Online Travel Agency Channel Pricing Policy based on Dynamic Pricing Model to Maximize Sales Profit Using Nonlinear Integer Programming Approach

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Abstract. A dynamic pricing strategy on the cooperation between a hotel and an online travel agency (OTA) is commonly applied to build a pricing policy. The purpose of this study is to propose a pricing policy according to the dynamic pricing model on a single online travel agency channel. The paper provides a dynamic pricing model adjusted to hotel problems with multiple room types. The study consists of two stages. First, we apply a revenue management tool that is dynamic pricing to model the effect of price on demand. The price dynamically changes based on the parameter of demand model. Second, we use a nonlinear integer programming approach to maximize the profit by substituting the demand model which has the lowest root mean square error. The parameter of the demand model is estimated by using the historical sales-price data from one of the hotels in Bandung, West Java, Indonesia. Our results propose a pricing policy of each room types that able to increase 18.54% from the historical sales profit. The proposed pricing policy completes the gap of the method in the existing pricing policy. Moreover, the findings provide an optimal room rate to the front office manager along the planning horizon.

Introduction

In the last few decades, many hotels have collaborated with online travel agency (OTA) to book hotel rooms in the tourism industry [1]. The challenges facing for the hotel is to utilize the OTA channel to maximize revenue by managing hotel room information, such as the offered room rate. To obtain the optimal rate, the hotels generally develop a pricing policy by using the tools on revenue management [2].

Revenue management has commonly applied for hotel industry to achieve an optimal level of net revenue that mostly generated from the room sales [3]. Particularly, hotel revenue management defines as an essential instrument for selling the right room to the right customer, the right time, the right price, and the right distribution channel with the best commission efficiency [3,4].

The tools used in the concept of revenue management to manage the price strategy called as pricing tools [3]. A few researchers have developed pricing policy with the pricing tools such as price discrimination, dynamic pricing, price presentation, price parity, and lowest price guarantee. However, in the last few years, dynamic pricing has increasingly adopted and successfully operated in terms of evolving pricing policy in hotel industry [2,5]. Dynamic pricing is defined as a strategy to model the effect between the price for a product or service on the specific period and price along the planning horizon or known as demand model [6].

Previous researches have addressed dynamic pricing for hotel revenue management. For example, dynamic pricing approach is based on price multipliers that use Monte Carlo Simulation as an optimization algorithm [7]; structure of dynamic pricing depending on the type of customer, star rating, and number of suppliers with available rooms that using panel data analysis [8]; and proposed dynamic pricing optimization model use the reservation scenario which forecasted demand generated from hotel simulator [2].

Existing research has developed dynamic pricing by considering multiple room types [2,7], but not considering the demand model of each room types. This study proposes dynamic pricing models by considering demand model with multiple room types. Particularly, the demand models which the most used are a linear model, exponential model, and multinomial logit model [6].

A few of researches has applied a heuristic method to solve the optimization problem, such as delay time optimization [9], reducing of block product [10], and reducing travel distance [11]. In this study, the heuristic method that will be used is nonlinear integer programming. It is adopted from [2] and adjusted based on the form of decision variables that has an integer form. The problem of dynamic pricing optimization is solved by nonlinear integer programming to get the global optimal average price with the result that maximum profit will be obtained on the entire range of curves.

This paper is organized as follows. Section 2 describes research methodology including the research approach and data collection. Section 3 shows the modeling framework concerning the formulation of dynamic pricing model and the demand model. Section 4 presents the numerical examples by comparing each demand model and describes the analysis of numerical results. Section 5 summarizes the results of this study and determining future work.

Research Methodology

Research Approach. This study present pricing policy for multiple room types with applying the dynamic pricing model and considering the demand model. The idea of pricing for multiple room types is acquired from [3] because each room has its own characteristics of segments. These characteristics show that each room cannot be generalized as an identical price because the different price leads to different service value expectations and perception among the customers. Hence, we are involving the index of room types to the dynamic pricing model, among others superior and deluxe. The components of dynamic pricing model are adopted from [6] to represent the influence of price along planning horizon on the demand in a certain period. These components model include the average price of product, the number of sales, and variable cost. This model illustrates the relationship the price of each period in the planning horizon on demand of a certain periods. To discover the relationship between price and demand, we refer to the demand models on [6] that are the most extensively used. Fig. 1 shows the research approach according to the other literature and researches.

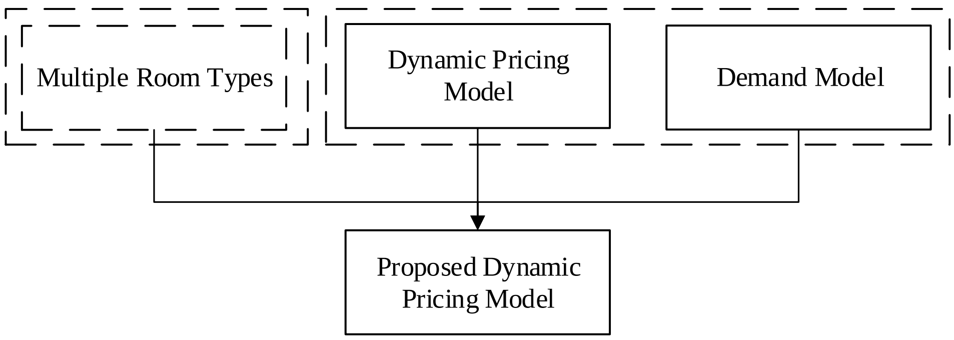

Fig. 1. Research Approach

Data Collection. Data used in this study were obtained from the results of interviews and data collection of room bookings throughout 2017 – 2018 at one of the hotels in Bandung, Jawa Barat, Indonesia. Room booking data through a single OTA channel was used in this study. This following data is taken to serve as input data: historical sales of each room types along 2017 – 2018; historical average room rate of each room types along 2017 – 2018; and variable cost of each room types.

Modeling Framework

In this section, we present an adjusted modeling framework based on the problem of dynamic pricing optimization at the hotel. The proposed model focuses on the application of pricing tools. The modeling framework in this research is illustrated in Fig. 2. The assumptions of the proposed model are: capacity for each type of room and each period are fixed, average room rate constrained based from the highest and the lowest historical average room rate, total profit is not affected by length of stay, and sales of rooms along the planning horizon are fitted based on the demand model.

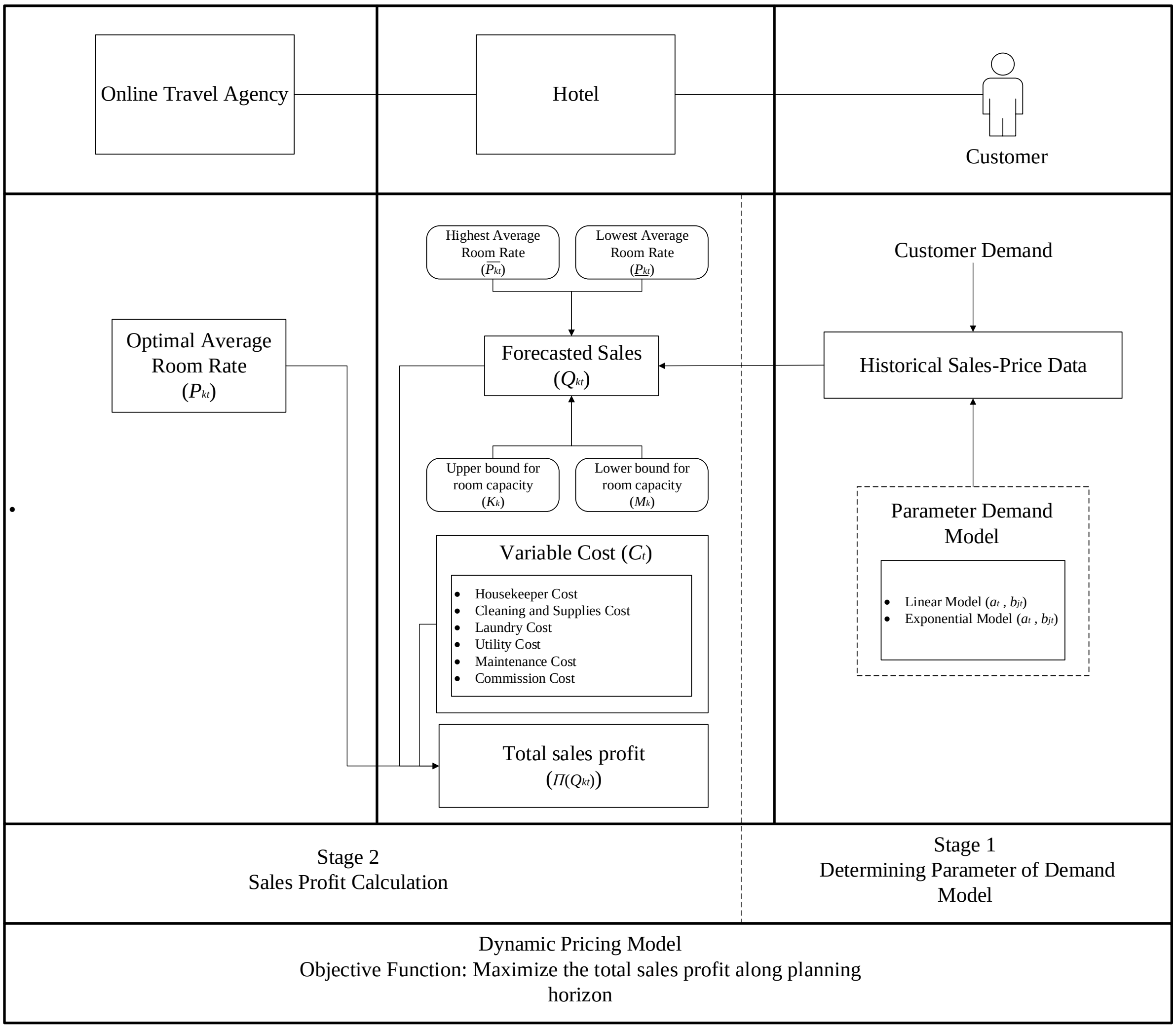

Fig. 2. Modeling Framework

The stakeholders of the real system are hotel, customer, and OTA. The purpose of the first stage is to determine the model parameters and compare the root mean square error of the demand models. In this study, we apply the linear model and exponential model which fitted to the historical sales-price data [6]. The historical sales-price data is obtained from customer demand. In the linear model and exponential model, linear regression is used to obtain the model parameters.

Furthermore, the hotel and OTA involved in the second stage. The aim of the second stage is calculating the sales profit of each room types along the planning horizon ($\Pi(Q_{kt})$). Total sales profit is obtained from the difference between the total sales revenue ($Q_{kt}P_{kt}$) and total variable cost ($Q_{kt}C_{kt}$). The forecasted sales (Q_{kt}) defined as a function of average room rate for each room types and period by substituting the demand model parameters. Forecasted sales should be on integer form, because of the room demand characteristic. Therefore, Q_{kt} and P_{kt} will be estimated with nonlinear integer programming to maximize the total sales profit along the planning horizon. Forecasted sales have a value that not exceeded the room capacity constraint ($M_k \leq Q_{kt} \leq K_k$) and P_{kt} must be in the price band ($\underline{P_{kt}} \leq P_{kt} \leq \overline{P_{kt}}$).

Demand Model Formulation. The demand model in each period obtained from historical sales-price data. The demand model function is determined based on the price dependent relationship to the number of demand/sales [6]. These are two types of demand models used in this study: linear model and exponential model.

1. Linear model
   This model assumes that prices depend linearly on the demand. Linear model formulation is shown in Eq. 1 where a_t is an intercept of linear model that explains the number of customers who are willing to buy the room in period t and b_{jt} is a slope of linear model which defines the effect of prices in period j on demand in period t.

$$Q_t = \psi_t(P_1, P_2, \dots, P_N) = a_t + \sum_{j=1}^{N} b_{jt} P_j \tag{1}$$

2. Exponential model
   In this model, it is assumed that the relationship between price and demand is exponential. The formulation of exponential demand model is shown in Eq. 2. The parameters consist of a_t and b_{jt} are the same as the parameters in the linear model. While the value of e is the basis of natural logarithms (e = 2.718).

$$Q_t = \psi_t(P_1, P_2, \dots, P_N) = e^{a_t + \sum_{j=1}^{N} b_{jt} P_j} \tag{2}$$

Dynamic Pricing Model Formulation. The idea of dynamic pricing is to model the influence of product prices along planning on demand at a certain period. The most important factor on the amount of demand is the price itself [6]. In this study, the objective of dynamic pricing model is to maximize sales profits on the single online travel agency channel. The dynamic pricing model is stated as Eq. 3 that refer to [6] and considering multiple room types.

$$max\ \Pi(Q_{kt}) = \sum_{k=1}^{L}\sum_{t=1}^{N} \Pi\big(Q_{kt} = \psi_{kt}(P_{11}, \dots, P_{kt}, \dots, P_{MN})\big) = \sum_{k=1}^{L}\sum_{t=1}^{N} Q_{kt}(P_{kt} - C_{kt}) \tag{3}$$

The value of $\Pi(Q_{kt})$ means the total sales profit from period t to N of each room types that offered to online travel agency ($k = 1, \dots, L$). Equation 1 describes total sales profits in each period and type of room derived from the multiplication of the number of sales (Q_{kt}) with the profit margin (P_{kt} - C_{kt}). Sales of each room in the period t are within room capacity range of each type of room for online channels. In this case, the amount of capacity or can be called allocation for all types of rooms per period is the same so that the capacity constraint for these problems is shown in Eq. 4. The number of sales must be integer values. By that statement, the model includes an integer bound that stated in Eq. 5.

$$M_k \leq Q_{kt} \leq K_k, \qquad t = 1, \dots, N, k = 1, \dots, L \tag{4}$$

$$Q_{kt}\ is\ integer, \qquad t = 1, \dots, N, k = 1, \dots, L \tag{5}$$

The price band for all room types for each period is determined based on the highest value and the lowest value of historical room rate data. The determination of the price band is intended so that the proposed average room rate will produce profits that are not lower or higher than the historical profit. Eq. 6 shows the price constraint for the average room rate that will be proposed each period.

$$\underline{P_{kt}} \leq P_{kt} \leq \overline{P_{kt}}, \qquad t = 1, \dots, N, k = 1, \dots, L \tag{6}$$

Optimization Algorithm. We present the workflow of an algorithm to elaborating the main step of optimization. This algorithm is used to solve the dynamic pricing problem according to the demand model. We apply nonlinear integer programming to perform the algorithm and obtain the optimal solution. These are the main steps of the optimization algorithm.

1. Obtain the parameter of demand model by using multiple linear regression.
2. Input the parameters from demand model (a_t, b_{jt}) with the lowest root mean square error and the variable cost (C_{kt}) to the objective function.
3. Generate a room rate (P_{kt}) consisting of N and L solution.
4. Select the solution set of room rate that subjecting to capacity constraint, integer bound and price band.
5. Update the total sales profit ($\Pi(Q_{kt})$) that input from step 3 until the maximum objective is meet.

Numerical Examples and Analysis

This experiment is intended to determine the average room rate of deluxe room (k = 1) and superior room (k = 2) for the next four weeks (N = 4). We consider the historical data of sales (room nights) and prices throughout the 26 weeks. The initial stage of the experiment was conducted to determine the demand model for each room types based on the root mean square error value.

$$RMSE = \sqrt{\frac{\sum_{i\epsilon k}(Expected_i - Observed_i)}{K}} \quad (7)$$

Eq. 7 shows the formula of RMSE, where the value of K is the number of sample data. The RMSE value aims to measure the level of accuracy of the results of a model. Table 1 displays the RMSE values of each demand model in each room types.

Table 1. RMSE Value

Room Type	Demand Model	RMSE
Deluxe	Linear	5.47073
	Exponential	5.59113
Superior	Linear	4.03382
	Exponential	4.16241

Based on the results of the RMSE calculation for each demand model, we can see that the linear model produces the best performance. This is because the smaller the RMSE value means that the demand model approaches the optimal policy [7]. Therefore, the parameters in the linear model are input for the profit optimization model using nonlinear integer programming. Table 2 shows the linear model parameters for each room type.

Table 2. Linear Model Parameters of Each Room Types

Deluxe Room					
t	a_t	b_{1t}	b_{2t}	b_{3t}	b_{4t}
1	11.06525	1.67922E-05	-4.55121E-05	6.25390E-05	-3.68797E-05
2	3.60741	-2.53174E-05	5.02677E-05	-3.11485E-05	1.60515E-05
3	9.99326	-1.64401E-05	-2.22002E-05	4.63863E-05	-1.27777E-05
4	-1.52062	-3.00716E-05	-1.05629E-06	3.76617E-05	2.08698E-05
Superior Room					
t	a_t	b_{1t}	b_{2t}	b_{3t}	b_{4t}
1	37.74385	8.74744E-06	-5.14554E-05	3.73707E-05	-5.50743E-05
2	29.33012	-8.37052E-06	2.34505E-05	-6.60623E-05	1.04070E-05
3	40.75649	-7.10526E-05	-3.00008E-05	1.26975E-05	6.45356E-06
4	47.87436	-2.15231E-05	-2.70908E-05	-9.26502E-05	3.87806E-05

We considered parameters for capacity constraint and price band that used to solve profit optimization are presented in Table 3. The component of optimization describes as follows: sales of each rooms are defined as system variable; average room rate (ARR) is defined as decision variable; and the total profit of each room type along the planning horizon is defined as an objective function. Table 4 present the results of optimization using nonlinear integer programming.

Table 3. Parameters for Capacity Constraint and Price Band

Room Type	M_k	K_k	$\underline{P_{kt}}$ (Rp)	$\overline{P_{kt}}$ (Rp)
Deluxe	0	28	$\underline{P_{11}}$ = 311,000; $\underline{P_{13}}$ = 258,750; $\underline{P_{12}}$ = 277,750; $\underline{P_{14}}$ = 258,750	$\overline{P_{11}}$ = 757,500; $\overline{P_{13}}$ = 379,261; $\overline{P_{12}}$ = 427,500; $\overline{P_{14}}$ = 427,500
Superior	0	28	$\underline{P_{21}}$ = 258,750; $\underline{P_{23}}$ = 216,000; $\underline{P_{22}}$ = 226,925; $\underline{P_{24}}$ = 216,000	$\overline{P_{21}}$ = 444,000; $\overline{P_{23}}$ = 361,000; $\overline{P_{22}}$ = 380,000; $\overline{P_{24}}$ = 380,000

Table 4. Optimization Results

t	Number of sales/room nights		ARR (Rp)		Total Sales Profit (Rp)
	Deluxe	Superior	Deluxe	Superior	
1	6	11	345,242	260,098	26,327,868
2	11	24	422,262	317,430	
3	7	18	370,653	220,234	
4	10	28	401,978	379,776	

Furthermore, we validate the model to ensure the purposed model represent the real system. The model is valid if the results show the logical behavior. We build a scenario by changing the value of ARR to analyze the model. The logical behavior should be present the lower profit if the ARR has a different value compared to the optimal result. Table 5 clarifies the validation result by calculate the sales profit between the lowest room rate, the highest room rate, and the proposed average room rate.

Table 5. Validation Result

	Lowest ARR		Proposed ARR		Highest ARR	
	Deluxe	Superior	Deluxe	Superior	Deluxe	Superior
Sales Profit (Rp)	5,169,790	13,130,041	9,340,203	16,987,665	6,782,290	12,182,124
Total Sales Profit (Rp)	18,299,831		26,327,868		18,964,414	
% Deviation		-43.869%		-38.828%		

The result shows that the sales profit is decreasing during the changes of ARR. This is logical because the purchasing power of customers to book a room is low when it is high-priced. Another logical behavior is shown that the sales profit has a lower value because the room selling power is too low or in other words the offered price is not competitive. Based on the previous result, we conclude the proposed model is logical in which the profit turns into non-optimal.

According to the optimization purpose, we compare the historical sales profit with optimized sales profit. The historical profit is taken from the corresponding month. Table 6 shows the increase of profit after the optimization.

Table 6. Sales Profit Comparison

t	Historical Profit (Rp)		Optimized Profit (Rp)	
	Deluxe	Superior	Deluxe	Superior
1	3,089,035	4,438,838	1,426,857	1,877,973
2	1,357,552	3,886,127	3,283,422	5,181,501
3	1,592,233	1,950,416	1,804,813	2,507,679
4	1,126,176	4,770,328	2,825,112	7,420,512
Total	22,210,704		Rp 26,327,868	
% Increase	18.54%			

The optimization can increase the sales profit by 18.54% from historical sales profit. The proposed model gives an option for the front office manager in determining the room rates. The existing pricing policy is subjective, because it is determined based on intuition from the front office manager. This is potentially bad if the front office manager is no longer working at the hotel later. The hotel needs a method to build a pricing policy without relying on the front office manager in order to increase the sales profit or at least be equal to the previous horizon. Our proposed model completes the gap of the method in the existing pricing policy. Furthermore, the average room rate can be adjusted daily based on the certain event such as national holiday, graduation, new year eve, and other events as long as the offered room rate reach the optimal average room rate in a week.

Conclusion

Utilization of the online travel agency channel by setting the room rate is important to maximize the total sales profits. The dynamic pricing can be a strategic tool to optimize the profit by differing prices based on the demand model. The front office manager can adjust the price according to the effect of price along the planning horizon on the demand for certain period by fitting the historical sales-price data to the demand model.

This study has shown the linear model has a minimum root mean square error that represents a better performance rather than the exponential model. This study also shows the proposed average room rate that generates a higher sales profit than the historical sales profit. We also validate the model to confirm the logical behavior of the model result. The validation result shows the profit is decreasing when the ARR changes to be lower or higher. Our proposed model also handles the gap of the method in the existing pricing policy.

In future work, we will consider the length of stay, overbooking, group size, cancellations, and no show up to build a pricing policy. For handling the complex problem, we will consider using the evolutionary algorithm that obtains a more accurate pricing policy. Furthermore, the multinomial logit model can be compared to involve customer behavior when the room rate changes dynamically along the planning horizon.

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