DEVELOPMENT OF A PRACTICAL FLEET VEHICLE REPLACEMENT POLICY FOR A FEDERAL GOVERNMENT CONTRACTOR

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CASE DESCRIPTION

This case presents a scenario to develop an equipment replacement policy for a large federal government contractor. This contractor serves as a facility maintenance manager for a federal government research and development organization. The maintenance company has a medium size fleet of cars, vans, pickup trucks and specialty vehicles. Currently, there is no real vehicle replacement policy in the company. However, the company keeps some maintenance records of the vehicles that can be used in the development of a vehicle replacement policy. The objective of this case is to illustrate basics of equipment replacement decision making. This presents a practical application of the probability and statistics. The situation is not very complex and is appropriate for use in undergraduate production/operations management, engineering economics, business statistics or managerial accounting courses. The case should take no more than one hour to explain in the class. The students can complete it as a take home assignment. It may involve one to two hours of preparation and research time from students. Total student time should not be more than four to six hours including research time.

BACKGROUND

A large federal government research facility is located in Southeastern part of Virginia. This facility is located on 810 acres of land. It has over 250 office and laboratory buildings including very large hangers, turbines and tunnels; and other large scale research outfits. Approximate annual budget of the research facility is $650 million of which 40% is operating budget. The research facility has about 2,000 direct employees on the site. Additionally, there are 2,500 contract/indirect personnel on the site. The maintenance budget is approximately 8-10% of the operating budget of the research facility.

The facility management functions for this federal government research organization are contracted out to a private company. The private maintenance company is responsible for all repair and maintenance of facilities other than specific scientific equipment repair. The current maintenance contractor was awarded the maintenance contract in 2003. This contractor took over all office space, equipment, vehicles and repair part inventory from the previous facility management contractor. The company has onsite office, workshop and other necessary facilities needed for building and equipment maintenance. It employs approximately 150 repairmen, supervisors and support staff. The repair job varies from simple light bulb replacement to complex turbine repair. The company maintains inventory of necessary tools and some repair parts on the site.

Typically, a repairman responds to a service call according to a pre-determined priority scheme. A repairman completes a service call in one or more trips to the location of service call. Generally, the first trip involves assessment of the fault and determination of required parts for

the repair, if it needs any parts. If repairman does not have the necessary parts with him, he would return to the shop. He will either go back to the repair site with necessary parts if parts are available in the part storage area to complete the task or he will place an order of the part necessary to make repair. Some repair jobs may require more than two trips. The service request completion time is one of the most important customer satisfaction measures in the organization.

To deliver the repair services, the company maintains a fleet of trucks, vans, cars, and specialty vehicles. In general, a repair van or truck is assigned to a specific repairman. The assigned vehicle serves as a small mobile workshop for the repairman. The cars are usually used by the supervisors for site visits. The specialty vehicles are called into the service as need arises. The mobility of repairmen and supervisor depends on the availability of the required type of vehicle. During the time when a vehicle is unavailable due to failure or other maintenance need, the assigned repairman's productivity is substantially reduced leading to the delay in the repair work. Therefore, it is important that the vehicle down-time is reduced to as low as possible. The company wishes to develop a comprehensive vehicle usage policy including a useful vehicle replacement policy so vehicle downtime and associated cost can be reduced.

DESCRIPTION OF FLEET TYPE

General vehicles- are driven by maintenance repairmen to perform the daily tasks. These vehicles include vans or pick-up trucks. Tasks that do not require specialty vehicle are performed with general vehicles. These vehicles also store repairman's tools and parts.

Specialty vehicles-are used when the allotted task requires it. Specialty vehicles include bucket trucks, cranes, flatbeds, etc.

Supervisory vehicles--are used by supervisors and management personnel for on-site visits. These vehicles provide an enclosed and secured cabin. These include cars, fully enclosed golf carts, etc. Supervisory vehicles provide a safe environment for transporting paper work, computers and other supervisory materials to the work sites.

DESCRIPTION OF FLEET MAINTENANCE

Regular Preventive Maintenance--Each vehicle has a regular oil changes as specified by manufacturer. Vehicles also maintain annual state inspection. The regular maintenance contributes to the efficiency of vehicle serviceability. Normal preventive tasks include the following: state inspection, as required by the law; oil changes, as stated by the manufacturer of the vehicle; tune-up, as stated by the manufacturer of the vehicle; and minor maintenance and safety items like wiper, bulbs, etc., as needed.

Oil changes and minor repairs are carried out in a timely fashion at the specified vehicle maintenance facility. The federal facility contractor has selected a vehicle repair sub-contractor close to the research facility for these tasks. Estimated time for this service is one and a half hours including all travel times.

Major maintenance--any vehicle failure not covered under regular preventive maintenance is defined as a major failure event. Currently there is no established assessment policy for major maintenance. Estimated repair time for major maintenance work is on an average 8 hours. During vehicle downtime repairmen are highly constrained in carrying out their

tasks. A vehicle needing major maintenance is repaired as needed. The company wishes to examine this policy.

Catastrophic failure—any vehicle is out of commission when the estimated repair cost is high and possibly exceeds the future benefits from the usage of the vehicle in question. There is no formal system in place for estimating the future value of the vehicle. However, if it is felt by the vehicle supervisor that cost of repair is too high, it is considered catastrophic failure and such an event triggers in automatic vehicle replacement process.

FLEET DATA

The vehicle data available in the company records includes make, model and type of vehicle, age of vehicle, years in service at the company, type of use, and assignment of vehicle. The fleet financial data available includes purchase price, book value, and the depreciation schedule used. The maintenance data on each vehicle is also available including type and cost of maintenance of each vehicle each year.

A total of 84 vehicles' records are included in the following report. Table 1 shows number and distribution of the type of vehicles considered.

Table 1: Vehicle Type Distribution

Type	Number	Percent
Car	13	15%
Pickup Truck	11	13%
Van	48	57%
Specialty Vehicle	12	15%
Total	*84*	*100%*

Specialty vehicles are ignored from the analysis as each one is unique. Their maintenance and repair cost do not mirror other vehicles data. Age of the three main category of vehicles namely cars, vans and pickup trucks is shown in the Table 2. And Table 3 presents the distribution of the vehicles by the year of manufacturing.

Table 2: Age of the Fleet by the Vehicle Type

Type	Age-Years
Car	8.77
Pick-up	6.91
Van	10.98

Table 3: Year of Make of the Fleet Vehicles

Year of Make	Number of Vehicles
1983	1
1986	2
1989	23
1993	8
1995	1
2001	1
2003	1

2004	33
2005	2
Total	*72*

The total repair and maintenance cost due to major breakdowns for each vehicle over the last three years is presented the Table 4. It also includes the number of major breakdown per vehicle. The year of make of the vehicle is included to determine its age in 2007, the year of this study. As expected the oldest vehicles failed frequently and are more expensive to maintain.

<INSERT TABLE 4 HERE>

VEHICLE REPLACEMENT POLICY

While creating the vehicle replacement model for this company, it should be considered that the model is very simple and can be easily applied. That is the advanced mathematical programming models like dynamic programming are not an option. It is also a consideration that this can easily be automated in a simple computer tools like Excel. Furthermore, the company is interested in having one policy for all non-specialty vehicles. In other words, differences in maintenance pattern of three vehicle types, car, pick-up trucks and vans, are ignored. The vehicle replacement policy/model must consider the purchase, capital, major repair, opportunity and salvage costs. The assessment year for the replacement policy is 2007.

Assumptions:

1. Cost of insurance, fuel, supervisory personnel are ignored.
2. Tax implications are not considered.
3. Vehicle is fully depreciated in three years
4. Vehicle acquired is kept at least for three years (until book value is zero.) Once book value is zero, the company's overhead cost is reduced to maintenance related cost only.
5. Total vehicle requirement is not decreasing.
6. Vehicle retirement age is normally distributed with mean of 16 years and standard deviation of 1.5 years. These numbers are adjusted upwards here as vehicles have much lower mileage compared to national average.
7. Regular maintenance cost is ignored as those will roughly be similar in for vehicles.
8. It was given that each major maintenance incident results in slow down of two workers (50% efficiency.) Overall average cost of worker is assumed to be $40 per hour (including pay, benefits, and other associated costs.).
9. Due to lack of data available for each breakdown, it is assumed that the vehicle would be out of service for on an average for one day (8-hours).
10. Catastrophic failure results in average of $1,000 opportunity loss including supervisory time, loss to worker efficiency, time to remove tools and inventory from old vehicle restock, and refitting new vehicle.
11. Cost of capital and discount rate are 10%.

CASE QUESTION

Develop a replacement model for fleet vehicles where total cost is minimized for each vehicle over a three-year period. It is required that proposed model is simple to use without much mathematical complexity so that it could be used by the floor supervisors.

Table 4: Maintenance data of the Vehicle Fleet

No.	Type	Year	Total Major Maint. Cost 2004-06	Total Number of Major Maint. Cost 2004-06	No.	Type	Year	Total Major Maint. Cost 2004-06	Total Number of Major Maint. Cost 2004-06
1	Van	1989	$2,689.40	13	37	Van	2004	$643.80	3
2	Van	1989	$2,495.85	14	38	Pick-up	2004	$359.03	2
3	Van	1989	$3,687.24	9	39	Pick-up	1983	$1,553.84	3
4	Van	1989	$2,371.43	8	40	Pick-up	2004	$375.00	1
5	Van	1989	$4,356.82	11	41	Van	2004	$263.55	1
6	Van	1989	$2,620.97	9	42	Van	2004	$240.74	1
7	Van	1989	$1,860.95	7	43	Van	2004	$232.85	1
8	Van	1989	$1,698.37	9	44	Van	2004	$202.24	1
9	Van	1989	$1,986.08	7	45	Pick-up	2004	$196.04	1
10	Van	1989	$1,982.37	7	46	Van	2004	$35.00	2
11	Van	1989	$1,682.85	6	47	Van	2004	$359.88	0
12	Van	1989	$813.30	8	48	Car	1993	$0.00	0
13	Car	1993	$1,819.53	7	49	Car	1995	$0.00	0
14	Van	1989	$3,534.95	5	50	Van	2001	$353.42	1
15	Van	1989	$1,676.48	4	51	Car	2003	$0.00	0
16	Van	1989	$1,134.96	6	52	Van	2004	$448.32	1
17	Van	1989	$1,179.16	6	53	Pick-up	2004	$262.25	1
18	Car	1993	$1,299.30	7	54	Van	2004	$180.15	1
19	Van	1989	$1,207.88	6	55	Van	2004	$103.31	1
20	Van	1989	$1,255.35	3	56	Van	2004	$0.00	0
21	Car	1993	$2,115.64	6	57	Pick-up	2004	$0.00	0
22	Pick-up	1993	$1,042.85	6	58	Van	2004	$0.00	0
23	Van	1989	$920.76	5	59	Van	2004	$0.00	0
24	Van	1989	$2,303.21	4	60	Van	2004	$0.00	0
25	Van	1989	$437.33	4	61	Van	2004	$0.00	0
26	Car	1993	$1,553.55	7	62	Van	2004	$0.00	0
27	Van	1989	$892.17	4	63	Van	2004	$0.00	0
28	Van	1986	$1,359.55	5	64	Van	2004	$0.00	0
29	Car	1993	$2,416.77	5	65	Van	2004	$0.00	0
30	Van	1986	$1,159.41	4	66	Pick-up	2004	$0.00	0
31	Pick-up	1993	$459.93	4	67	Car	2004	$0.00	0
32	Van	2004	$835.05	2	68	Car	2004	$0.00	0
33	Van	1989	$573.47	2	69	Car	2004	$0.00	0
34	Pick-up	2004	$589.84	2	70	Car	2004	$0.00	0
35	Pick-up	2004	$791.17	3	71	Van	2005	$0.00	0
36	Van	2004	$431.58	2	72	Car	2005	$0.00	0

TEACHING NOTES: DEVELOPMENT OF A PRACTICAL VEHICLE REPLACEMENT POLICY FOR A FEDERAL GOVERNMENT CONTRACTOR.

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REPLACEMENT POLICY

In this section a vehicle replacement policy development process is suggested for maintenance operation's fleet. The process considers relevant vehicle age, maintenance cost, opportunity cost of downtime, depreciation, salvage value and cost of capital. It presents a simple method of determining which vehicle should be replaced.

BASIC COST CALCULATIONS

Following table (Table 5) shows the calculation major maintenance cost by the age. These calculations are carried to show that in general vehicle maintenance cost increases with the age of the vehicle. A slight decline in 1983 and 19866 is due to the sample size. There are 23 vehicles from 1989 where as only one from 1983 and two from 1986. Table 6 shows the average number of major breakdown by the vehicle age. This makes age as the most important independent variable to determine both number of major breakdowns and associated repair costs.

Table 5: Avg. Maintenance Cost per Vehicle for Three-Year Period (2004-2006) by the Year of Make.

Year	Average 3-year Major Maintenance Cost per Vehicle
1983	$1,553.84
1986	$1,259.48
1989	$1,885.28
1993	$ 1338.45
1995	$ -
2001	$ 353.42
2003	$ -
2004	$ 198.48
2005	$ -

Table 6: Avg. Breakdowns per Vehicle for Three-Year Period (2004-2006) by the Year of Make.

Year of Make	Average Number of Major Breakdowns per Vehicle in 3-years Period
1983	3.00
1986	4.50
1989	6.83
1993	5.25
1995	0.00
2001	1.00
2003	0.00

2004	0.79
2005	0.00

COST CONSIDERATIONS IN THE REPLACEMENT MODEL

As indicated in the assumptions, several cost considerations are excluded. The replacement policy needs not to consider any insurance, fuel, taxation, parking/garaging, supervision and other incidental cost associated with vehicle maintenance. Most of these excluded costs are paid directly by the federal government or the parent company of this contractor. Thus, this policy will consider only initial purchase cost, cost of capital, major maintenance cost, opportunity cost, and opportunity cost due to catastrophic failure.

Note that the all costs are calculated based on the age of the vehicle at the end of three year from now. A three-year period is used as the time period to compare old and new vehicle as new vehicles are amortized over three years by the contractor.

The replacement model could be further expanded by calculating yearly cost over useful life of each vehicle and then calculating present value of each cash-flow. However it was one of the requirements to create a simple model that can be used for quick assessment, therefore, tedious yearly assessments are not considered. An instructor can decide based on the purpose of the case in his or her course weather to include that level of complexity.

REPLACEMENT MODEL:

The replacement model is to compare the cost of maintaining a current fleet vehicle versus the total cost of buying and maintaining a new vehicle. When the cost of maintaining a current fleet vehicle is more than the cost of owning a new one then the current fleet vehicle should be replaced, i.e.,

Cost of maintaining current fleet vehicle over next three years >=
Cost of buying and maintaining a new vehicle over next three years. *(1)*

Where,

Current cost of maintaining a current fleet vehicle over three years =
Present Value of (Expected sum of major maintenance cost over three years + Expected sum of opportunity cost over three years + Expected opportunity lost due to catastrophic failure –Salvage value of vehicle three years from now)(2)

Current cost of buying and maintaining a new vehicle over next three years=
Purchase cost of vehicle +Present value of (Cost of capital + Expected sum of major maintenance cost over three years + Expected sum of opportunity cost over three years + Expected opportunity lost due to catastrophic failure – Salvage value of vehicle three years from now) *(3)*

CALCULATION OF COSTS

As shown before, the age of vehicle is one of the most important factors in determining the expected cost of maintenance due to major breakdowns. Table 4 has provided data for total major maintenance cost over three year period. The linear regression model can be used to determine expected total maintenance cost over three years. The vehicle age is treated as the

independent variable. The vehicle age can be calculated from the year of make of the vehicle and the year of assessment (2007.) The regression equation is given below. The R-squared value is not very high for the model (55%) due to characteristics of the sample; however regression model is highly significant (Prob ≈ 0)

Expected of sum of major maintenance cost over three year =
*(-$120.30+ $102.80 * Age of the vehicle)* *(4)*

The expected opportunity lost cost due to major breakdowns can also be calculated based on the age of the vehicle. Table 4 has provided data for total number of major breakdowns over three year period. It is also indicated that that every major breakdown reduces productivity of two repairmen by 50% for 8 hours. That is the opportunity lost cost of each breakdown is:

Opportunity lost cost per breakdown =
50% 2 repairmen *8 hours *$40/hour/repairman = $320* *(5)*

Another linear regression can be used to determine expected number of breakdowns per three year period. Again, the vehicle age is treated as the independent variable. The regression equation is given below. The R-squared value is not very high for the model (60%) due to characteristics of the sample however; regression model is highly significant (Prob ≈ 0.)

*Expected of number of failures in three year = -0.297 + 0.362 * Age of the vehicle*

Expected opportunity lost cost over next three years =
*$320 * (-0.297 + 0.362 * Age of the vehicle) =*
*(-$95.04 + $115.84 * Age of vehicle)* *(6)*

The opportunity cost due to catastrophic failure can be calculated based on the probability of a catastrophic failure. A catastrophic failure is defined as vehicle being unserviceable after the failure. It is given that age of vehicles follows a normal distribution with a mean of 16 years and a standard deviation of 1.5 years {N(16, 1.5)}. The cumulative probability of catastrophic failure will rise with the age. The probability can be calculated using Z table or Excel function NORMDIST(x, mean, St dev, cum).

Opportunity lost cost due to catastrophic failure =
*Cum. probability of failure *$1,000 =*
*$1,000*NORMDIST(Current age,16,1.5,1)* *(7)*

Furthermore, an investment into a new vehicle will use company's capital for replacement of an existing asset. Once used to buy a vehicle this capital is unavailable to the company for further investment. Hence, there will be an opportunity loss as capital is consumed for replacement purposes. A cost of capital and discount rate are provided as 10% per year. It is stated that a vehicle is depreciated over three years using straight line method. The net present value of cost of capital will be 17%, where cost of capital is calculated based on the book value of the vehicle. The cost of capital factor of 17% is calculated using Excel net present value

formula, NPV(rate, cost of capital each year for three years), i.e., NPV(10%,$1*10%, ($1-$1/3)*10%,($1-$2/3)*10%).

Cost of Capital = 17% Purchase cost of the vehicle (8)*

The replacement model will be as follows once equations 4, 5, 7 and 8 are substituted in the equations 1 and 2.

*[(-$120.30+$102.80 * Age of the current vehicle) + (-$95.04 + $115.84 * Age of current vehicle) + $1,000*NORMDIST(Age of current vehicle,16,1.5,1)- Present value of salvage value of current vehicle three years from now)]>=*

*[Purchase cost + .17*Purchase cost + (-$120.30+$102.80 * Age of the new vehicle) + (-$95.04 + $115.84 * Age of new vehicle) + $1,000*NORMDIST(Age of new vehicle,16,1.5,1)- (Present value of salvage value of new vehicle three years from now)]*

That can be simplified as:

*[$218.64 * Age of the current vehicle + $1,000*NORMDIST(Age of current vehicle,16,1.5,1)- Present value of salvage value of current vehicle three years from now)]>=*

[1.17 Purchase cost + $218.64 * Age of the new vehicle + $1,000*NORMDIST(Age of new vehicle,16,1.5,1)- (Present value of salvage value of new vehicle three years from now)] (9)*

Note that to calculate the present value of the expected cost of maintenance and expected opportunity lost, simply use the current age of the vehicle in the regression model. This would provide an estimate of future cost. Present value of the salvage price of the vehicle can be obtained from sources like "Kelly Blue-Book (KBB.)" Simply using the resell value of the car from KBB based on current vehicle age plus three year will eliminate any discounting requirement. The equation (9) can be automated in the Excel or other similar tool without much difficulty.