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OPTIMIZATION OF SCHEDULED SERVICING FUNCTIONS OF PASSENGER CARS USING A MATHEMATICAL MODELLING APPROACH

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ABSTRACT

This article explains an approach to formulate Field Data Based Model (FDBM) for optimization of passenger car's scheduled service process. In view of the sustainably increasing competition in the automobile sector, different automobile companies are taking great efforts to improve their after sales service. One of the most important aspects of after sales service is the scheduled servicing of a vehicle. The scheduled servicing offers certain advantages, such as preplanning (ordering spares, costs are distributed more evenly, no initial costs for instruments for supervision of equipment) and avoiding inconvenience. However, often the delays during these scheduled servicing negates the advantages offered. Hence, was necessary to generate a reliable and valid approach (such as FDBM) for delineating a model for optimization of Scheduled Servicing Functions of automobiles in general and Passenger Cars in particular.

Keywords: Scheduled service, dimensional equation, anthropometry, cycle time

FUNDAMENTALS OF A FIELD DATA BASED MODEL

Man Machine Systems

During the course of our daily activities (from domestic Situation, social life, industrial activities, service sector or even education field) many of them (activities) often take place in a planned way. The context where such activities take place (i.e. the workstation is expectedly designed; however many times these designs are inadequate to achieve the desired level of efficiency. Nevertheless, it is important to note that all such systems are effectively the Man-Machine systems [1] [2][3].

A series of experiments were performed to study the effects of various attributes on the cycle time of the scheduled servicing of the passenger cars in the workshops. These experiments were carried out to investigate the effects of various field parameters such as availability of the tools and equipments, work place design, skill levels of the technicians, process and environmental parameters on the cycle time of the operation i.e. total time of scheduled servicing. The output was measured and recorded using appropriate storage devices (personal computer) for furtheranalysis.

Systems, Causes, Effects and Extraneous Variables

It is well known that any activity within a system is a function of four essential attributes, which are system, causes, effects and extraneous variables. This can be illustrated by one activity of oil filter replacement in a vehicle (passenger car). For example a technician is performing an oil filter replacement operation on a diesel vehicle. This activity is realized by arranging

(a) **System**: This is a specific place in an engine with prevailing environmentalconditions.

(b) **Causes**: These are the forces, which are actuating the system (which sets the system in action)

(c) **Effects**: These are the responses to the execution of anactivity.

(d) **Extraneous Variables**: These are the Factors/Parameters/Causes, which do influence the performance of the activity but which cannot be measured [4] . At times, these variables are abstract.

As regards to technician performing scheduled service operation of passenger cars, causes would be: Information about operator (i.e. his anthropometric data [5] (variables A1, A2, A3, A4), PERSONAL data i.e. Qualification, training, Work experience, his age (variables P1, P2, P3, P4, P6). Accessibility & ease of opening Air & Fuel Filter, Engine Oil Sump Capacity, Number of bolts to be inspected/tightened, Gear Oil Sump Capacity (variables C1, C2, C3, C4) , workplace related parameters Car Lift, Tools Trolley Design, Torque & other setting values display, Spares, General & special tools Availability (variables W1,W2, W3, W4). Extraneous variables would be: condition of vehicle parts (such as wear & tear, rusting), motivation of technicians. Responses (i.e. effects) are: Cycle time of car servicing activity (Y1) & Human Energy Input of technicians(Y2).

FIELD DATA BASEDMODELS

Data sets contain information, often much more than can be learned from just looking at plots of those data. Models based on observed input and output data (from real life situation) help us abstract and gain new information and understanding from these data sets. They can also serve as substitutes for more process-based models in applications where speed is critical or where the underlying relationships between different activities are poorly understood. Thus, it is not possible to plan such activities on the lines of design of experimentation [6], especially for the dynamic system (which exists in scheduled service process). When one is studying any completely physical phenomenon but the phenomenon is very complex to the extent that it is not possible to formulate a logic based model correlating causes and effects of such a phenomenon, then one is required to go in for the field data based models [7 &8].

In view of the dynamic nature of the context under investigation (which reveals complex phenomenon), it was decided that to formulate a field data based model in the present investigation rather than using a theoretical approach. In such a situation various steps involved in formulating model for such a complex phenomenon is same as follows [9]

1. **Identification of independent, dependent and independent extraneous variables**: This step involves identification of the Causes and Effects by performing qualitative analysis of physics of such aphenomenon.

2. **Reduction of independent variables adopting dimensional analysis**: This step involves establishing dimensional equation for such a phenomenon. Once a dimensional equation is formed, it is a confirmatory face that all involved physical quantities are considered. Getting dimensionless inputquantitiesthroughphysicalquantities,thesearethecauses(orInputs).AccordingtoTheories

of Engineering experimentation by H. Schenck Jr., Chapter 4 [10], "The choice of Primary Dimensions". most systems require at least three primaries, but the analyst is free to choose any reasonable set he wishes, the only requirement being that the variables must be expressible in his system. In this research all the variables are expressed in mass(M), length(L), time(T) hence M, L, and T are chosen for the dimensional analysis. The process variables, their symbols and dimensions are listed in Table 1. M, L and T are the symbols for the mass, length and time respectively.

3. **Test planning comprising of determination of test envelope, test points, test sequence and experimentation:** This involves deciding Test Envelope, Test Points, Test Sequence, etc.[11]

Test Envelop: To decide range of variation of an individual independent Π term

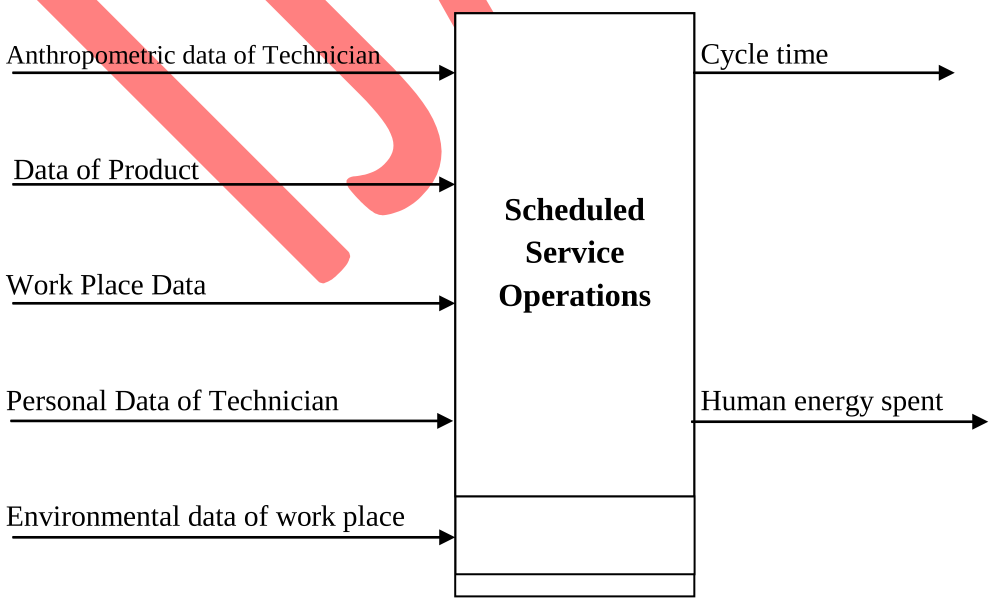
Test Points: To decide & specify values of independent Π terms at which experimental setup be set during experimentation.

Test Sequence: To decide the sequence in which the test points be set during experimentation

Plan of Experimentation: Whether to adopt Classical Plan or Factorial Plan

Physical Design of an Experimental setup: The physical design of an experimental setup is an important aspect which governs the overall ease or difficulty of the operations of the process (workshop in this case).

Service Process during scheduled maintenance: Service activities in automobile service station are broadly divided in two categories; scheduled service & breakdown service. Through-put indicates number of vehicles serviced from a given workshop and bay productivity is an indication of number of vehicles serviced on a bay per day. Furthermore, operationally, Inspect, Adjust & Replace are the activities performed by technician during scheduled maintenance. Scheduled maintenance is performed with different vehicle positions i.e. vehicle on ground while work is performed from top by lifting bonnet, vehicle partially lifted on a two post lift & work performed from sides, vehicle lifted above the head/ height of technician & work performed from below the vehicle. Quality parameters include repeat complaint, breakdown, collateral damage during service & time required for service.



Block Representation of Scheduled Service Phenomenon under Study.

5. **Physical design of an experimental set up**: this step included physical design of the experimental area for datacollection.
6. **Execution of experimentation for data collection**: this step included execution of the experimentation as per test planning and collection of data regarding causes (Inputs) and effects (Responses).

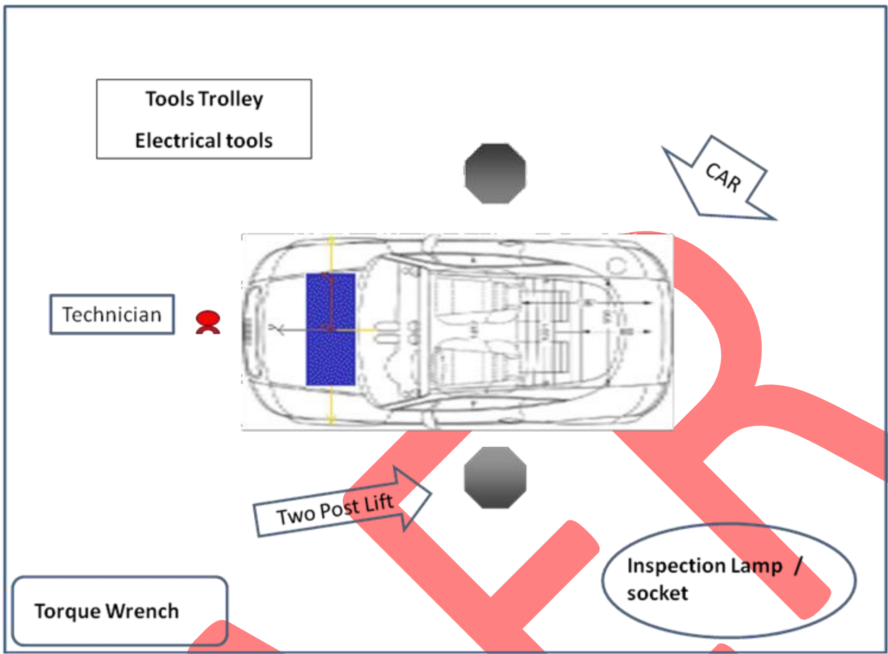


Fig. 1: The work station for scheduled servicing of a passenger car

Generally, there is only one technician for this work station. He has a standing posture whereas for other operation, intermittently he has to adopt sitting posture whereas for some operations he has to adopt bending position. Posture means the geometry of outline of body adopted by the technician. Besides, he uses torque wrench & inspection lamp & other tools & spares.

7. Purification of experimentation data: this step included purification of the gathered data using statisticalmethods
8. Formulation of the field data basedmodel.
9. Model optimization
10. Sensitivity analysis and Reliability of themodel.

The first six steps mentioned above constitute design of experimentation. The seventh step constitutes of model formulation where as eighth and ninth steps are respectively optimization and sensitivity and reliability of model. Description of work & sequence of work is given in the table.

Table 1: List of different Process Variables

S. N.		**Variable Name**	**MLT indices**	**Unit of measurement**
1	C_1	Accessibility / ease of opening Air & Fuel Filter	$M^0 L^0 T^0$	Dimensionless

2	C_2	Engine Oil Sump Capacity	M^0 L3 T^0	liters (cm 3)
3	C_3	Number of bolts to be inspected / tightened	$M^0 L^0 T^0$	Dimensionless
4	C_4	Gear Oil Sump Capacity	M^0 L3 T^0	liters (cm 3)
5	A_1	Arm Span	$M^0 L^1 T^0$	cm
6	A_2	Arm Reach	$M^0 L^1 T^0$	cm
7	A_3	Height	$M^0 L^1 T^0$	cm
8	A_4	Sitting Knee Height	$M^0 L^1 T^0$	cm
9	W_1	Car Lift	$M^0 L^0 T^0$	Dimensionless
10	W_2	Tools Trolley Design	$M^0 L^0 T^0$	Dimensionless
11	W_3	Torque & other setting values display	$M^0 L^0 T^0$	Dimensionless
12	W_4	Spares, General & special tools Availability	$M^0 L^0 T^0$	Dimensionless
13	P_1	Qualification of Technician	$M^0 L^0 T^0$	Dimensionless
14	P_2	Training of Technician	$M^0 L^0 T^0$	Dimensionless
15	P_3	Experience of Technician	$M^0 L^0 T^1$	Years
16	P_4	Age of Technician	$M^0 L^0 T^1$	Years
17	P_5	Body Mass Index- prime (BMI)	M0 L0 T^0	Dimensionless
18	E_1	Dry Bulb Temperature	$M^0 L^0 T^0$	Degree Centigrade
19	E_2	Illumination in Workshop	$M^0 L^0 T^0$	Lux
20	E_3	Noise Level Workshop	$M^0 L^0 T^0$	Decibel
21	E_4	Noise level of Pneumatic Tools (while working)	$M^0 L^0 T^0$	Decibel
22	E_5	Wet Bulb Temperature	$M^0 L^0 T^0$	Degree Temperature
23	E_6	Illumination at Workplace	$M^0 L^0 T^0$	Lux

It was necessary to formulate relationships such as

Z 1 = f1 [(C1,C2,C3,C4), (A1,A2,A3, A4), (W1,W2,W3,W4), (P1,P2,P3,P4,P5), (E1, E2, E3, E4,E5, E6] ---------- (1.1)

Z 2 = f2 [(C1,C2,C3,C4), (A1,A2,A3, A4),(W1,W2,W3,W4), (P1,P2,P3,P4,P5) , (E1, E2, E3,E4, E5,E6] ------------(1.2)

Where,

- Product/ car related variables(C1,C2,C3,C4)
- Anthropometric data of an operator (A1, A2, A3, A4)
- Personnel factors of an operator (P1, P2, P3, P4,P5)
- Workplace parameters (W1,W2, W3,W4)
- Environmental conditions (E1, E2, E3, E4, E5, E6)

Because once such relationships are formed, then only it is possible to improve the method of working.

Reduction of variables through dimensional analysis: The various independent and dependent variables of the system with their symbols and dimensional formulae are given in nomenclature. There are several quite simple ways in which a given test can be made compact in operating plan without loss in generality or control. The best known and the most powerful of these is dimensional analysis. In the past dimensional analysis was primarily used as an experimental tool whereby several experimental Variables could be combined to form one. Deducing the dimensional equation for a phenomenon reduces the number of independent variables in the experiments. The exact mathematical form of this dimensional equation is the targeted model. This is achieved by applying Buckingham"s π theorem (Hibert, 1961) [12]. The Pi terms are presented in Table 2.

Table 2: List of different Dimensional Pi terms formulated by Buckingham's Pi theorem

Pi Term	Code	Description of Pi terms	Pi term Equation
π1	C_1	Accessibility / ease of opening Air & Fuel Filter	**π1** = C1 . C2 / C3.C4
	C_2	Engine Oil Sump Capacity	
	C_3	Number of bolts to be inspected / tightened	
	C_4	Gear Oil Sump Capacity	
π2	A_1	Arm Span	**π2 = A1 A2 / A3.A4**
	A_2	Arm Reach	
	A_3	Height	
	A_4	Sitting Knee Height	
π3	W_1	Car Lift	**π3** = W1 W2 / W3.W4
	W_2	Tools Trolley Design	
	W_3	Torque & other setting values display	
	W_4	Spares, General & special tools Availability	
π4	P_1	Qualification of Technician	**π4** = P1 P4 P5 / P2.P3
	P_2	Training of Technician	
	P_3	Experience of Technician	
	P_4	Age of Technician	
	P_5	Body Mass Index- prime (BMI)	
π5	E_1	Dry Bulb Temperature	**π5** = E3 E2 E1 / E4 E5 E6
	E_2	Illumination in Workshop	
	E_3	Noise Level Workshop	
	E_4	Noise level of Pneumatic Tools (while working)	
	E_5	Wet Bulb Temperature	
	E_6	Illumination at Workplace	
π6	Tc	l cycleTime	Tc/ Tp
	T_p	Preparation Time	

π7	HB_r	Pulse of worker at rest	HBr / HBw
	HBw	Pulse of worker after work	

PROCEDURE FOR GETTING FDBM FOR ACTIVITY OF AUTOMOBILE SCHEDULED SERVICE

In this paper, it is decided to detail procedure for getting FILED DATA BASED MODEL activity of scheduledservice.

Description of the Work Station and Activity of Work Station:

Causes or Inputs to the Activity:

In this case complete anthropometric data of the operators A1, A2, A3, A4, Parameters defining the work station such as W1, W2, W3, W4, product parameters C1, C2, C3, C4, technicians personal factors P1, P2, P3, P4, P5. Environment related factors E1, E2, E3, E4, E5, E6 wereinputs.

Effects or Outputs or Responses of the Articles:

For this operation, the effects/outputs/responses were: Cycle time needed to complete the schedule service i.e. preparation time plus operation time & human energy (HE) input.

Extraneous Variables:

These were

1. Condition of fasteners & clamps, which may be rusted & hencelocked
2. The influence of environmental conditions on working oftechnician
3. Motivation of technicians on a particular day ortime.

DETERMINATION OF PLAN FOR EXPERIMENTATION AND DATA GENERATION

For multifactor experiments two types of plans viz. classical plan or full factorial and factorial plan are available, in this experimentation conventional plan of experimentation is recommended. In all data was collected from total 250 vehicles of three different models (products).

Rejection of Erroneous Data

Out of these 250 observations, there are chances of some data being erroneous either from inputs or responses. Adopting techniques of rejecting the erroneous data [13] [14], the observed data was purified for proceeding further with the step of Formulation of Models. Vehicles with rusted nuts & bolts required abnormal time for completion. Similarly customer intervention also increased the cycle time. Vehicles which had developed some major fault, discovered during the standard checks were not considered. There were cases where the technician had to be shifted to other job or vehicle in case of urgent jobs & some other technician completed the servicing these data were rejected. Cases which involved any delay due to malfunctioning of the equipment viz. a car lift were rejected. When the initial readings were taken technician were overcautious, such data wererejected.Therewerecaseswhentechniciandidnotperformsomeoperationorskippedsome operation, this happened during operations of inspection (leakage, wear etc) these data were rejected.

Approach For Formulation Of Models Based On Observed Data

It is necessary to correlate quantitatively various independent and dependent terms involved in this very complex phenomenon. This correlation is nothing but a mathematical model as a design tool for such situation. The Mathematical model for step turning operations is as given below:

For the vehicle servicing time operation Five independent pi terms ($\pi 1$, $\pi 2$, $\pi 3$, $\pi 4$ and $\pi 5$) and one dependent pi terms (π 6) were decided during experimentation and hence are available for the model formulation. Each dependent π term is the function of the available independentterms,

$\pi\ 6 = F(\pi_1, \pi_2, \pi_3, \pi_4 \& \pi_5)$

A probable exact mathematical form for the dimensional equations of the phenomenon could be relationships assumed to be of exponential form [5]. For example, the model representing the behavior of dependent pi term π 6 with respect to various independent pi terms can be obtained as under.

$\pi\ 6 = K1\ (\pi_1)^{a1}.(\pi_2)^{b1}.(\pi_3)^{c1}.(\pi_4)^{d1}.(\pi_5)^{e1}$ .... (5.1)

* Therefore six unknown terms in the equation 5·1 i.e. Constant of proportionality K_1& indices a_1, b_1, c_1, d_1,e_1
* To get values of these unknowns we need six sets of values of π_1, π_2, π_3, $\pi_{4,}\pi_5$
  * As per the experimental plan in design of experimentation we have 243 sets of these values. If any arbitrary six sets from these tables are selected & values of unknown‟s a_1,b_1,c_1,d_1,$e_{1,}K_1$ are computed then it may not result in to one best unique solution representing best fit curve (unique) for the remaining sets of values. To be specific, we can find out ^nCr combinations of r sets taken together out of the available n sets of thevalues

^nC_r= 243 C_6

Algorithm developed in „MATLAB‟ can achieve this. This method generated 248C_6 sets of solutions, which on averaging resulted in single solution.

Model

But this is also not a true representative unique solution of all the available sets or a true model of the phenomenon. Hence, it was decided to solve this problem by curve fitting technique (Spiegel 1980). To follow this method is it necessary to have equations as under:

$Z = a + b\cdot x + c\cdot y + d\cdot z +$--------------(5.2)

Equation 5.1 can brought in the form of 5.2 by taking log of both sides of equation 5.1 we get.

$\log\pi_6 = \log k_1 + a_1.\log(\pi_1) + b_1.\log(\pi_2) + c_1 \log(\pi_3) + d_1.\log(\pi_4) + e_1 \log(\pi_5)$…. (5.3)

let **log π_6=Z_1 ; log K_1=k_1' ; log (π_1) =A**

log (π_2) =B; log(π_3)=C ; log (π_4)=D ; log (π_5) =E

Then equation 6.3 can be written as

$Z1 = K_1" + a_1A + b_1B + c_1C + d_1D = e_1E$ ....(5.4)

Equation 5.4 is a regression equation of Z on A, B, C, D, & E.

In an n-dimensional coordinate system this represents a regression hyper plane. To determinetheregressionhyperplanewedeterminea$_1$,b_1,c_1,d_1&$e_1$in equation5.4 sothat

$\Sigma z_1 = nK"_1 + a_1\cdot\Sigma A + b_1\cdot\Sigma B + c_1\Sigma C + d1\Sigma D + e_1\Sigma E$

$\Sigma z_1 \cdot A = K''\Sigma A + a\,\Sigma A_1 \cdot A + b\,.\Sigma B_1 \cdot A + c\,\Sigma C_1 \cdot A + d\,\Sigma D_1 \cdot A + e\,\Sigma E_1 \cdot A$

$\Sigma z_1 \cdot B = K''\Sigma B + a\Sigma A_1 \cdot B + b\,.\,\Sigma B_1 \cdot B + c\,\Sigma C_1 \cdot B + d\,\Sigma D_1 \cdot B + e\Sigma E_1 B$

$\Sigma z_1 \cdot C = K''\Sigma C + a\Sigma A_1 \cdot C + b\,.\,\Sigma B_1 \cdot C + c\,\Sigma C_1 \cdot C + d\,\Sigma D_1 \cdot C + e\Sigma E_1 C$

$\Sigma z_1 \cdot D = K''\Sigma D + a\Sigma A_1 \cdot D + b\,.\,\Sigma B_1 \cdot D + c\,\Sigma C_1 \cdot D + d\,\Sigma D_1 \cdot D + e\Sigma E_1 D$

$\Sigma z_1 . E = K''\Sigma E + a\,\Sigma A_1 \cdot E + b\,.\Sigma B_1 \cdot E + c\,\Sigma C_1 E + d\,\Sigma D_1 E + e\Sigma E \cdot E_1$ **5.5**

Where n is the a number set or number of sum of the values

These equations are called normal equations corresponding to the equation 5.4 and are obtained as per the definition. In the above sets of equation the values of the multipliers of K''_1 a_1, b_1, c_1, d_1& e_1 aresubstituted tocompute thevaluesof theunknowns Viz.K_1 a_1,b_1,c_1,d_1&e_1. Thevalues ofthe termson LHS andthemultipliersof$K''_1$$a_1$,$b_1$,$c_1$,$d_1$&$e_1$inthesetofequations 5.5arecalculated & tabulated. After substituting there values in the equation 5.5 we get a set of six equations which are tobesolvedsimultaneouslytogetvaluesof K''_1 a_1,b_1,c_1,d_1&e_1.

The matrix method of solving these equations is given below

Let A = 6 x 6 matrix of the multipliers of K''_1 a_1, b_1, c_1, d_1& e_1

B = 6 x 1 matrix of the terms on RHS

C=1x6matrixofsolutionsorvaluesof$K''_1$$a_1$,$b_1$,$c_1$,$d_1$&$e_1$ Than C

= inv(A)·B

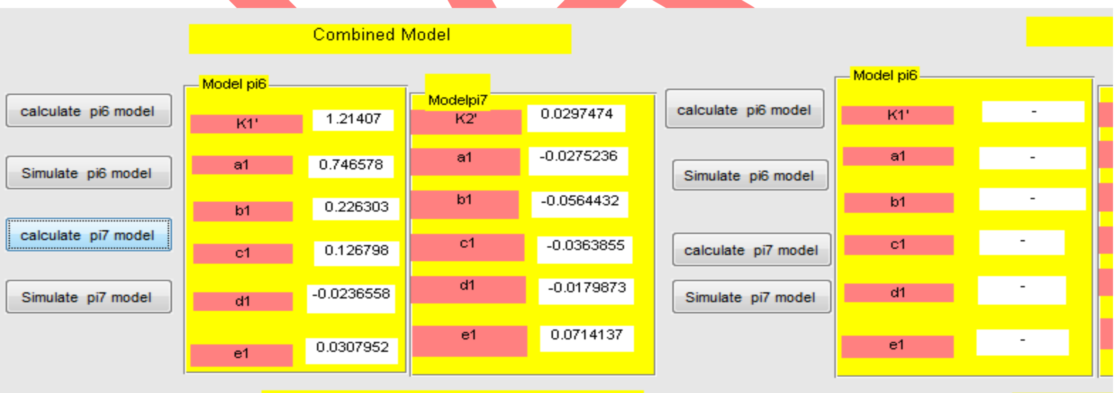
Gives the unique values of K''_1 a_1, b_1, c_1, d_1& e_1& antilog K''_1 a_1,b_1, c_1, d_1& e_1 will be the solution for the equation 6.1.

Hence, the model for Cycle Time all products is

$$\pi_6 = 3{\cdot}367161\,(\pi_1)^{0\cdot746578}\,(\pi_2)^{0\cdot226303}\,(\pi_3)^{0\cdot1267}\,(\pi_4)^{-0\cdot0236}\,(\pi_5)^{0\cdot0308}$$

And for the Human Energy Spent all products is

$$\pi_7 = 1{\cdot}030187\,(\pi_1)^{-0\cdot02752}\,(\pi_2)^{-0\cdot05644}\,(\pi_3)^{-0\cdot0363855}\,(\pi_4)^{-0\cdot017987}\,(\pi_5)^{0\cdot0714137}$$



Screenshot showing output of Matlabprogramme for π6 & π7

RESULT ANALYSIS

Model Sensitivity Analysis

Sensitivity analysis was performed to study how the variation (uncertainty) in the output of the developed mathematical model can be assigned, qualitatively as well as quantitatively, to different sources of variation (independent variables) in the input of a model. The main purpose of the sensitivity analysis was to determine the robustness of the study. Besides, the sensitivity analysis also helped to identify what source of uncertainty weights more on the study's conclusions as to ensure the quality of the model.

The influence of the various independent π terms has been studied by analyzing the indices of the various π terms in the models. Through the technique of sensitivity analysis, the change in the value of a dependent π term caused due to an introduced (known) change in the value of individual π term was evaluated. In this case, change of ±10% was introduced in the individual independentπtermindependently(oneatatime).Thus,totalrangeoftheintroducedchangewas ±20%. The effect of this introduced change on the change in the value of the dependent π terms was evaluated .The average values of the change in the dependent π term due to the introduced change of ±10% in each independent π term. The total % change in output for ±10% change in input is shown in **Table 4.** The result of the sensitivity analysis (with respect to different pi terms) is presented in **Fig. 2** and**3**.

Pi Terms	**Scheduled servicing process**			
	Cycle time		**Human Energy**	
	% Change	**Indices of the Model (Π6)**	**% Change**	**Indices of the Model (Π7)**
π1	-0.81	0·746578	-4.56	-0·02752
π2	0.88	0·226303	3.74	-0·05644
π3	0.06	0·1267	2.21	-0·0363855
π4	2.35	-0·0236	1.97	-0·017987
π5	-1.24	0·0308	2.58	0·0714137

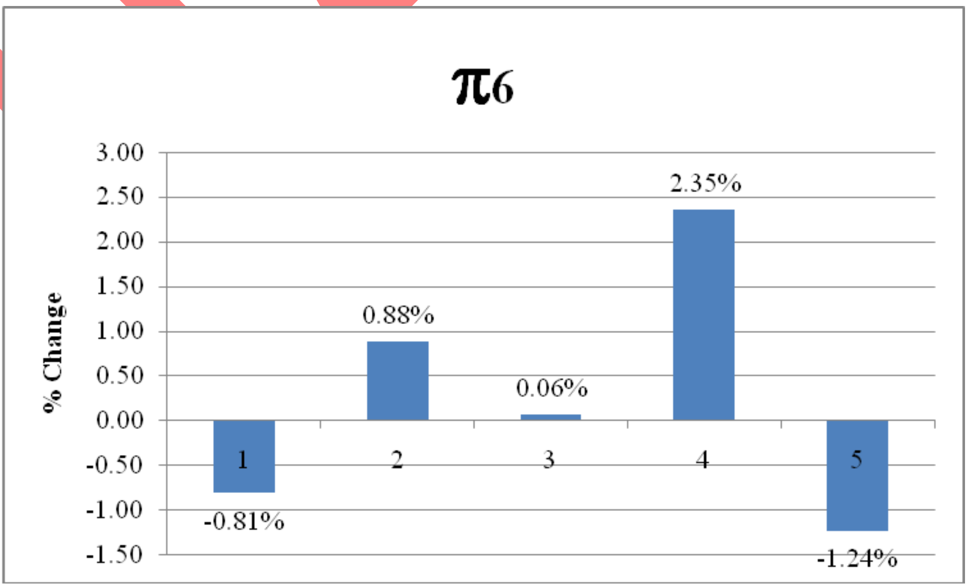


Figure 2: Sensitivity analysis of the formulated model for cycle time of scheduled service process

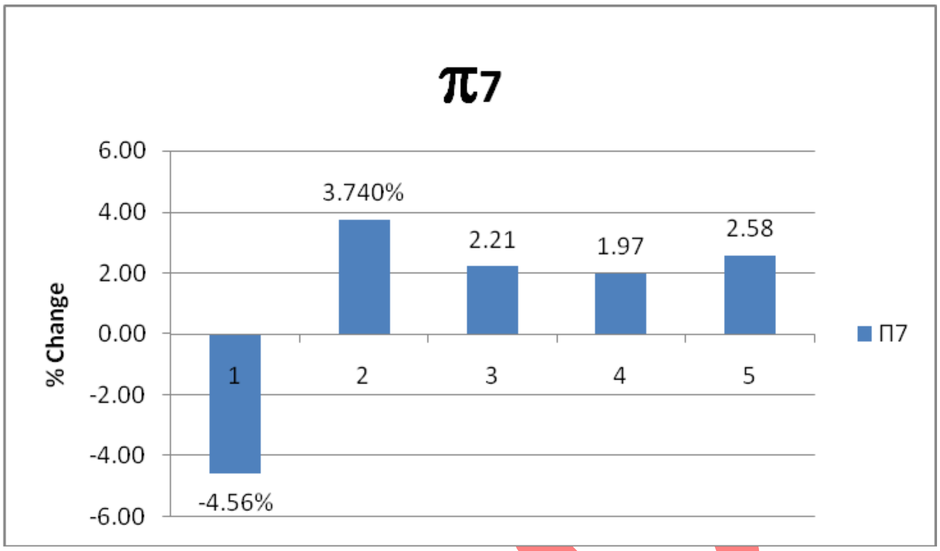
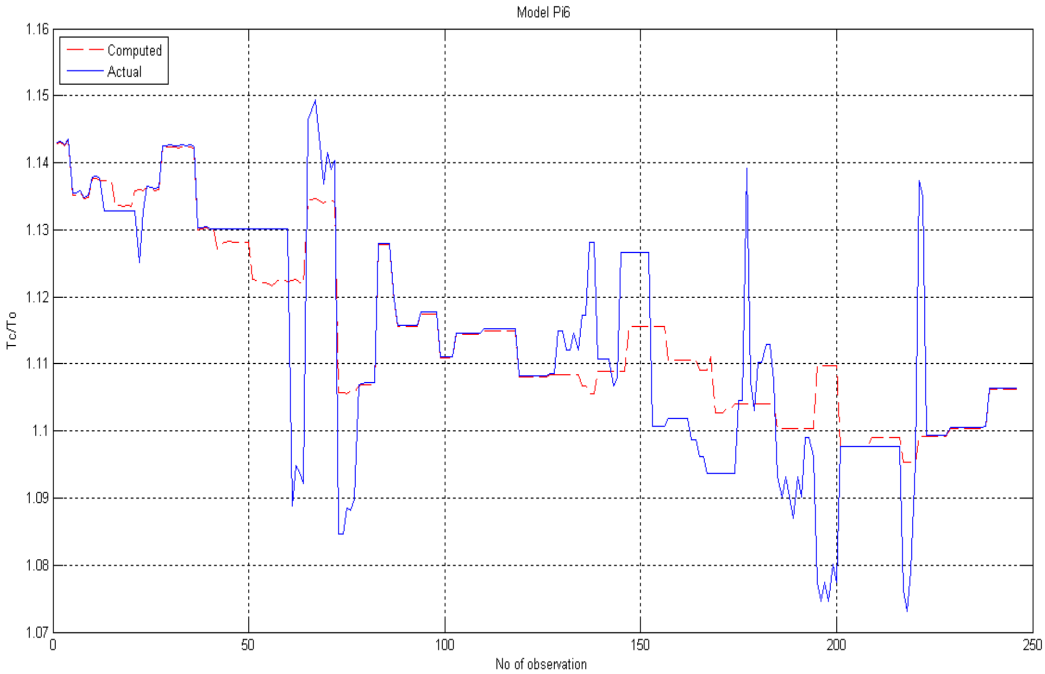


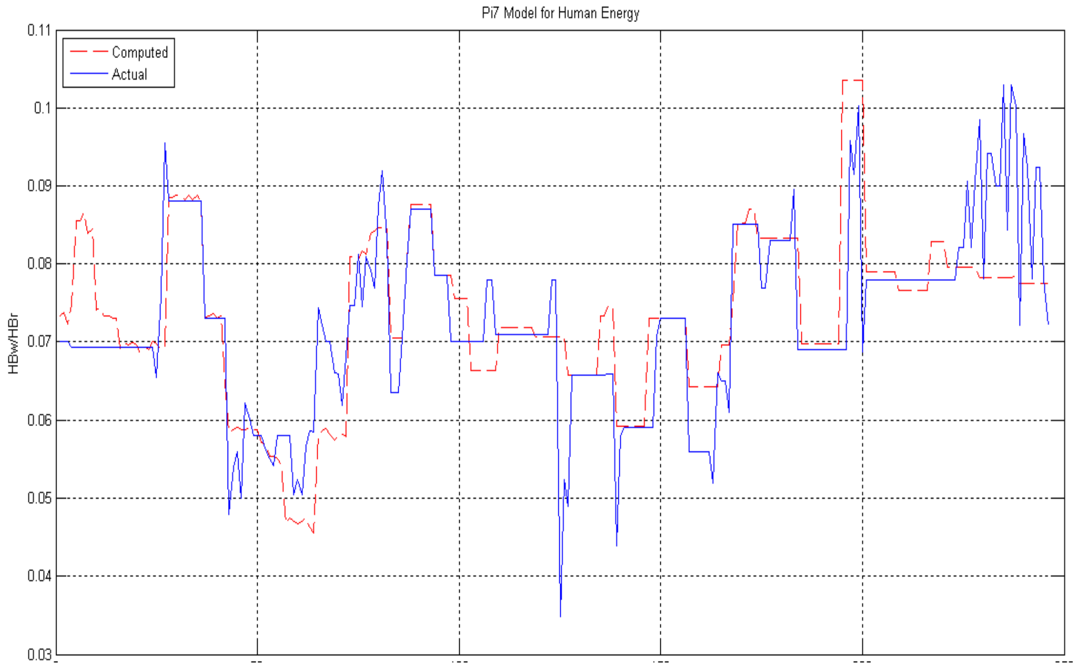
Figure 3: Sensitivity analysis of the formulated model for human energy expenditure during scheduled service process

Validation of the formulated field data based model

Subsequent to the formulation of a field data based model, validation of the same was varied out to check whether the model reproduces system behavior within acceptable bounds. The validity of the formulated model was checked by comparing the actual experimental value of the pi term related with scheduled servicing process and its simulated value obtained from the formulated mathematical model. **Figures 3 and 4** indicate the variation of the actual and simulated result. From the results, it is clear that there is a good congruency in both the datasets i.e. experimental and simulated values. Hence, it may be conclude that the developed models are valid. However, the variation that exists can be attributed to the measurement error.



Figures 3: Figure showing actual and computed output for model 1 i.e. cycle time of scheduled servicing process



Figures 4: Figure showing actual and computed output for model 2 i.e. human energy expenditure during scheduled servicing process

CONCLUSIONS

In this investigation, a generalized field data based model was developed to simulate the scheduled servicing process for passenger cars. This approach was observed to be the most appropriate approach, especially in view of the complexity and dynamism evident in this process (scheduled servicing process). It is evident from the equations of the models for cycle time (Π6) and human energy (Π6) that these models are valid. Furthermore, based on the analysis of data following conclusions appear to be justified for thesemodels.

- It was evident that **π1** had maximum influence i.e. vehicle design parameters like accessibility of air filter, fuel filter & oil filter on cycle time of scheduled servicing of the passenger cars.
- The difficulty in dismentaling, changing seal & assembling seemed to have significant effect on cycle time of scheduled servicing of the passengercars.
- Inspection for leakage becomes difficult & time consuming if accessibility ispoor.
- Anthropometric factors seem to have impact on the cycle time in as much as the service operation is being performed in all three positions i.e. sitting on legs, bending & standingposition.
- Other influencing factor include those parameters, which are workplace related. In this context (workplace), the tools trolly design also has an impact on the number of postures technician needs to take & hence have a bearing on cycle time of scheduled servicing of the passengercars.
- Furthermore, adequate illumination & display of torque values reduces the time for standard checks (preventive measures), which technicians have to carry out at 40different

places during the scheduled service process. Furthermore, spares need to be kept ready in a basket depending on the number of kilometers the service is being performed. Hence, in view of this, it is recommended to have a helper who will work as runner to bring spares to work place. Tools (general & special) neatly put on the board will in a definate orientation will reduce the time & energy for service.

- Environmental aspects have more impact on the human energyconsumed.

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