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SPARE PARTS CONSUMPTION NORM FOR A TRANSPORT FLEET

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of **Master in Mechanical Engineering.**

The work included in this thesis was carried out by the author in the Department of **Energy & Auto. Engineering** Ain Shams University, from **9/11/1987** to **18/4/1992.**

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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To

My Parents in Gratitude

and

My Family with Love.

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ABSTRACT

A successful implementation of works or projects that utilize equipment and vehicles necessitates their operation according to the specified time table without stoppage. This requires planning for an economical size of suitable spare parts in due time to keep the equipment in the proper technical condition capable for performing their duties to satisfy the project time table.

It has been observed that there is an acute deficiency in the spare parts availability; this is due to the irrational local planning methods which are not subjected to specified norms. Failure of these methods may be due to the non conformability with the dictated adoption of the fleet age.

A sample of old vehicles (eight years old) of the same type has been selected working in the field of goods transportation under the same operation and maintenance conditions. Data, concerning the operation and spare parts consumed for maintenance and repairs of these vehicles since the starting date of service till now, has been collected.

A computer package has been designed to store, process, and analyze after the data has been coded. The study has concluded the following:

1. Cost of the consumed spare parts to implement all levels of repairs is proportional to the vehicle age. This relationship is in the power form. The power factor is less than one in the case of current repairs, while it is more than one in the case of medium and capital repairs.

2. The life time of the vehicle is divided into three phases (from zero up to 50%, more than 50 up to 70%, and more than 70% of the age). Each phase has its own distinctive spare parts consumption cost relationship.

3. Spare parts index has een defined to indicate the spare parts consumption with the fleet age, and equals to: the ratio of the total cost of spare parts consumed through a period divided by the cost of spare parts consumed for preventive maintenance and current repairs for the same period.

4. A mathematical model has been established for the spare parts index with the fleet age.

NOTATIONS

SPC	=	Spare Parts Consumption
A	=	The Average Age of the Vehicle Group in [km]
P	=	Constant Cofficient
q	=	Roughness Cofficient
R	=	The transitinal Value of Road Roughness
a & b	=	Coefficient of the Linear-Tangential Extension of the Exponential Relationship
F	=	Road Roughness for Paved and Unpaved Roads
SP	=	Spare Parts Cost in [paise/km]
Lk	=	Age of Vehicle in [100 km]
Rf	=	Rise and Fall in Road in [m/km]
Rg	=	Roughness of Road in [mm/km]
W	=	Pavement Width in [m]
PW	=	Power to Weight Ratio [k.watt/tone]
GA	=	Government Average Labour Intensity
GH	=	Government High Labour Intensity
PA	=	Private Sector Average Labour Intensity
PH	=	Private Sector High Labour Intensity
n	=	Sample Size
B	=	Precision Coefficient (bound on the error)
σ^2	=	Variance of the Population
CPPL	=	Coding of Parts Price List
TST	=	Tractor Simi-Trailer
Y	=	Spare Parts Consumption Rate [LE] per 1000 km
X	=	Percentage of Vehicle Life Time
f_1	=	Equation of Preventive Maintenance
f_2	=	Equation of Current Repairs
f_3	=	Equation of Medium and Capital Repairs
I_i	=	Spare Parts Consumption Index for the i^{th} Phase
C_i, d_i, e_i & f_i	=	Constants
i	=	I, II, III Phases
M	=	Population
M_i	=	Number of Classes
N_i	=	Number of Students in Each Class
μ	=	Mean
X	=	Sample Mean

CHAPTER ONE

INTRODUCTION AND PREVIOUS WORK

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INTRODUCTION AND PREVIOUS WORK

Spare parts planning, like any planning activity, is an effort to optimally estimate the needs according to the operating conditions to achieve a desired goal, in this case, least possible downtime, and longevity of equipment. No plan can be perfect as the resources are generally inadequate in relation to goals. A good plan is one which makes the best use of the existing resources. However, planning should strive for perfection. There are several ways by which planning can be structured to push ever closer to approximations of the ideal goal. One of these ways is to envision the planning effort as occurring in two time-frames at the same time: the short-term in which the available resources are known, and the long-term, over which resource increments can be expected. Though this thesis provides specific planning approach for the long-term planning effort for vehicles in general, and, tractor of a simitrailer units (TST). The latter is considered the main goods' land transports in Egypt.

The TST as a large amount of investment, as well as other equipment of the type, they should be utilized with the minimum down-time and maximum availability. Both are atchieved primarily through implementing proper planned maintenance and repairs. This proper planning can only be realized if the supply of the spare parts needs are available with the right type and quantity in the right time otherwise, a non-planned down-time is inevitable.

Spare parts procurement starts with the determination of needs as a pre-requisit to allocate the funds. The common practice in Egypt is to allocate 20% of the TST procurement cost for the supply of spares (usually it covers for the first 3 years of TST utilization). However, field experience has shown that some of this supply has turned to be stagnant till the end of the TST life, i.e. an idle investment, and shows that this strategy is an expensive one. The problem starts after the first 3 years elapse and a new year-to-year supply is needed and personal judgement starts to be the rule in ordering the spare parts needs. The practice is to procure them just in time when they are needed and not being inhand just-in-time for repair. As a result:

- Waste of labour effort (man - h)
- Prolonged down-time
- Increase in repair frequency when the repair is not complete

which all result in decreasing the availability of vehicles and consequently in loss of production.

To solve the above mentioned problem it is required to have the needed spare parts in the workshop in the appropriate time. This can be achieved through proper planning of spare parts stock.

Ashok Dhareshwar and Rodrigo Archondo-Callas(8)* constructed the Vehicle Operating Cost Prediction Model (VOCPM) with IBM program Diskette and prediction tables (April 9, 1986). One part of the VOCPM is concerning the spare parts consumption (SPC). This part proposed a mathematical model to plan for spare parts planning needs [SPPN] taking into consideration the following:

- Road roughness
- Vehicle age

The effect of these two factors are multiplicative. Holding the age constant the relationship between spare parts cost per 1000 vehicle-km and road roughness is generally exponential. The way of modeling parts consumption was in terms of the ratio of the monitory cost of parts consumed per 1000 vehicle-km to the price of a new vehicle in the same period. Under the assumption that the prices of spare parts and of a new vehicle vary together by the same proportions.

The effect of age has been found to be multiplicative with an exponent. The age exponent is remarkably stable for a given type over environments. Symbolically SPC is given by:

$$SPC = A * P * \exp(q * R) \qquad \text{for } R < F \text{ .... (i)}$$

and

$$SPC = A(a + b * R) \qquad \text{for } R > F \text{ .... (ii)}$$

Where

SPC	=	Spare parts consumption
A	=	The average age of the vehicle group in (KM)
P	=	Constant coefficient in the exponential relation between SPC and roughness
q	=	Roughness coefficient in the exponential relationship between SPC and roughness
R	=	The transitional value of road roughness
a & b	=	are coefficients of the linear-tangential extension of the exponential relationship.
F	=	Road roughness for paved and unpaved roads. The road conditions are presented by all possible combination of:

Average Roughness [m/km]	0	40	80
Average Horizontal Curvature [degree/km)	0	500	1000
Road Roughness for paved Roads	25	75	125
Road Roughness for Unpaved Roads	50	150	250

* **References are given at the end.**

Thus the spare parts consumption can be obtained by two components according to the road roughness:

- This model does not take the other operating conditions (mainly; average speed, Load, etc ...) into consideration.

- Also the values of the constants and coefficients not easy to be identified and is subjected to the personal judgement.

- Not applicable in Egypt because of the impact of custom and duty taxes which differ from one country to another.

Another model for spare parts consumption was developed by LR.KADIYAH(5). This model is only one equation taking into consideration the vehicle age, road characteristics, power to weight ratio and intensity of labour for maintenance. This model is as follows:

$$\log_e SP = 5.656\ PA + 2.695\ PH + 10.520\ GH + 27.716\ GA + 0.01843\ LK - 1.293\ PW + 0.01235\ RF + 0.01270\ RG/W$$

where:

SP	=	Spare parts cost in [paise/km] (Basic Year 1987)
LK	=	Age of vehicle in [1000 km]
RF	=	Rise and fall in road in [m/km]
RG	=	Roughness of road in [mm/km]
W	=	Pavement width in [m]
PW	=	Power to weight ratio [k.watt/tone]
GA	=	Zero or 1 variable, GA = 1 if government undertaking with average intensity of labour for maintenance, otherwise GA = 0
GH	=	Zero or 1 variable, GH = 1 if government undertaking with high intensity of labour for maintenance, otherwise PA = 0.
PA	=	Zero or 1 variable, PA = 1 private operator with average intensity of labour for maintenance, otherwise GH= 0.

PH = Zero or 1 variable, PH = 1 private operator with high intensity of labour for maintenance, otherwise PH = o.

This equation is valid for the trucks only. The other types of vehicles (cars, busses, ...) have its own equation for each.

It is clear that this equation can be utilized for either government or private sectors fleets.

Since the present work is dealing with public sector company (Governmental), so, the terms PA and PH could be cancelled from the equation.

Also other terms can be discussed in order to make the equation in a simple form as follows:

- The terms RF, RG and W are constants for a certain type of roads
- The term PW is also constant for a certain type of trucks
- The terms GH and GA are also constant according to the intensity of labour for maintenance, otherwise equals to zero.

Thus the final form of this equation will be:

$$\log_e SP = 0.10843\ LK - C$$

Where:

C = Constant containing all the above mentioned constant values (terms) for a certain type of trucks maintained with a certain intensity of labour and operating on a certain type of roads.

This equation can be written in the form:

SP = e ** (0.01843 LK + C)

i.e. The spare parts consumption is an exponential relationship with vehicle age.