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SIMULATING DIFFERENT LEVELS OF CAR CLASS UPGRADES IN A CAR RENTAL COMPANY'S OPERATIONS

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ABSTRACT

The car rental business has experienced recent growth under a fiercely competitive market. This paper describes a generic discrete event simulation tool for studying the complex nature of a car rental company's operations. To construct the tool, we conducted several interviews with experts to first establish the proper requirements, after which we collected relevant data for populating the simulation model, thereby determining the best strategies for car class pricing and upgrade offers that would result in the highest revenue. A realistic case study was conducted to assess the tool and gain a better understanding of the underlying system. Finally, simulation experiments regarding rental prices and car upgrades were designed, and the system was run, achieving a 0.5% error for various performance criteria. For the given case, we found that two upgrade offers and setting prices slightly higher than the average customer budget provides the best strategy.

1 INTRODUCTION

The business of car rentals has recently been gaining in importance. In 2015, in the United States alone, the revenue in this sector reached $27.11 billion, representing a 4% improvement since 2014. Moreover, the average car rental fleet growth is 5% (Auto Rental News 2015); this growth has been steady since 2010 and is forecasted to continue (Oliveira et al. 2017).

The large car rental companies run their businesses using similar processes in this fiercely competitive industry. Despite the economic growth in this sector, the operations of car rental companies are complex. Thus, companies are constantly racing to increase their operational efficiency. However, the complex nature of such a large network makes it difficult to analyze and improve operational efficiency. One of the main factors increasing the complexity of such networks is the presence of fluctuations in the demand for pickup and drop-off locations of the car. This makes it difficult for companies to guarantee the availability of their cars for customers with advance reservations. All major car rental companies offer their customers upgrades in case the car class the customer reserved is not available at the time of pick up. This offer may seem compulsory for car rental companies to maintain customers' satisfaction; however, it is also important to understand the effects of the upgrades, which may cause losses to the company due to missed opportunities of sales for the higher class. To analyze an operational system with a view to increasing its efficiency, and ultimately, improving it, we need to use tools like simulation to effectively enhance the operational process.

To increase the operational profitability and availability of each class of cars at each location, companies employ different pricing strategies to adjust the demand. In this paper, we develop a generic simulation tool for a large car rental network. Then, we apply this to a realistic case study that embodies a minimum of 15 locations and five car classes. The paper aims to gain a better understanding of the effects of different pricing policies for each car class on the turnover (rental fee) under this complex operation. Furthermore, the effect of offering upgrades on turnover will be analyzed.

The developed simulation tool will enable large car rental companies to input their historical data into the system and analyze the effects of different pricing policies for each car class for their specific operations.

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This will allow the companies for better understanding their operations to increase their operational efficiency and the availability of cars at each location while maintaining customer satisfaction.

Section 2 of this paper presents additional background and motivation, as well as a literature review. Section 3 describes the methodologies used to develop the generic simulation tool. A detailed description of the features of the developed simulation tool is given in Section 4. Section 5 describes a case study used to demonstrate the developed simulation tool and discusses the results. Section 6 concludes the paper.

2 LITERATURE REVIEW

2.1 Background

Oliveira et al. (2017) reviewed fleet and revenue management of car rentals, despite the lack of available research in this area. They proposed a research direction for fleet management of car rentals and noted a few problems that need to be fixed, such as the network of division in pools of stations, fleet size, and mix between types of vehicles (car classes). Fink and Reiners (2006) proposed a realistic approach to the fleet size and mix problem and presented a realistically implementable model to tackle various real-world issues, such as considering multi-periods, a country-wide network, and car groups with partial substitutability.

Yang et al. (2008) published a literature review on the car rental logistics problem and suggested some interesting future research guidelines, along with the focus on the vehicle-reservation task. The authors compared several specific issues with those faced by the airline enterprise and claimed that some problems are applicable in each industry. This descriptive review used Pachon et al.'s (2006) work as a basis. However, there are significant idiosyncrasies of the car rental business that require a more detailed analysis of the sector, and there may be sufficient growth potential in this area so as to justify a more challenging and critical approach to the proposed frameworks.

Car upgrades are no longer only essential for the business; they are necessary for proper model optimization formulation as well. If there is no substitution between car types, the model can be separated by means of type and the complexity is considerably decreased; this is why some works consider the simplest one-car type with no upgrades (Li and Tao 2010; Haensel et al. 2012; You and Hsieh 2014). Nevertheless, a number of realistic models consider upgrading strategies to a greater or lesser extent. The choice of this extent is a trade-off in itself, although higher upgrade flexibility results in better fleet utilization.

Pricing is becoming more dynamic, substantially less complicated, and faster, as it is now possible to gather prices in actual time with rate-updating techniques via the internet (Oliveira et al. 2017). In this area, Bitran and Caldentey (2003) reviewed the principle pricing models in revenue management and highlighted their significance within the capacity and inventory decisions. They claimed that prices are efficient variables to be used by managers for controlling demand. Şen (2013) confirmed that the use of dynamic pricing strategies may have an extensive effect on companies' revenues, even if accessible dynamic heuristics are used to exchange prices. Those papers aimed to emphasize the influence and benefits of this practice, which seemed to be missing in the revenue management literature; this was specifically due to the technique's inherent computational problems.

Simulation, especially DES – a tool used to mimic complex operations with different variabilities – is rarely used in the car rental literature. We have developed a generic simulation tool to better understand and analyze such a complex operating system. Although the developed tool is generic, in this research, an industrial case study has been investigated to address the effect of allowing car upgrades when a reserved car is not available. We have applied different strategies to compare among the following scenarios: (i) when car upgrades are not allowed, (ii) when car upgrades are allowed for only one level of upgrade, and (iii) when car upgrades are allowed for only two levels of upgrades.

2.2 Comparing Different Modeling Approaches

Numerous mathematical modelling approaches are obtainable from mathematical programming and heuristic strategies. Techniques along with Queuing Theory have been employed as analytical tools for a range of applications; however, they suffer from several flaws. The use of queuing theory for analytical models frequently seems to be challenging when it comes to explaining the service mechanisms, complexity of the system design, nature of the queuing discipline, or a combination of these factors.

Simulation, especially Discrete Event Simulation (DES), is one of the most widely used techniques for better understanding and analyzing an operations system (Pannirselvam et al. 1999). According to Robinson (2004), simulation is "experimentation with a simplified imitation of an operations system as it progresses through time for the purpose of better understanding and enhancing that system." On the other hand, Sterman (2000) describes System Dynamics (SD) as a specific form of continuous simulation, which is a set of stocks and flows to represent a system. SD is applied at a strategic level where fewer operational details are required (Borshchev and Filippov 2004). If a system needs to be modelled in great detail, DES is more suitable than SD, especially if individual items must be traced within the system (Robinson 2004). This is because SD is abstract and does not capture the detail of individual transactions (Sterman 2000).

Agent-based simulation (ABS) has emerged as another popular simulation modeling approach. In ABS, a complex system is represented via a collection of agents, which are programmed to follow a few (often simple) behavioral rules (Shannon 1975). Consequently, ABS is stronger in social behavior modelling, but in this research, where process modelling is the dominant characteristic, DES is deemed to be the most suitable technique.

2.3 Suitability of Discrete Event Simulation

From the above research review, it is evident that research in this field has been growing recently in car rental settings, resulting in unique differences from other, similar sectors, such as the airline industry. In this paper, we concentrate on the effects of car upgrades, which have become a critical issue for car rental companies, as they increase the complexity of the system and potentially increase the costs for the car rental businesses, especially in a wider, diverse network operating system. The DES approach is a technique that can capture the dynamic behavior of car rental operating systems. In this paper, we develop a novel DES generic tool that includes several branches of a car rental network and different car classes to better understand this system. An industrial case study is applied to assess the developed tool and address the effect of upgrade strategies on the car rental business.

3 METHODOLOGY

3.1 Simulation Tool Requirements

To create a generic DES tool for addressing the complex car rental operations, a set of tool requirements (input–output) first needed to be established. We carried out several semi-structured interviews (see, for instance, King 1994) with academics and practitioners to establish a list of tool requirements to be developed as part of our generic DES tool for the analysis of a car rental company's complex operations. Five interviews were conducted with experts in academia and industry. The interviewees were selected from experts with simulation, car rental, and operations management backgrounds.

The interviews were conducted mostly face to face, although telephone interviews were conducted in certain cases (when the interviewee is not available to meet in person, telephone interview was conducted). The interviews were carried out consecutively over three months, and they were concluded when the received responses did not add any new requirements to the tool.

3.2 Generic DES Tool Capabilities

The generic DES tool for car rentals was created in ExtendSim (2018), which incorporates adequate flexibility and can be fitted to any car rental operating system of any size. The software was selected due to its robustness and ease of use. The DES tool has no practical limitation on the number of locations and car classes (categories) in the system. The model has a simple interface, which users with no simulation background can easily use via a simple Excel spreadsheet that the DES tool can read. The DES tool can work in three different modes, as follows:

- Reading car rental data from Excel and generating demand accordingly;
- Creating car rental data based on random distributions for customer arrival time, rental duration (drop-off time), difference in time between reservation and rental start, customer type (walk-in or by reservation), percentage of customers requesting each car category, pickup location preference percentage, and drop-off location preference percentage;
- Reading car rental data entered from Excel and generating random additional car rental data.

Moreover, the developed DES tool can facilitate decisions on the number of upgrade levels to be offered to customers if the car class they asked for is not available at the pickup time. The number of upgrade levels to be offered to the customers can be entered by clicking the upgrade button in the main user interface. The user can simply also decide on the precision (desired standard errors) of the estimated mean values of the turnover; and then the simulation model runs replications until the relative error for the calculated mean of the turnover is less than the value entered by the user.

4 DES TOOL DESCRIPTION

The following subsections provide a detailed description of how the DES tool was created, along with a detailed user guide on how to use this generic DES tool for complex car rental operations.

4.1 DES Tool Interface

DES modeling is complex, and surprisingly few people in the car rental industry are familiar with the use of simulation software packages. To allow researchers and practitioners for easily using the simulation, we developed an interface for data entry. The interface is composed of four sections – the buttons on the left side, the simulation model at the center, the main inputs at the bottom left, and the results at the bottom right corner, as depicted in Figure 1 and as explained in detail in the following subsections. We first describe the various buttons.

4.2 Categories Button

The categories button is where the car classes are defined in the system. The user can define as many car classes (categories) as he/she wishes. When the user clicks on the categories button, a pop-up menu appears. Here, the user can simply input the car class name and price of each category. The percentage column is only effective in the mode when the demand data are created randomly and represents the percentage of customers requesting each car class. “MaxPrice” represents the distribution and mean for the budget of customers asking for that car class. The price values for each car class can also be entered via the main user interface screen without clicking any buttons.

To add new car classes, the user can simply right-click anywhere in the table and choose the “Append Rows” option. A window will pop up asking how many rows to be appended to the table. The user can add as many rows (car classes) as desired and input the values for all the columns in the appended rows. If the user wishes to reduce the number of car classes, he/she can simply select the row(s) to be deleted by left-clicking on the record # values of the relevant row(s). Then, it is necessary to right-click and select the “delete selected rows” option.

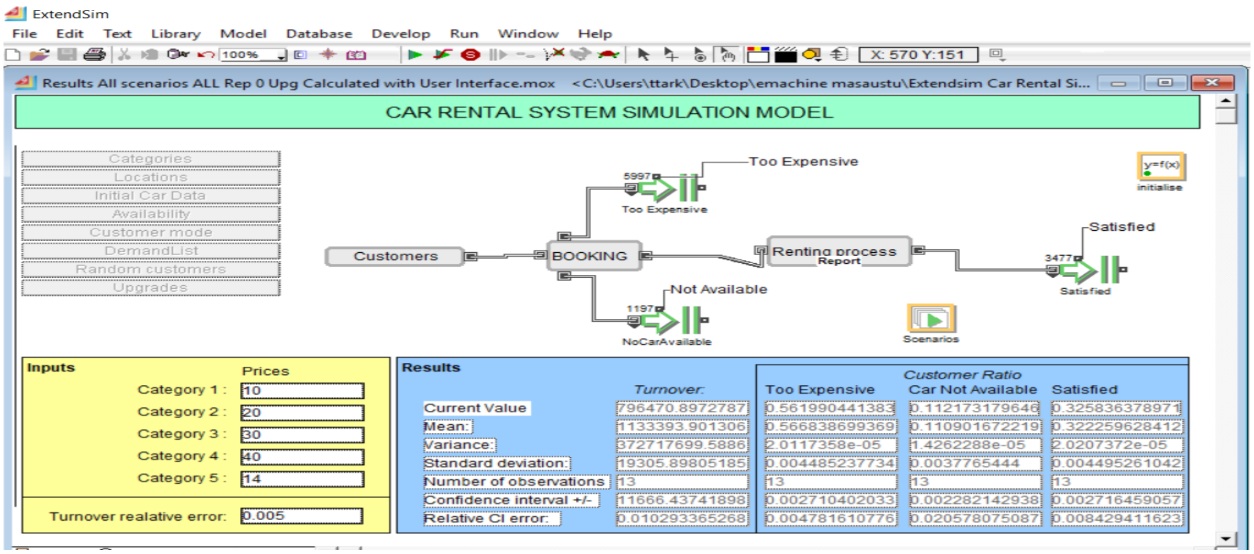

Figure 1: Car rental system simulation model interface.

4.3 Locations Button

In this section, the pickup and drop-off locations in the system are defined. Users can add as many locations as they need to and delete existing locations, in a manner similar to that described in the previous subsection. Pickup and Return Probability columns are required only for the random demand generation mode.

4.4 Initial Car Data Button

The initial car data button is where the data regarding the numbers of cars available for each car class at each location at the beginning of the simulation are entered. Initially, as a crude default, there are five cars available at each location for each category.

4.5 Availability Button

The table that pops up when the availability button is clicked shows the availability of each car class at each location over different timeframes. The availability table is constantly updated throughout the simulation run as new reservations and car hires are made. All the values in the table are only indicative and calculated values, no values need to be entered in this table.

4.6 Customer Mode Button

The customer mode button is where the user can choose the mode of the simulation run. As described above, the simulation model can run in three different modes, namely, “List,” “Random,” and “List and Random.” When the List mode is chosen, the simulation will only read the data entered in the demand data section and generate customers accordingly. When the Random mode is selected, the simulation will create customers based on the distribution and parameters entered regarding the arrival rate, customer class preference, rental duration, time between booking request and pickup, drop-off location, and pickup location. When both options are selected, the simulation will create customers, both from the demand data entered and randomly according to the parameters for the above-mentioned criteria.

4.7 Demand List

The demand list button allows the user for entering the demand data into the model in order to generate customers. The demand data require the following information in each column:

- Booking date and time;
- Pickup date and time;
- Rental duration;
- Category (demanded car class);
- Pickup location; and
- Return location.

The booking time must be greater than or equal to the pickup time. The difference between the two times represents the delay between the booking request time and the requested pickup time. If the two values are equal, the customer is regarded as a walk-in customer.

4.8 Random Customers Button

The random customers button is where the parameters for the randomly generated customers are entered. The values entered in this table are only effective when the "Random" or "List and Random" choice is selected in the Customer Mode option.

4.9 Upgrades Button

In the upgrades option, the number of upgrades offered to the customer can be entered. What we mean by the number of upgrades is how many levels of car classes the customer is allowed to upgrade to. An upgrade is offered to the customer when the car class the customer requested is not available at the pickup time.

5 DES TOOL DEMONSTRATION

5.1 Case Study Description

We used our DES tool to analyze an industrial case study. The aim of this application is to test the tool and gain a better understanding of the effects of the levels of upgrades that are allowed for customers whose desired car class is unavailable. The ultimate objective of this research is to monitor the upgrades' influence on car rental companies' revenue.

Large car rental companies around the world adopt similar business processes. The description of the (large) car rental company case for which the simulation model has been built is given below.

There are two types of customers who wish to rent a car, namely, walk-in and reservation customers. Walk-in customers arrive at a car rental location where they ask for the availability of the car category they wish to rent, for the duration they desire, and to be dropped off at their desired destination. Walk-in customers ask for the immediate rental of the car. In contrast, reservation customers make a reservation for the car class they wish to rent for a rental starting date in the near future and the duration they desire, and they pay or secure the amount for the payment to the car rental company at the time of reservation.

All demands (walk-in and reservation customers) arriving at the car rental office or via the reservation system include the following information:

- The class of car the customer is willing to rent;
- The duration of car rental (in days);
- The maximum amount the customer is willing to pay per day for renting the desired car class;
- The location of the start of the rental (pickup point); and
- The location of the end of the rental (drop-off point).

The walk-in customers are not aware of the availability of the cars and their prices before arriving at the car rental office. They make a decision based on the response they receive regarding the availability and price of the cars. Reservation customers entering the reservation system act in a similar fashion regarding the price and availability of the cars. If they find an available car in their budget and for the time and duration they require, they fill in the online form to complete the reservation. In this case study, the budget (maximum amount a customer is willing to pay) for a specific car class is determined by assigning an exponential random variate for this value. This is because the exponential distribution reasonably represents the maximum amount a customer is willing to pay for any product or service, at least according to the interviews with the subject matter experts. This feature of the simulation model adds real-life complexity to the system where the demand for any car class depends (in a random way) on the price of that car class.

The customers arriving at the car rental system already know the car class they want to rent, which can be determined either in the entered demand data or by percentage values for each car class in the random demand generation mode. In this case study, the simulation runs with the entered demand data, and all car classes have uniform demand. The initial number of cars available at each location for each car class is set to five, and there are 15 car rental branches (locations). However, by changing the price of any of the car classes, the demand for that car class will also change, which will affect the availability of the car class. Furthermore, by enabling upgrades to customers, the demand and the ability to provide cars from the next (higher) car class to subsequent customers will also be affected. The rental fee (turnover) is calculated using the following formula: number of rental days multiplied by the price for the asked car category. In this case study, the effects of different pricing strategies will be investigated. In addition, the effects of offering car class upgrades on the turnover will also be analyzed. In particular, we study the question of how the turnover is affected by the change of price for each category under the following policies:

(i) No car class upgrade is allowed;
(ii) One level of car class upgrade is allowed; and
(iii) Two levels of car class upgrade are allowed.

5.2 Experiments

To understand the change in expected revenue when different pricing policies are employed, we carried out a design of experiments consisting of 96 scenarios. In the first research question, where we investigate how the turnover is affected by change of price under the first policy applied (i) No car class upgrade is allowed, it is expected that the system will represent the highest expected revenue when the prices for each car class are entered as the mean value of the exponential distribution for the budget of customers for that class. It is of interest to see how the revenue will be affected when one level of car class upgrade is allowed and which pricing policy will perform better.

The inputs (factors) for the design of experiments are the prices for each category. The main output (response) of the system to be evaluated is the expected revenue generated. The other outputs (responses) that we have observed are the percentage of customers that are satisfied, the percentage of customers who have no car available to pick up, and the percentage of customers who choose not to rent due to the high price. The demand data cover a 1-year period; therefore, the simulation length is set to 365 days. The simulation runs replications until we have 95% confidence that the relative error for the mean of revenue generated is less than 0.005 of the true mean. This value can be modified through the inputs section in the main model interface. The required number of replications calculated by the system is usually about 50–80 for each scenario. The reason for this modest number of required replications is that the input for the demand data is the same for each run; however, the customers' budget values are assigned by the exponential distribution for the car class they ask for, which creates variation for every run. Each simulation run (replication) takes about 20 seconds to calculate on a computer with an Intel i5 8250U processor @ 1.60 GHz. Calculating all scenarios for the research question with all replications took around 6 days to run with the above-mentioned specifications.

The demand data input to the simulation model for this study represents estimates provided by an expert in this industry, and so portrays realistic values. One of the key inputs in the model is the budget of customers for each car class. The budget values for customers for each car class are assigned by an exponential distribution with different mean values for each class. The mean value of the exponential distribution for the budget is 10 for car class 1, 20 for class 2, 30 for class 3, 40 for class 4, and 50 for class 5. The demand data consisting of arrival times and demand for each class and location are input through Excel, and they are static for each simulation run. However, the budget values of customers are reassigned by the exponential distribution with the mean values specified above for each new simulation run. By using this static data, along with reassigned values for the budget values, we can analyze via the common random numbers simulation output analysis variance reduction technique the same case and find out the best values for pricing strategy and other response values, such as the required number of car upgrades.

Considering that the system is expected to portray the highest revenue for the price value near the mean value of the exponential distribution for the maximum budget of customers for that car class, the experiments are created by changing the price of one car category when the prices of other car classes are equal to the mean value of the exponential distribution for the budget of customers of that class. The experiments are designed in such a way that there are at least nine consecutive price values around the mean value of the exponential distribution for the specific car class, followed by the diverging values from the mean value along with three extreme values for both the minimum and maximum of a specific car class's price. For instance, when designing the experiments for the second car class, the prices for all other car classes are set to the mean values for the budget of customers for the corresponding car classes (i.e., car class 1 = 10, class 3 = 30, class 4 = 40, class 5 = 50). Then, the price of the second car class, which has the mean value 20 for the exponential distribution of the budget for customers for this class, are set to have these following 9 consecutive values: 17, 18, 19, 20, 21, 22, 23, 24, 25. Following this, new scenarios are created by assigning diverging values for the price of this car class such as 27, 29, 30, 50, 100, and 1000 for high values and 7, 9, 11, 13, 15 for low values. Having consecutive price values near the mean value of the budget enables us to more closely analyze the system output where the highest value for the revenue is expected to be. Thus, there are 19 experiments for each car class price value when other car class values are equal to the means of their respective exponential distributions of the budget for those car classes. Plus, we have one baseline scenario in which each car class price value equals the mean value of the budget for the corresponding class.

5.3 Results and Analysis

5.3.1 No Car Class Upgrade is Allowed

The top 10 performing scenarios where no car upgrades are offered can be found in Table 1. As can be observed from the table, the results among the scenarios are highly similar. Considering that there can be 0.005 error between the true mean and calculated means of turnover for each scenario, this corresponds to +/– $6,900.00 statistical error in the calculation of the mean value for the turnover when the turnover is around $1,371,935. This means that, statistically, it is not always possible to prove definitively that one of the scenarios presented in Table 1 is superior to the other. However, when the results of scenarios 90, 91, and 92 are observed, it is possible to conclude that, when we increase the price of category 5 from 50 to 60, the turnover still portrays high values.

It is also valuable to observe that the average percentage of customers who find the price too expensive is around 64%. This result is quite reasonable, since the prices for each category are equal to or higher than the mean value of the exponential distribution for the budget of customers for the corresponding car class. Further, the percentage of customers who are unable to find the car they wish to rent and, thus, leave the system, is around 7.5%. This value certainly depends on the demand data and availability of the cars. The number of cars for each car class at each location equals 5 when the simulation starts; however, due to fluctuations in the demand for each car class and drop-off and pickup locations, the car class the customer wishes to rent is not available. The missed opportunity cost due to cars being unavailable at the pickup location varies between $365,016 and $379,185, with the average being $373,007. Finally, the percentage of customers who are satisfied is around 27.6% in the best performing scenarios.

Table 1: Top performing scenarios when car class upgrades are not allowed.

Scenario Name	Cat 1 Price	Cat 2 Price	Cat 3 Price	Cat 4 Price	Cat 5 Price	Turnover	Too Expensive	Not Available	Satisfied	Missed Oppo. Cost
Scenario 70	10	20	30	45	50	$ 1,371,935	0.649	0.0744	0.277	$365,527
Scenario 30	10	22	30	40	50	$ 1,370,909	0.648	0.074	0.277	$375,803
Scenario 90	10	20	30	40	55	$ 1,369,214	0.648	0.075	0.277	$372,469
Scenario 72	10	20	30	50	50	$ 1,368,212	0.657	0.072	0.271	$365,016
Scenario 29	10	21	30	40	50	$ 1,367,322	0.644	0.076	0.280	$375,149
Scenario 33	10	25	30	40	50	$ 1,367,313	0.656	0.072	0.271	$371,890
Scenario 91	10	20	30	40	57	$ 1,367,135	0.649	0.075	0.275	$370,665
Scenario 12	12	20	30	40	50	$ 1,366,613	0.653	0.074	0.273	$376,526
Scenario 68	10	20	30	43	50	$ 1,365,702	0.646	0.076	0.278	$374,921
Scenario 11	11	20	30	40	50	$ 1,365,512	0.648	0.075	0.276	$379,185
Scenario 87	10	20	30	40	52	$ 1,365,114	0.644	0.076	0.280	$376,542
Scenario 10	10	20	30	40	50	$ 1,365,088	0.640	0.078	0.282	$378,878
Scenario 92	10	20	30	40	60	$ 1,364,814	0.654	0.074	0.272	$366,518
AVERAGE	-	-	-	-	-	$ 1,367,299	0.649	0.075	0.276	$373,007

5.3.2 One Level of Car Class Upgrade is Allowed

The results for the top performing scenarios when one level of car class upgrade is allowed portray even less variable results than those of the first case as shown in Table 2. But, most notably, when the results of the first case (no upgrade is allowed) are compared with the second case (one level of car class upgrade), we immediately see that the maximum turnover has increased to $1,485,912 from $1,371,935, an increase of about 8%. Therefore, it is possible to conclude that, for the given price and demand parameters, it is far more profitable for the car rental company to offer at least one car upgrade to their customers in case the car they wish to rent is not available.

Taking a look at the first three rows of the simulation results, we realize that the results are highly similar for the following three cases: the prices of each car class are equal to the mean value of the exponential distribution (Scenario 10), the price of one category is slightly discounted in relation to the mean value of the exponential distribution for demand of the specific car class (Scenario 29), and the class price of one category is increased by 20% while the other categories' prices are equal to the mean value for the exponential distribution of the demand for the other categories (Scenario 52). This observation suggests that turnover is more sensitive to discounts than it is to price increases.

When percentages for the customers' rental activities are compared between the first case (no upgrade is allowed) and second case (one level of car class upgrade), the ratio of satisfied customers has risen from 27.6% to 31.07%. Furthermore, the ratio of the customers who leave the system due to no car being available has been reduced to 4.36% from 7.5%. The cost of missed opportunity due to unavailability of the cars at the pickup locations has been reduced to $255,164 from $373,007 in the previous case with no upgrade offered. The ratio of the customers finding the price too expensive is independent of the upgrades offered; therefore, these values have not changed. However, it can be concluded that, when the exponential distribution is entered for the budget distribution of customers, the best performing scenarios result in 63.24–65.46% of customers finding the price too expensive.

The results for this second policy showed that offering one level of car class upgrade to customers results in both a higher ratio of satisfied customers and higher turnover for the car rental company with the given parameters and entered data. However, this conclusion cannot be generalized for all cases. Models with different demand data and car rental prices may result in different conclusions.

Table 2: Top performing scenarios for one level of car class upgrade.

Scenario Name	Cat 1 Price	Cat 2 Price	Cat 3 Price	Cat 4 Price	Cat 5 Price	Turnover	Too Expensive	Not Available	Satisfied	Missed Oppo. Cost
Scenario 46	10	20	29	40	50	$1,485,912	0.638	0.045	0.317	$260,075
Scenario 52	10	20	36	40	50	$1,485,229	0.655	0.042	0.303	$252,786
Scenario 10	10	20	30	40	50	$1,484,602	0.641	0.045	0.314	$264,832
Scenario 71	10	20	30	46	50	$1,484,218	0.652	0.042	0.306	$243,793
Scenario 68	10	20	30	43	50	$1,483,545	0.647	0.043	0.310	$250,465
Scenario 90	10	20	30	40	55	$1,482,060	0.648	0.043	0.309	$252,825
Scenario 11	11	20	30	40	50	$1,481,422	0.649	0.044	0.307	$255,484
Scenario 09	9	20	30	40	50	$1,481,307	0.634	0.045	0.321	$254,791
Scenario 85	10	20	30	40	49	$1,480,827	0.639	0.046	0.315	$258,515
Scenario 51	10	20	35	40	50	$1,480,409	0.653	0.042	0.305	$258,075
AVERAGE	-	-	-	-	-	$1,482,953	0.646	0.044	0.311	$255,164

5.3.3 Two Levels of Car Class Upgrade are Allowed

We now see if we can do even better. In fact, the results when two levels of car upgrade are allowed show even higher turnover values than in the second case (one level of car class upgrade) as can be found in Table 3. The maximum average turnover value reached $1,493,066 in this case, while it was $1,485,912 for the previous policy. With regard to the policy allowing two levels of upgrade, it is valuable to observe that, for all the best performing scenarios, the price values are higher than the mean values of the exponential distributions for their corresponding classes. This observation suggests that, when the number of car upgrade opportunities to customers is increased, the price for the car classes should also be increased.

When the rental experience results for the customers are inspected for this case, we see that the average ratio of satisfied customers in the top performing scenarios increases slightly, from 31.07% in the one upgrade case to 31.38% in this two upgrade case. This minimal change in the percentage of customers satisfied leads to higher turnover results. Moreover, the average missed opportunity cost for the top 10 performing scenarios is calculated as $243,780, whereas it was $255,164 when only one upgrade was offered. Therefore, it can be concluded that offering the two–car class upgrade opportunity to customers results in both more satisfied customers and higher turnover values. Again, this conclusion is specific for this case and cannot necessarily be generalized.

Table 3: Top performing scenarios of two levels of car class upgrade.

Scenario Name	Cat 1 Price	Cat 2 Price	Cat 3 Price	Cat 4 Price	Cat 5 Price	Turnover	Too Expensive	Not Available	Satisfied	Missed Oppo. Cost
Scenario 90	10	20	30	40	55	$1,497,664	0.648	0.036	0.316	$245,662
Scenario 70	10	20	30	45	50	$1,494,988	0.651	0.036	0.313	$242,465
Scenario 68	10	20	30	43	50	$1,493,625	0.647	0.037	0.316	$243,997
Scenario 87	10	20	30	40	52	$1,492,991	0.644	0.038	0.318	$244,702
Scenario 53	10	20	37	40	50	$1,492,438	0.657	0.036	0.307	$245,163
Scenario 88	10	20	30	40	53	$1,492,161	0.646	0.037	0.317	$248,590
Scenario 10	10	20	30	40	50	$1,492,084	0.642	0.038	0.320	$246,093
Scenario 50	10	20	34	40	50	$1,492,056	0.652	0.036	0.312	$241,775
Scenario 92	10	20	30	40	60	$1,491,744	0.655	0.034	0.312	$239,460
Scenario 52	10	20	36	40	50	$1,490,907	0.656	0.037	0.308	$239,892
AVERAGE	-	-	-	-	-	$1,493,066	0.650	0.037	0.314	$243,780

6 CONCLUSIONS

This paper discussed a simulation-based approach for studying complex car rental operations. In particular, a new generic simulation tool was developed to mimic the current and potentially optimized operations of such a system. The paper aimed to understand the effects of car rental pricing strategies and upgrade offers on revenue performance and customer satisfaction. A realistic case study was conducted to illustrate the developed simulation-based approach. With a 0.5% error rate, the analysis showed that, for the given dataset, the best strategy is to selectively offer two car class upgrades to customers. Moreover, our results suggested that the cars in the higher categories (which are sometimes given to lower car class customers as a free upgrade) ought to be offered at slightly higher prices than the average budget of customers for that car class. In addition, our tool can capture certain missed opportunity costs.

Although the results of this study are specific to the given case, our simulation model is generic in the sense that it can analyze a car rental operation of any size. Furthermore, it is possible for any car rental company to enter its recent car rental data into the model and conduct various “what-if” scenarios regarding pricing strategies and car upgrades to determine which strategy would be the best for their specific operations.

Since our rental center simulation tool was built in a generic way, it will be possible to examine other scenarios with respect to customer satisfaction and company cost–benefit analysis. Thus, for future research, the model can be further modified to conduct analyses on strategies other than car upgrades, such as same city drop-off discounts and long-term rental discounts.

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