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Modeling and simulation of maintenance operations at Kuwait public transport company

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ABSTRACT

In this study, a simulation model is developed to analyze and improve maintenance operations of a bus fleet at Kuwait Public Transport Company (KPTC). Bus fleet maintenance has been one of the major problems at KPTC. The company operates about 600 buses daily on 40 different routes for public transportation in Kuwait. Frequently these buses fail and need corrective maintenance in addition to regular preventive maintenance activities. The company has two maintenance locations, which handle 349 and 248 buses each. In this study, the facility for 349 buses is analyzed in detail and the effects of several operation strategies on system performance are evaluated by a simulation model. The simulation results are incorporated into a cost model in order to evaluate each strategy. The results show that significant savings can be achieved by using an appropriate operation policy.

Keywords: Bus fleet maintenance; simulation; bus failures; public transportation.

INTRODUCTION

Today, costs of maintenance related activities in industrial systems are estimated to be as much as 40% of total operational costs (Mobley, 1990). While maintenance costs are very high, related activities are inevitable in any system in order to keep the equipment in running condition. Extensive studies have been carried out in the area of maintenance management. The existing body of theory on system maintenance is scattered over a large number of scholarly journals belonging to a diverse variety of disciplines. The majority of maintenance research work are related to maintenance of industrial facilities. In particular, models are developed for analysis of maintenance operations on industrial equipment. Savsar (1992, 1997, 2006, 2011) discussed maintenance modeling and analysis issues in production systems. Haghani & Shafahi (2002) presented a model and a formulation for bus maintenance scheduling. Ramadass, *et al.* (2004) presented a simulation model for bus maintenance facility. Maze & Cook (1987) discussed performance measurement systems for transit bus maintenance. Etschmaier (1985) discussed the issues related to transit bus maintenance management in the United States. Waeyenbergh & Pintelon (2004) presented a case study illustrating maintenance concept development in general. In this paper, maintenance of Kuwait Public Transport Company (KPTC) bus fleet system is considered. Necessary data is collected and a detailed computer simulation model is developed to analyze maintenance operations.

KPTC is a service company that has more than 600 buses with 1050 drivers to transport passengers all over the state of Kuwait in nearly 40 routes. Frequently these buses fail and need corrective maintenance in addition to regular preventive maintenance activities. The fleet is subject to regular maintenance of a superior standard carried out by highly qualified professional maintenance crew. KPTC has two maintenance facilities, which are designed to receive all types of trucks and heavy buses of various models and sizes. One facility is located in Sabhan area, which handles 349 buses of types Mercedes MCV, Mercedes Busscar, Volvo Andare, and Volvo Busscar. The second maintenance facility is located in Sulaibiya area which handles 248 buses of type Daewoo. In this study, we have analyzed the facility in Sabhan location, which consists of a large garage and workshops. While maintenance activities are similar in both locations, Sabhan facility has larger number of buses maintained and experiences more delays. Therefore, it was analyzed in detail by a simulation model to study effects of several possible operational strategies on system performance. All of the repairs and maintenance procedures carried out in the facility have been taken into consideration in this study. In particular, data was collected and the current maintenance system was simulated for comparison purposes. After validation and verification of simulation results, the model was used to analyze the system under different proposed operational strategies. Simulation results are incorporated into a cost model to evaluate each strategy and its effect on total system cost. Finally, the best policy is selected based on minimum cost. The simulation results show that significant savings can be achieved by using an appropriate operational strategy.

PROCESS DESCRIPTION AT MAINTENANCE FACILITY AND DATA ANALYSIS

KPTC Maintenance facility at Sabhan area consists of two major repair shops: Mechanical Workshop and Body Workshop, which have 47 and 38 employees respectively. While many of the employees are utilized for regular check ups and preventive maintenance (PM) operations, 9 mechanics and 3 electricians are allocated to mechanical and body workshops for repair and corrective maintenance (CM) operations and are employed 8 hours in a daily shift from 6:30 AM to 3:30 PM with 1 hour of break. The mechanical workshop is responsible for the repair of mechanical failures and the spare parts. Engine repair is a section of mechanical workshop. The Body Workshop, on the other hand, works on repairing body related failures, accidents and other damages. Some body related works, such as denting and painting are done in afternoon and night shifts by special workers. Also preventive maintenance and regular checkups are done in the night shifts by special workers, which were not included in the simulation model. Figure 1 illustrates basic flow of activities when a bus arrives to the facility. Whenever a bus experiences a breakdown, either the driver drives the bus to the garage or a mechanic with a truck is informed to lift the bus. The failed bus is brought to the garage to correct the failure and put it back into its operational condition. As it is seen in Figure 1, depending on the accident or complaint from driver about the bus, an inspection is carried out and the bus is moved to main repair/maintenance workshop. While PM is always carried out as a routine daily checkup during a fixed time, the CM operations are done at random times as a result of failures. An unscheduled repair activity is required when a bus fails for any reason on the road. In Sabhan maintenance facility, daily bus breakdown/failure schedules are filled out by the technicians. From recorded data in maintenance facility, daily bus breakdowns were extracted for a period of nearly 3 months (84 days exactly) in order to analyze time between failures and identify failure distributions.

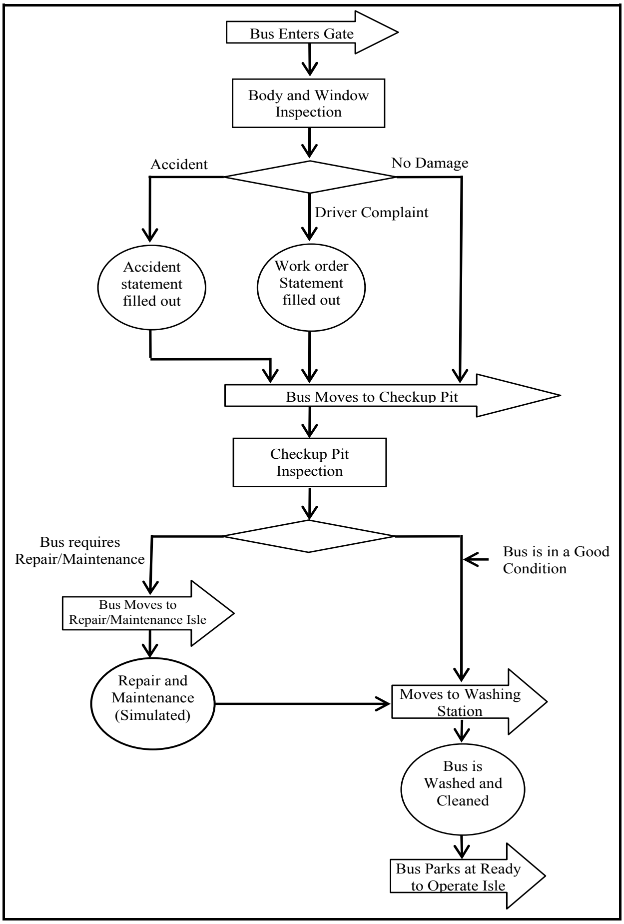

Fig. 1. Typical activities leading to repair/maintenance in the bus maintenance facility

The data was sorted according to bus types and failure types as shown in Table 1. A total of 868 failures have been recorded during the period of study and the failures were categorized into three basic types; including body failures, engine failures, and mechanical/electrical (M/E) failures. Using Excel sheet, bus number, bus type, date of failure, time between consecutive failures, and the failure classifications according to the failure types, were all entered into computer. Next, the time between failures were sorted according to the bus types and the data was entered into ARENA Software input analyzer to determine the type of distribution and related parameters for each bus type. Table 1 shows the time between failures (TBF) distributions for each bus type, and the parameters of the distributions obtained from the best fitting. For example, the time between failures for Mercedes Busscar was exponential with a mean of 545 minutes or 9 hours 5 minutes. Similarly, other buses are shown in the table. Most of the random failures in real life are proven to be exponentially distributed. The analysis of data for the time between bus failures also resulted in exponential distribution, which is known to have a memoryless property such that when a failure occurs, the system restarts. In this particular case, when a bus fails, the time to failure for the rest of the buses will be refreshed, which is a natural phenomenon that occurs in most random events.

Table 1. Bus types, codes, quantity, and number of failures recorded

Bus No.	Bus Type	Distribution Fit For TBF	Number of Buses	Number of failures recorded			
				Body	Engine	M/E	Total
1	Mercedes Busscar	EXPON(545)	71	34	67	55	156
2	Mercedes MCV	EXPON(246)	143	101	116	131	348
3	Volvo Andare	EXPON(1280)	42	13	23	29	65
4	Volvo Busscar	EXPON(286)	93	72	93	134	299
		Total	**349**	**220**	**299**	**349**	**868**

In order to capture as much detail from the real system as possible, failure types were further analyzed with respect to three groups of failures, including, body, engine, and mechanical/electrical types of failures based on time required for repair processes. Table 2 shows specific types of failures, related repair time distributions, number and types of workers involved, and related percentages in each group of failures for each bus type. Repair time distributions are also obtained by fitting repair times using ARENA input analyzer, which selects the best distribution, based on Chi Square statistical test. The best fit is selected in all cases. When a bus arrives to the maintenance facility, its type is identified first. Next, reason for failure is recorded as body, engine, or M/E failures. Finally, the specific type of failure which has occurred is determined. Then the maintenance is started by the appropriate worker in related repair section.

Table 2. Data for specific types of failures in each failure group for each bus type

Body Specific Failures			Bus Types			
		Worker Type &	1	2	3	4
	Repair Distribution	(No) Required	Failure Percentages			
Accident	60 + EXPO(1580)	Mechanic (1)	27%	20%	0.1%	16%
Broken Mirror	NORM(10,2)	Mechanic (1)	12%	23%	8%	12%
Broken Window	NORM(120,24)	Mechanic (1)	21%	28%	38%	26%
Bumpers	NORM(10,2))	Mechanic (1)	0.1%	3%	0.1%	1%
Doors	NORM(90,18)	Mechanic (1)	30%	17%	46%	36%
Seats	NORM(60,12)	Mechanic (1)	3%	3%	8%	4%
Roll Film	NORM(120,24)	Mechanic (1)	0.1%	2%	0.1%	4%
Wipers	NORM(20,4)	Mechanic (1)	6%	4%	0%	0%
Engine Specific Failures						
Oil	NORM(30,6)	Mechanic (1)	8%	12%	5%	8%
Water Leak	NORM(120,24)	Mechanic (1)	24%	27%	25%	30%
Exhaust	NORM(30,6)	Mechanic (2)	0.1%	0.1%	0.1%	1%
Diesel Leakage	NORM(405,81)	Mechanic (1)	21%	22%	50%	33%
Engine Belt	NORM(90,18)	Mechanic (2)	18%	18%	0%	3%
Air Belt	NORM(195,39)	Mechanic (1)	24%	16%	20%	24%
Battery	NORM(180,36)	Electrician (1)	5%	5%	0.1%	0.1%
Mechanical/Electrical Specific Failures						
Breaks	NORM(60,12)	Mechanic (1)	23%	12%	25%	36%
Dynamo	NORM(120,24)	Electrician (1)	2%	4%	13%	4%
Fan	NORM(120,24)	Mechanic (1)	0.1%	3%	0.1%	1%
Flashlights	NORM(20,4)	Electrician (1)	2%	6%	3%	2%
Flat Tire	NORM(20,4)	Mechanic (1)	25%	24%	9%	16%
Gears	NORM(180,36)	Mechanic (2)	14%	12%	28%	16%
Lights	NORM(10,2)	Electrician (1)	16%	15%	3%	8%
Elect. Shortage	NORM(720,144)	Electrician (1)	0.1%	4%	0.1%	3%
Tilting	NORM(75,15)	Mechanic (1)	4%	7%	9%	3%
Steering Wheel	NORM(210,42)	Mechanic (1)	16%	13%	9%	11%

SIMULATION MODEL OF THE AS-IS SYSTEM USING ARENA

A simulation model is developed based on several processes and steps as they occur in real maintenance setting. Each process is described in detail in the following sections.

Arrival and Decision Process: Four types of simulation entities are created to represent failures for four types of buses. Time between failures follow certain distributions for each type of bus and each specific type of failures as listed in Table 1. After the arrival process, the buses are assigned three attributes denoted as TYPE, TIMEIN, and TIMEIN I. TYPE is assigned the value of 1, 2, 3, or 4 depending on bus type and TIMEIN is assigned value of TNOW, the current time in simulation, so that average time in system could be calculated when the buses depart the system. TIMEIN I is used for each bus type I in order to direct different types of specific buses to the required repair facility and repair crew. A decision node is used to divert each entity according to failure and repair category followed by additional decisions to direct the entity to each of 25 specific types of repairs needed.

Assigning Repair Distributions and Resource Quantity: After deciding the specific type of failure that has occurred and the repair type needed, the next step is to assign the repair time distribution with specific parameters to each bus entity according to failure reason, followed by the number of repairmen required. Repair distributions, type of repairmen, and the number of repairmen required for each failure type are listed in Table 2. The maintenance facility has specified standard times for each repair type with 20% deviation. Repair times were estimated as normally distributed with an average standard time and standard deviation as given in Table 2. However, repairs for accident related operations did not have standard times. Therefore, data was collected on accident related repairs and distributions were determined by using ARENA input analyzer, which resulted in exponential distribution of the form: 60 + EXPO(1580). The number of workers and the repair distribution for each failure is assigned in the ARENA accordingly.

Repair Process, Counting Buses Repaired, and Time in System: Depending on the type of failure and the repair crew required, the bus is directed to the appropriate repair process, such as an Electrical or a Mechanical Repair Process. The repair distribution was assigned earlier with the number of workers. Each bus repair requires 1 pit out of 12 available pits, which are modeled as resources in the ARENA model. The number of buses that go through electrical and mechanical repairs is counted independently for statistical purposes. The number of buses completed and the total time in system for each bus type are recorded for further analysis. Finally, the overall average time in the system is recorded for all bus types. A simulation model needs specification of resources and the related working schedules. In the maintenance facility there were 12 repair pits in which buses are repaired. Therefore, fixed pit capacity was set as 12 units in Resource Data Module. Mechanics and electricians work according to specific schedule, set as schedule 1 for mechanics and schedule 2 for electricians. The corrective maintenance shift starts at 5:30 AM and continues until 3:30 PM with one hour break at 10:00-11:00 AM. If the worker is busy working on a bus when the break starts, he will take a break and then return back to work on the same job. Therefore, the preemption rule is used for the breaks.

Table 3. Current shifts and schedules for mechanics and electricians and bus operation

	Schedule 1		Schedule 2	
Shifts	**Number of Mechanics**	**Duration of Work (Hours)**	**Number of Electricians**	**Duration of Work (Hours)**
1	9	9 (6:30 AM-3:30 PM)	3	9(6:30 AM-3:30 PM)
2	0	8	0	8

Table 3 shows the two schedules for the mechanics and electricians. Since the data was collected over a period of 84 days, the simulation models were also run for 84 days for accurate comparison. The simulation runs were replicated 35 times with 1 hour of warm-up period in each case. Each day is assumed to be 17 hours since the buses are operated 17 hours per day, 5:00 AM to 10:00 PM.

VERIFICATION AND VALIDATION OF THE GENERAL MODEL RESULTS

After running the current system with as-is-model using ARENA package, average values were obtained based on 35 simulation replications for various performance measures as shown in Table 4. Simulation model and its results are validated by comparing the simulated results with actual system results, which were obtained from the analysis of real data obtained from the current system in operation. In particular, hypothesis testing was performed on the equality of the average number of buses completed for simulated and actual results. Table 5 summarizes hypothesis testing results.

Table 4. Various performance measures for the current system

Performance measure	Average Simulation results
Number of buses completed	876
Waiting Time for Mechanical Queue	1.92 hours
Waiting Time for Electrical Queue	1.88 hours
Instantaneous Utilization of Mechanics	44.5%
Instantaneous Utilization of Electricians	9.6%
Instantaneous Utilization of Pit	20.2%
Total Time in System	5.821 hours
Number of Type 1, 2, 3 and 4 buses repaired	160, 350, 67 and 299 buses respectively

In all cases, we failed to reject the hypothesis that simulated mean = actual mean ($H_0 : \mu = \mu_0$) at 95% confidence when t test was utilized. Furthermore, average differences between total times in system in the simulated model were compared to the average actual total time in system for all buses at 95% confidence limits using paired t test. Upper and lower confidence limits were found as -137.01 and 154.18 respectively, indicating that average simulated results were close to actual results and that simulation model could be used to study the system under other input parameters and operational conditions. Similar results were obtained for such performance measures as average waiting times for mechanics and electricians as well as utilizations of the technicians and the maintenance pits.

Table 5. Hypothesis Testing on the Equality of Simulated Mean to Actual Mean Values

Performance Measures: Number of Buses of Each Type Completed	Simulated No. ($\mu = \bar{X}$)	Std. Dev. (S)	N	Actual Number (μ_0)	Reject $H_0 = \mu = u_0$
Type 1 Buses Repaired	160	17.7	35	156	Fail to Reject
Type 2 Buses Repaired	350	32.3	35	348	Fail to Reject
Type 3 Buses Repaired	67	10.8	35	65	Fail to Reject
Type 4 Buses Repaired	293	24.1	35	299	Fail to Reject

SIMULATION OF ALTERNATIVE STRATEGIES FOR IMPROVEMENT

After verifying and validating the simulation model, several possible scenarios are simulated to see what possible improvements could be made in the system.

First, it was necessary to develop a cost model so that total system cost could be used as a performance measure in addition to waiting times of buses, time in system, and resource utilizations. The following cost equation is adapted based on different cost elements involved. Different scenarios are compared with respect to the total maintenance related cost values.

$$TC = N_m * C_m + N_e * C_e + (C_d + C_b + C_t + C_o) * \sum_{i=1}^{n} (B_i * D_i) \quad (1)$$

Where,

$TC =$ Total system cost during simulation period

$N_m =$ Number of mechanics

$N_e =$ Number of electricians

$C_m =$ Cost of a mechanic during simulation period

$C_e =$ Cost of an electrician during simulation period

$C_d =$ Cost of a driver during down time per hour per bus

$C_b =$ Fixed cost of a bus during down time per hour per bus

$C_t =$ Opportunity cost of tickets lost during down time per hour per bus

$C_o =$ Overhead and administration cost per hour per bus

$B_i =$ Average number of bus types i repaired during simulation period

$D_i =$ Average down time each bus type i experiences during repair process.

$n =$ Number of bus types, n = 4 in this case.

Cost figures are calculated as follows:

1 - Cost of a mechanic is 188 KD/month while cost of an electrician is 150 KD/month, which resulted in $C_m = 525$ KD and $C_e = 420$ KD respectively during the simulation period of 84 days.

2 - Driver salaries are 177 KD/month. Thus, driver cost per day is 177/30 = 5.90 and cost per working hour is $C_d = 5.90/8.5 = 0.694$ KD/Hour.

3 - Fixed cost of a bus is obtained by assuming a 6 years of useful bus life and average bus cost of 34,000 KD. This resulted in 5666 KD/year. Assuming a bus operates 6 days per week, 313 days/year (about 1 day off per week) and 17 hours per day, fixed bus cost would be $C_b = 5666/(313*17) = 1.065$ KD/hour per bus.

4 - Cost of lost opportunity due to bus down time and lost ticket sales is

obtained by assuming a ticket price of 0.200 KD and average ticket sold per bus as 35 per hour. This resulted in $C_t = 7.000$ KD/hour of lost income.

5 - Administrative overheads are calculated based on factory overheads as 1,714,180 KD/year and company overheads as 334,555 KD/year resulting in a total overhead of 2,048,735 KD/year. Based on 350 buses and 4250 hours/year of working time for administration, the overhead costs are calculated to be $C_o = 1.377$ KD/hour per bus.

Based on the calculation above, down time cost adds up to:

$$C_d + C_b + C_t + C_o = 0.694 + 1.065 + 7.000 + 1.377 = 10.13 \text{ KD/hour per bus.}$$

$$TC = [525 * N_m + 420 * N_e] + 10.13 * \sum_{i=1}^{4} (B_i * D_i)$$

Number of repair crew (N_m and N_e) will be changed according to different operational policy or scenario as will be explained below. Similarly, number of buses of each type i that fail and undergo repair (B_i) and average down time of each bus type i (D_i) will be obtained from simulation of each operation policy. We have considered three general operational policy cases, each with three sub policies, in addition to the current system of operation:

1 - Case 1. Current scenario (or operation strategy): Only one shift with duration of 9 hours; 9 mechanics and 3 electricians are allocated to the shift.

2 - Case 2. Scenario 1: Add a 6-hour shift and keep resources constant, but redistribute them to each shift in different ways: adding another shift to the working hours for the maintenance facility with 9 hours in the first shift and 6 hours in the second shift (both with 1 extra hour of break). The number of mechanics and electricians are kept constant as in current case. However, they are redistributed to different shifts in different numbers as shown in columns 3, 4, and 5 of Table 9. The simulation results for several performance measures and calculated total system costs for all cases of strategy 1 are summarized in Table 6.

3 - Case 3. Scenario 2: Keep one shift as it is, but add more repair crew resources, such as 1, 2, and 3 additional mechanics and electricians as shown in columns 6, 7, and 8 of Table 9. Related simulation outputs for performance measures and calculated total system costs for all cases of strategy 2 are given in Table 7.

4 - Case 4. Scenario 3: Add another shift and make the two shifts equal in number of working hours (7.5 working hours each plus 1 hour break each). Resources are kept constant and redistributed as in scenario 1. Simulation

of performance measures and calculated total system costs for all cases of strategy 3 are given in Table 8.

All strategies are compared in Table 9 and Figure 4. Strategy 1a was the best in minimizing the total down time as well as total system cost, which resulted in average down time of 4.051 hours for each failing bus and an expected total system cost of 42,088 KD during 84 days of simulation period.

Table 6. Simulation results and calculated costs for current case and scenario 1

Scenarios (In all shifts 1 hour break is given)	Time in System in hours for Bus Types				Number of Buses Completed for Bus Types				Total Cost (KD)
	1	2	3	4	1	2	3	4	
Current: 1 Shift 5:30 - 3:30	6.04	5.90	5.33	5.73	160	350	67	299	57670
1a. 2 Shifts 5:30 - 3:30 3:30 - 10:30	4.37	4.11	3.41	3.97	160	352	67	300	42088
1b. 2 Shifts 5:30 - 3:30 3:30 - 10:30	4.45	4.23	3.55	4.06	160	352	67	300	43023
1c. 2 Shifts 5:30 - 3:30 3:30 - 10:30	4.84	4.58	3.95	4.43	160	352	67	300	46284

Table 7. Simulation results and calculated costs for scenario 2

Scenarios (In all shifts 1 hour break is given)	Time in System in hours for Buses				Number of Buses Completed for Bus Types				Total Cost (KD)
	1	2	3	4	1	2	3	4	
2a. 1 Shifts 5:30 - 3:30	6.022	5.855	5.314	5.710	160	350	67	299	58351
2b. 1 Shifts 5:30 - 3:30	6.016	5.880	5.308	5.705	160	350	67	299	59357
2c. 1 Shifts 5:30 - 3:30	6.014	5.879	5.308	5.703	160	350	67	299	60284

Figure 2 illustrates the variation between policies in total maintenance costs graphically. Thus, the optimal scenario is policy **1a** that imposes 2 shifts: The 1st from 5:30 AM to 3:30 PM for 9 hours and the 2nd from 3:30 PM to 10:30 PM for 6 hours. Both shifts have a 1-hour break. The numbers of mechanics allocated are 5 in the 1st shift and 4 in the 2nd shift. The numbers of electricians allocated are 2 in the 1st shift and 1 in the 2nd shift. The total numbers of repairmen are the same as the current, as-is system, but reallocated over two shifts rather than one shift. The reallocation resulted in better performance because buses operate and fail over 17 hours, or the two shifts. With the implementation of the proposed two-shift system, the total system cost can be reduced from the current 57670 KD down to 42088 KD, which is a reduction of 15582 KD (about $55,000) or 27.02%. This reduction corresponds to about 5500 KD (almost $20,000) per month for only one maintenance facility. The next best solution was case **3a**, which required the same reallocation of the number of repair crew over two shifts as in the case **1a**, but at equal shift durations of 7.5 hours each instead of 9 hours and 6 hours in shifts 1 and 2 respectively. The total cost for case 3a was 42852 KD as compared to 42088 KD for case 1a.

Table 8. Simulation results and calculated costs for scenario 3

Scenarios (In all shifts 1 hour break is given)	**Time in System in hours for Buses**				**Number of Buses Completed for Bus Types**				**Total Cost (KD)**
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	
3a. 2 Shifts 5:30 - 2:00 2:00 - 10:30	4.525	4.175	3.478	4.043	160	352	67	300	42852
3b. 2 Shifts 5:30 - 2:00 2:00 - 10:30	4.470	4.393	3.730	4.237	160	352	67	300	44302
3c. 2 Shifts 5:30 - 2:00 2:00 - 10:30	5.190	4.923	4.279	4.798	160	351	67	300	49386

Table 9. Summarized total down time in system and total cost results for all scenarios

Scenario	**Current**	**1a**	**1b**	**1c**	**2a**	**2b**	**2c**	**3a**	**3b**	**3c**
No. of Mechanics in Shifts 1 and 2	9 0	5 4	6 3	7 2	10 0	11 0	12 0	5 4	6 3	7 2
No. of Electricians in Shifts 1 and 2	3 0	2 1	2 1	2 1	4 0	5 0	6 0	2 1	2 1	2 1
Average Down Time-All Buses	5.821	4.051	4.156	4.522	5.803	5.798	5.796	4.118	4.332	4.876
Total Cost	57670	42088	43028	46284	58351	59357	60284	42852	44302	49386

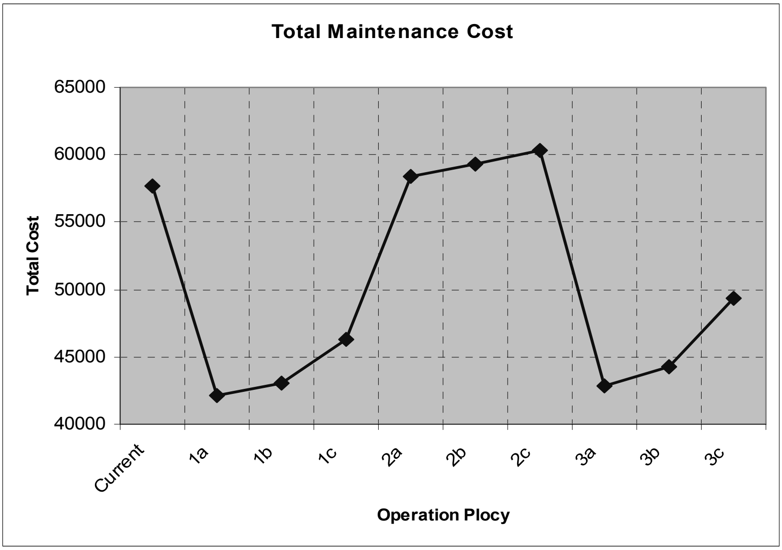

Fig. 2. Comparison of costs for different operating policies

CONCLUSION

Computer simulation is an important tool for evaluating a system operated under alternative operational conditions without costly implementation of these alternatives in real life. In systems with stochastic operations, it is almost inevitable to use simulation for modeling and analysis since analytical models are usually limited in abstracting real world systems in detail and require many restrictive assumptions. In this paper, simulation modeling has been used to analyze maintenance operations of a bus fleet in a public transportation company. The maintenance facility is used to perform preventive and corrective maintenance operations on 349 buses that are operated 17 hours daily in more than 40 routes. The company wanted to improve its operations to possibly reduce delays due to repair and maintenance activities. The goal was to try different maintenance scenarios and operating shifts in order to reduce down times and the total system costs without disturbing the system.

A simulation model of the current system was developed and validated by comparing its results with actual system results. Then, the model was used to analyze the system under nine alternative operational policies by changing the number of shifts, the operating hours, and the number of repair crew in each shift. Simulation results confirmed that operational costs could be reduced by about 27% if the best alternative was implemented in real system. The procedure outlined and simulation modeling approach presented in this paper can be useful for operation engineers and maintenance managers in improving similar maintenance systems.

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نماذج محاكاة لعمليات الصيانة في شركة النقل العام الكويتية

مهمت سافسار

كلية الهندسة والبترول - جامعة الكويت

خلاصة

في هذه الدراسة ستستخدم نماذج محاكاة مطورة لايجاد الحلول للمشاكل التي تواجه شركة النقل العام الكويتية (KPTC) في عمليات الصيانة لباصاتها. من المعلوم ان تلك تعد واحدة من أكبر المشاكل التي تواجه الشركة والتي تمتلك أسطول من الباصات بعدد 600 باص وتدار يومياً على 40 من الطرق المختلفة في الكويت. وعادةً ما تحتاج هذه الباصات إلى صيانة نتيجة الأعطال التي تصيبها بالإضافة إلى الصيانة الدورية. وتمتلك الشركة محطتان أحدهما بسعة 349 باص والأخرى بسعة 248 باص. وسنركز في هذه البحث على المحطة الكبرى حيث ستحلل بالتفصيل وسيدرس تأثير عدد من استراتيجيات الصيانة المختلفة على فعالية هذه العمليات باستخدام نماذج محاكاة. وبالإضافة إلى ذلك فإن سعر التكلفة سيدخل في نتائج هذه النماذج وذلك لتقييم كل استراتيجية. ومن المفيد إن نذكر أن النتائج الأولية تشير إلى أن هناك إمكانية توفير كبير في التكلفة إذا ما اتبعت هذه السياسات.

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- تسهم في تطوير الفكر الإداري واختبار الممارسات الإدارية وإثرائها.
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