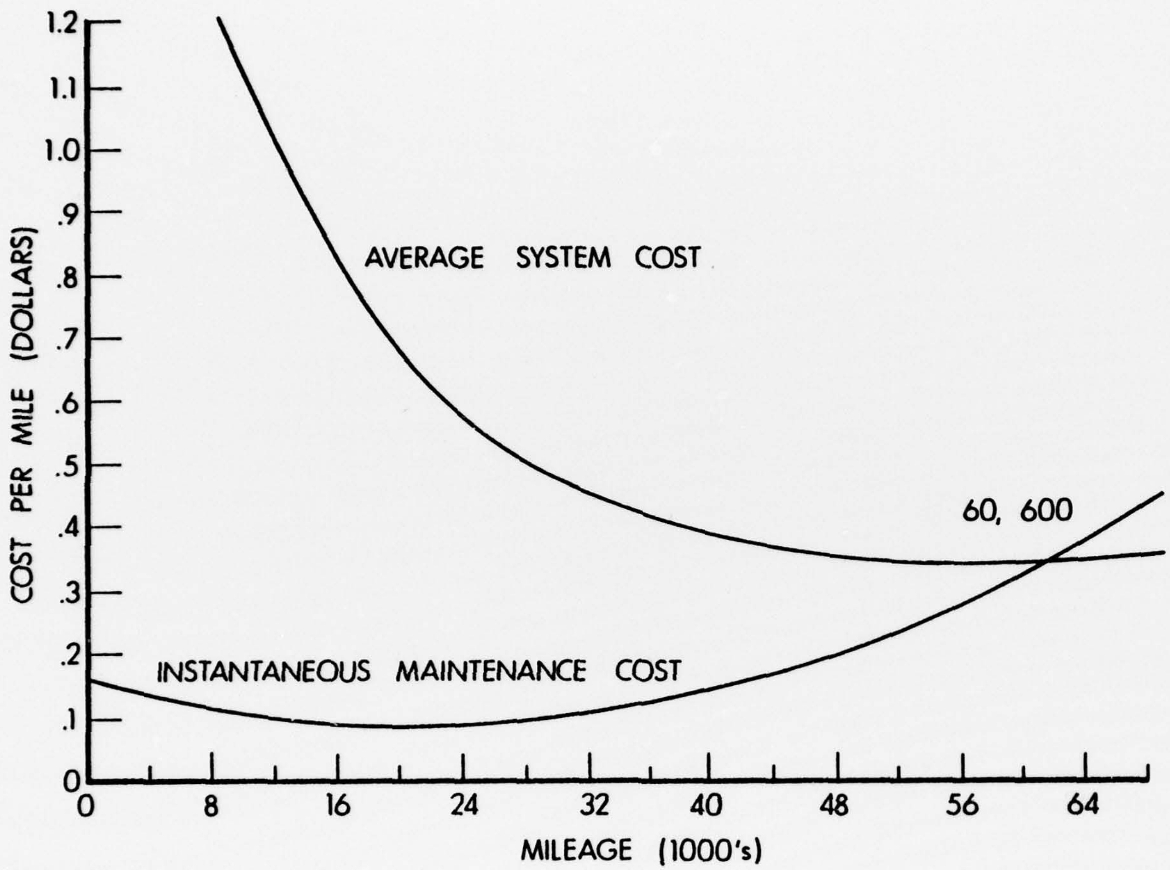

Figure 1. Cost Data – 2-1/2 Ton Truck.

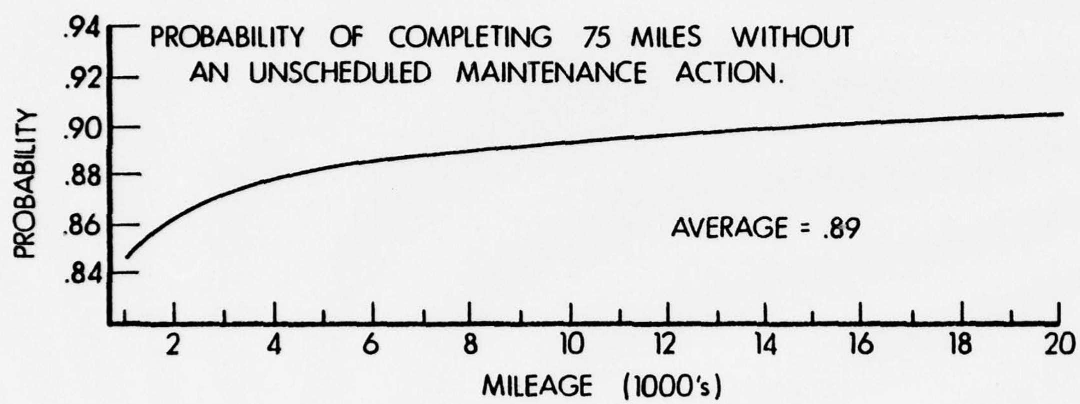

Figure 2. Reliability – 2-1/2 Ton Truck.