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Application of Analytical and Simulation Models to Solve the Problem of Car Hire at Vesta Safaris Company in Kenya

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Abstract- A car hire service is a form of public transportation that enables a group of people to share vehicles based at certain stations by making reservations in advance. The main objective of car hire companies is to provide quality services to its customers by providing prompt services when required. These companies compete one another and have clients locally and internationally. One of the common problems of car hire is that companies can have difficulty optimizing the number of vehicles in operation. This paper reports on investigations of the relationship between the number of cars and the number of reservations per day with either the acceptance ratio or utilization ratio based on the commercially operational dataset of a cars hire company in Kenya. This paper creates an analytical mode to enable this company estimate their daily costs by looking at the distance to be travelled, route type and car type. A simulation model is also constructed to simulate the best booking policy for the company.

Index Terms- Bayesian Networks Classifiers, Classification, simulation

I. Introduction

As the world population grows, private vehicles are becoming more attractive, leading to high energy consumption and high vehicle emission levels. Car hire is one of the transportation strategies that can reduce personal transportation usage and its negative impacts. Because of the worldwide environmental benefits involved, car hire evolved out of the economic motivations of individuals who could not afford to purchase a vehicle into a mainstream, worldwide transportation system.

(Shaheen and Cohen 2013), Simulation is an indispensable tool for rapidly quantifying the operational impact of changes to facilities, systems, and processes – and to experiment with "what-if" scenarios prior to implementation. It provides the ability to model, analyze, optimize, test and select the best possible alternative solutions, while taking into consideration variables associated with demand, schedules, priorities, equipment capabilities, layouts, costs and constraints.

In recent car hire systems, customers can access the portal of a car hire company and easily make a reservation via an Internet connection or by phone. The information, including traveled distances and rent duration, is recorded and charged as to the customer's bill. An intelligent transportation system can play an important role in making a car hire system user-friendly, easy to manage, and efficient.

Because of these benefits, car hire as an alternative transportation paradigm has become increasingly popular in many countries (Barth and Todd 1999). Previous research has demonstrated that the benefits of car hire include reducing costs and the negative impacts of private vehicle ownership and the environmental impacts of auto usage (e.g., congestion, energy consumption, vehicle emissions, and inefficient land use). In North America, the impact of car hire includes the reduction of emissions as a result of less driving and a 27 percent reduction in the average number of observed vehicle kilometers traveled per year (Martin and Shaheen 2011).

The paper is organized in five sections. The rationale for the conducted research work is presented in the Introduction. A review of the related research work is provided in Section 2, the analytical and simulation model construction Section 3, the obtained results and the comparative analysis are given in Section 4. The paper concludes with a summary of the achievements and discussion of further work

II. Review of the Related Research

As car hire increasingly becomes a mainstream transportation mode, it is expected that it will be further integrated into metropolitan transportation, land use strategies, and multimodal nodes (Shaheen and Cohen 2013).

Up-to-date car hire systems enable a car to be driven among multiple stations (one-way service), whereas traditional service (round-trip/two-way) allows users to use a car and return it to the same station only. Although one-way service can provide convenience for customers, the cars from each station become disproportionally distributed. Thus, a strategy of vehicle relocation is necessary to elevate the satisfactory level of users. A car hire system must be efficient, user-friendly, easy to manage, and advantageous to both companies and customers (Barth et al.2001).

Studies concerning data mining have been intensively conducted in car hiring related research areas. In particular, the forecasting technique is used to predict the net flow of vehicles in a three-hour period by using neural networks and support vector machines (SVM) (Cheu et al. 2006), and the results show that multilayer perceptron has slightly better accuracy compared to SVM. In another case, such as the one-way type, it is difficult to maintain the distribution balance of parked vehicles among stations. A method for the optimization of vehicle assignment is used according to the distribution balance of parked vehicles; thus, it is possible to maintain distribution balance of parked vehicles and keep the convenience of the car hiring system (Uesugi et al. 2007).

In regard to car optimization, one study shows an international comparison regarding car hire services (Shaheen and Cohen 2007). The paper shows that the member-vehicle ratio is an important key factor that characterizes worldwide car hire operations. The comparison demonstrates that the member-vehicle ratio based on the survey of each country is different; Asia, Australia, Europe, and North America are 26:1, 17:1, 28:1 and 40:1, respectively. The estimation for the average national ratios are approximately 20:1 and are lower in new markets where car hire companies must first position their vehicles to gain membership. However, in other research (Morency et al. 2007; Habib et al. 2012; Costain et al. 2012), studies about user behavior in car hiring transaction data sets show interesting results. the result reveals that there is variability in the number of transactions and distance traveled by each customer. Another study (Costain et al. 2012) found that increasing the home-to-parking-lot distance reduces trip duration. Thus, it is important to evaluate the member-vehicle ratio with respect

(Shaheen et al. 1998).Car hire services represent an intermediate service that bridges public transportation and private vehicle ownership to reduce the number of cars, provide cost savings, and reduce parking demand, among other benefits. To clarify, car hire was first implemented in Europe but has gained popularity in North American cities (Cervero and Tsai 2004; Zhou and Kockelman 2011) and Asia, including Singapore and Japan. Basically, members subscribe to a cars hire company and are able to use cars by making reservations in advance. The vehicle is picked up at the start of the trip and returned to the original station at the end of the trip (twoway or round-trip). Members pay a fee each time they use a vehicle, which covers the cost of vehicle use, insurance, maintenance, and fuel.

III. PROBLEM DEFINITION

Vesta Safaris Company in Kenya lends cars to its clients. Cars are hired at a rate of 1500 for in town use while out town use charges are done depending of the distance to be travelled and the route type such as rough road, smooth road, flat areas and mountainous areas. A customer must book a car 10 hours before use. Cases exists where a customer might find a car they had booked in use or a customer might turn up late than their car booking times hence resulting to cars being idle. The company has a policy of paying a client Ksh 200 per hour they spent in a waiting queue. To avoid making loses, the company has employed a specialist to help the company maximize profits as well as have fair prices for its clients and minimize the costs in cured to pay customers in a waiting queue.

Problems formulation:

a. <u>The analytical model solution problem.</u>

The company would like to maintain all cars in good condition for better customer service as well as spent the minimum in terms of fuel costs and car repair. There is need for an analytical model to enable this company estimate their daily costs by looking at the distance to be travelled, route type and car type.

b. <u>The simulation model solution problem:</u>

The specialist did an investigation for 8 days and observed that Vesta Safaris Company was undergoing a loss as a result of not having a booking policy. The specialist also found out that the company works 30 days a month. He wishes to know the booking policy which will be able to meet the client's bookings in the next 10 days. Three booking policies exist in the execution of this activity as follows:

i. 5 cars booked at a booking level of 5
ii. 10 cars booked at a booking level of 10
iii. 15 cars booked at a booking level of 15

The simulation problem is to determine the best booking policy that will suite Vesta safaris Company.

Scenarios related to the above problems:

➢ <u>The analytical model solution problem:</u>

Past records of the company show that :

a. A same model car used in smooth roads consumes the same level of fuel as the one used in a flat area covering the same distance.
b. A same model car used in Rough roads consumes the same level of fuel as the one used in a Mountainous areas covering the same distance.
c. A same model car used in smooth roads consumes less level of fuel as the one used in a Mountainous areas covering the same distance.

➢ <u>The simulation model solution problem:</u>

Past records of the company show that:

a. The company estimates to have at least a day 4 clients must be delayed in a queue.
b. A client will be delayed at a minimum of 1 hour.

Formulation of assumptions, Constraints and identification of key variables for the simple analytical model.

The simple analytical model is developed by adapting the directly proportionality mathematical relationship. ***The basic assumptions were:***

i. A vehicle used in a rough road and mountainous areas consumes more fuel due to friction and oppose to motion between the tyres and the rough surface.
ii. A vehicle used in a smooth road or a flat area consumes less fuel due fast acceleration as a result of less friction between the road and the tyres.
iii. Drivers speed has no or less impact on the amount of fuel consumed by a vehicle.
iv. Personal vehicles are petrol fuelled whiles commercial vehicles use diesel.

Constraints

I. The car hire company whose data was used to develop the model used seven car models namely: Mit/cedia, Toyota NZE, N/Bluebird, N/Adran, N/Wingroad,, T,Allex/Runx, M/Demio.
II. This cars are all personal cars and make use of the same fuel which is petrol.

III. Only four states of roads have been considered to develop the model namely: Smooth road, Flat road, Rough road, Mountainous roads.
IV. Cars can be hired per day only.

Key variables to the model.

i. SR to represent Smooth Road.
ii. RR to represent Rough Road.
iii. FR to represent Flat Road.
iv. MR to represent Mountainous Road
v. D to represent Distance travelled in Kilometres.
vi. TFC to represent Total Fuel Cost
vii. C to represent Cost.
viii. FC to represent Fuel Cost.

IV. Construction of the Simple Analytical Model

Past records of this company has shown that for every 1KM (Kilometre) travelled by a car in smooth road or Flat road there is an expense of 8 Kenya shillings and an expense of 10 Kenya shillings for a car used in either mountainous or rough road. The company has used this estimate to calculate costs of fuel for their clients in the past two years but in the recent past their has occurred two exceptional cases as explained in the critical evaluation of the simple analytical model part of this paper, which will require the company to review this formula.

Analysis and solution of the simple analytical model.

Fuel costs to be incurred by a client are determined by the formula 8*(SR or FR)*K+ 10*(MR or RR).

Example a: A client wishing to travel a distance of 300 km in smooth road and 100km in rough road will be charged (300 * 8) + (100 * 10)=2400+1000=3400.

Example b: A client wishing to cover a distance of 400KM in Flat Area, 10KM to cross a Mountain, 20KM in rough road and finally 50KM in Smooth road is estimated to in incur a fuel cost of (400 * 8) + (10 * 10) + (20 * 10) + (50 * 8)=3200 +100 +200+400 = 3900.

Critical evaluation of the simple analytical model.

The simple analytical model has been developed on an assumption of past cost incurrence's of the company. Despite the fact that the company has relied on this formula to make profit, there has been two exceptional cases from the same records which calls for the development of the revised analytical model.

Exceptional Case1:

A client travelled 800KM in Flat Area, 5KM in rough road and 400KM in smooth road. This client reported to have spent 9200 shillings. According to the formula, the same should spent (800 * 8) + (5 * 10) + (400 *8) = 6400 +50 + 3200 =9650

Exceptional Case2:

A client travelled 200KM in Mountainous Area, 20KM in rough road and 100KM in smooth road. This client reported to have spent 2620 shillings. According to the formula, the same should spent (200 * 10) + (20 * 10) + (100 *8) = 2000 +200 + 800 =3000

Due to the above two exceptions, the simple analytical model requires revision as below.

Construction of the revised analytical model and solution

Consider from the Appendix: Table 1 containing a random sample data collected from Vesta Safaris Company on fuel consumption of their vehicles.

From this table we can observe a trend hence the derivation of the below formula.

FCL α D α Route
FCL = K*D where K is a known constant for Route.
Example1: To calculate K=SR we pick three clients at random A, J and S. that is FCL for A=K*200=1500 => K=1500/200=7.5
FCL for J=K*635=4762.5 => K=4762.5/635=7.5
FCL for S=K*540=4050 => K=4050/635=7.5
SR=K=7.5……………………………………*1

Example2: To calculate K=RR we pick three clients at random B, K and P. that is FCL for B=K*400=3300 => K=3300/400=8.25
FCL for K=K*750=6187.5 => K=6187.5 /750=8.25
FCL for P=K*230=1897.5 => K=1897.5 /230=8.25
RR=K=8.25……………………………………*2

Example3: To calculate K=MR we pick three clients at random Z, H and L. that is FCL for Z=K*1000=8500 => K=8500/1000=8.50
H=K*350=2975=> K=2975/350=8.50
L=K*670=5695=> K=5695/670=8.50
MR=K=8.50……………………………………*3

Example4: To calculate K=FR we pick three clients at random Y, R and M. that is FCL for Y=K*290=2233 => K=2233/290=7.7
R=K*600=4620=> K=4620/600=7.7
M=K*900=6930=> K=6930/900=7.7
FR=K=7.7……………………………………*4

Therefore we can conclude that SR=K= 7.5, RR=K= 8.25, MA=K= 8.50, FR=K= 7.7.

That is every 1KM (Kilometre) travelled by a car in smooth road (SR) incurs a cost of 7.50 shillings, 1KM (Kilometre) travelled by a car in rough road (RR) incurs a cost of 8.25 shillings, 1KM (Kilometre) travelled by a car in Mountainous road (MR) incurs a cost of 8.50 shillings and 1KM (Kilometre) travelled by a car in Flat road incurs a cost of 7.7 shillings.

Critical evaluation of the revised analytical model for further recommendation.

- ✓ The revised model is more accurate as compared to the simple analytical model.
- ✓ This more has been tested with many other past data of the company and has proved functional.
- ✓ Using the revised analytical model, the exceptional cases would not be observed by the company that is for exceptional case1, the calculation would be 800*7.7+5*8.25+400*7.5=6160+41.25+3000=9201.25 and exceptional case2, the calculation would be

200*8.50+20*8.25+100*7.5=1700+165+750=2615 hence no loss or customer complain.

- ✓ The model has been developed with data collected one company that uses only personal vehicles (Vehicles using only one type of fuel Petrol). Hence it's open for further development for companies who use both personal and commercial vehicles.
- ✓ The model will require more testing with future data to be collected by the company

SIMULATION MODEL

Formulation of assumptions, constraints and identification of key variables for the simulation model.

Assumptions:

- ✓ A customer must book for a car 10 hrs before use.
- ✓ An average of 4 customers must be delayed in a queue per day.
- ✓ The minimum number of hours a client can be delayed in a queue is 1 hr.

Key variables

i. CD (Clients in a day)=30
ii. NCD (No of clients delayed in a day)=5
iii. MHLQ(Minimum Hours Lost in Queue)=4
iv. HC(Hourly cost per hour for delay)
v. MCCPC (Minimum Compensated Cost Per Client)=800
vi. TCCPD (Total Compensated Cost Per Day)=4000

Constraints

- ➢ 1≤ NCD≤ 10
- ➢ CD>0
- ➢ 00 ≤ RandNos ≤99 where RandNos are the generated random numbers.

11. Construction of the simulation model.

The specialist collected the below information

Delayed clients in a day	Probability
3	0.25
4	0.20
5	0.30
6	0.15
8	0.10

Random numbers were used to come up with probability distribution as shown below:

Policy	Day	1	2	3	4	5	6	7	8	9	10
Booking 5		30	10	20	50	60	70	00	10	30	25
Booking 10		13	50	50	89	76	54	56	60	89	70
Booking 15		16	70	30	49	56	34	43	56	54	60

Step 1 Objectives of simulation

The major objective is to simulate the behavior of the three booking policies:

i. 5 cars booked at a booking level of 5
ii. 10 cars booked at a booking level of 10
iii. 15 cars booked at a booking level of 15

Step 2: Identifying input variables:

The Controllable variables are booking level and number of cars while the non controllable variables are demand of cars in a season.

Step3: Determining the probability distribution.

Delayed clients in a day	Probability	Cumulative probability	Random Numbers
3	25%	25%	00-09
4	20%	45%	10-25
5	30%	75%	26-50
6	15%	90%	51-80
8	10%	100%	81-99

The random numbers were used to determine the number of customers delayed in a queue per day. Example under booking policy 10 on the second day, the random number generated was 50 which is in the range of 26-50, which is in the delayed number of customers of 5.

Step 4: Identifying parameters:

Clients in a day = 30
No of clients delayed in a day =5
Minimum Hours Lost in Queue=4
Minimum Compensated Cost per Client =800
Total Compensated Cost per Day=4000

Step 5: Identifying the output variables

The major output variables are the total cost spent in compensating clients on time spent in a queue and knowing the exact number of clients delayed in a queue in day.

Step 6: Determining the logic in the model:

MCCPC (Minimum Compensated Cost Per Client)=MHLQ(Minimum Hours Lost in Queue)* HC(Hourly cost for delay)

TCCPD (Total Compensated Cost Per Day)= MHLQ(Minimum Hours Lost in Queue)* HC(Hourly cost for delay)* NCD (No of clients delayed in a day

12. Critical evaluation of the simulation model and further recommendations.

Results produced by the model are real only that the results were not best. Example from the appendix under booking level 5, the company will have an expense of **KSH 29,800** while at booking level of 15, the company will have an expense of **KSH 20,200** . This figures are too big compared to the estimated profit made by the company per day **KSH 18,000.** Using the simulations, its recommendable for the specialist to adapt the booking level of 10 which has a minimum cost of **KSH 13,600** however this might not be a best choice of solution because booking levels of customers will vary depending on seasons. This problem was solved using Monte Carlos simulation which makes use of predictions. The number of customers delayed in queue per day was predicted using random numbers which helped to display the dynamism of the system.

V. Recommendations

The company can adopt booking level of 10 only when its not on a festive season because at this season clients will be more than expected Making the model open for extensibility. Kenya has one major festive season on December and its this time when the company should adapt an alternate booking level of the cars.

VI. Conclusion

A car hire business has rapidly grown currently in Kenya with companies competing each other in terms of offering the best customer service as well as maximizing profits. To make profit as well as be an organization of excellence in terms of customer satisfaction, an organization has to rely on its ICT systems. Daily charges to their customers has been a challenge for this organizations hence the need to use both analytical model and simulation models. The above two models are reliable to be used by this companies.

References

[1] (Ch. Gobert, June 2010), Analytical assessment of models for large eddy simulation of particle laden flow.

[2] (K. M. Captain Manager etl, March 2010), Analytical Tire Models for Dynamic Vehicle Simulation (Se-Hark Park,July 2006), Errors in reginal nonsurvey input-output models: Analytical and simulation results.

[3] Agirre-Basurko, E., G. Ibarra-Berastegi, and I. Madariaga. 2006. Regression and multilayer perceptron-based models to forecast hourly O3 and NO2 levels in the Bilbao area. Environmental Modeling & Software 21(4): 430-446.

[4] Al-Anazy, A. F., and I. D. Gates. 2010. Support vector regression for porosity prediction in a heterogeneous reservoir: A comparative study. Computers and Geosciences 36(12):1494-1503.

[5] Barth, M., J. Han, and S. Shaheen. 2002. Shared-use vehicle systems: framework for classifying carsharing, station cars, and combined approaches. Transportation Research Record 1791: 105-112.

[6] Barth, M., and M. Todd.1999. Simulation model performance analysis of a multiple station shared vehicle system. Transportation Research Part C: Emerging Technologies 7(4): 237-259.

[7] Barth, M., J. Han, and M. Todd. 2001. Performance evaluation of a multi-station shared vehicle system. Proceedings of the 4th IEEE International Conference on Intelligent Transportation Systems: 1218-1223.

[8] Catalina, T., J. Virgone, and E. Blanco. 2008. Development and validation of regression models to predict monthly heating demand for residential buildings. Energy and Building 40(10): 1825-1832.

[9] Cervero, R., and Y. Tsai. 2004. City carshare in San Francisco, California: Second-year travel demand and car ownership impacts. Transportation Research Record 1887: 117-127.

[10] Habib, K. M. N., C. Morency, M. T. Islam, and V. Grasset.2012.Modeling users' behavior of a carsharing program: Application of a joint hazard and zero inflated dynamic ordered probability model. Transportation Research Part A: Policy and Practice 46(2): 241-254.

[11] Ingalls, R. G. 2001.Introduction to simulation. Proceedings of the 2001 Winter Simulation Conference, December 9–12: 7-16.

[12] Karbassi, A., and M. Barth. 2003. Vehicle route prediction and time of arrival estimation techniques for improved transportation system management.

[13] Proceedings of the 2003 IEEE Intelligent Vehicles Symposium, June 9–11: 511-516.

[14] Kek, A. G. H., R. L. Cheu, and M. L. Chor. 2006. Relocation simulation model for multiple-station shared-use vehicle systems. Transportation Research Record 1986: 81-88.

[15] Kek, A. G. H., R. L. Cheu, Q. Meng, and C. H. Fung. 2009. A decision support system for vehicle relocation operations in carsharing systems. Transportation Research Part E: Logistics and Transportation Review 45(1): 149-158.

[16] Klein, C., F. Foerster, K. Hartnegg, and B. Fischer. 2005. Lifespan development of pro- and anti-saccades: Multiple regression models for point estimates. Developmental Brain Research 160(2): 113-123.

[17] Krose, B., and P. Van Der Smagt. 1996. An Introduction to Neural Networks, Eighth Edition. University of Amsterdam.

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Appendix.
Table1:

Date	Client	Route	TFC	FC	D
12/05/2010	A	SR	1500	96	200
10/06/2010	B	RR	3300	96	400
20/09/2010	F	SR	13125	96	1750
18/10/2010	G	RR	7837.5	96	950
19/01/2010	H	MR	2975	96	350

20/02/2010	I	FR	3850	96	500
10/03/2010	J	SR	4762.5	96	635
22/07/2010	K	RR	6187.5	96	750
11/09/2010	L	MR	5695	96	670
07/07/2010	M	FR	6930	96	900
14/04/2010	N	MR	4760	96	560
26/01/2010	O	SR	3375	96	450
30/08/2010	P	RR	1897.5	96	230
25/02/2010	Q	MR	2890	96	340
29/05/2010	R	FR	4620	96	600
01/11/2010	S	SR	4050	96	540
03/08/2010	T	RR	6435	96	780
01/06/2010	U	MR	13600	96	1600
02/07/2010	P	SR	30000	96	4000
05/10/2010	Y	FR	2233	96	290
06/11/2010	Z	MR	8500	96	1000

Table 2:
When booking level is 5

Date	Clients delayed	No of hrs delayed	Cost per hour delay	Total expenses
1	1	4	200	800
2	2	7	200	2800
3	3	5	200	3000
4	4	6	200	4800
5	5	4	200	4000
6	6	3	200	3600
7	7	2	200	2800
8	8	5	200	8000
Total				**29,800**

Table 2:
When booking level is 10

Date	Clients delayed	No of hrs delayed	Cost per hour delay	Total expenses
1	2	1	200	400
2	3	2	200	1200
3	2	1	200	400
4	4	5	200	4000
5	2	3	200	1200
6	4	6	200	4800
7	5	1	200	1000
8	1	3	200	600
Total				**13,600**

Table 3:
When booking level is 15

Date	Clients delayed	No of hrs delayed	Cost per hour delay	Total expenses
1	5	3	200	3000

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2	3	2	200	1200
3	2	1/2hrs	200	200
4	6	4	200	4800
5	2	5	200	2000
6	4	2	200	1600
7	7	1	200	1400
8	6	5	200	6000
Total				**20,200**