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Price Decision of Digital Parking with Capacity Constraint Based on Reservation System Considering by Changes Modes of Transportation

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ABSTRACT
The advancement in ICT has been providing some advantages for community, including cashless payment system. This is used by the Sidoarjo government to replace subscription parking to the digital one due to criticisms from society. Most people agree that the old parking mode is poor quality and expensive. However, the annual revenue of parking was only 21 Billion Rupiahs in which is so far below from the targeted 102 Billion Rupiahs. Therefore, for transparency, the parking should be automated for increasing the regional income. However, the implementation of digital parking should be organized well to maximize the income through parking rates. The shifting transportation mode to the online has to be limited in the cars and motorcycles usage to understand the public's preference. Therefore, parking prices will be determined by two ways including online channel and offline channel. Both of them apply game theory, a mathematical approach to formulate a strategy involving decision-makers. This scheme is Stackelberg Leadership and Vertical Nash. Then, the results obtained will be utilized for determining the best scenario providing much profit. The results show that the Vertical Nash Scenario which provides the most of Rp 1.243.140 with more online channel demand than offline channels and online channel prices are cheaper than offline channels.

Keywords—*cashless payment, digital parking, game theory, ICT*

I. Introduction

The development of information and communication technology is rapidly making internet users more. Based on survey conducted by the Association of Indonesia's Internet Service Provider (APJII) and Polling Indonesia in 2018, 64,8% of Indonesia population surf on internet. In the last few years, cashless transactions have experienced a growing trend [1]. Similarly, online payment shows the same trend for technology-literate people to reduce the hassle of using cash. This encourages the Sidoarjo government to implement online parking channels (digital parking). To support this policy, parking online channels must still be accompanied by an offline channel (traditional parking). This is called Dual-Channel Supply Chain (DCSC) as it has a single and double route having the same direction and destination [2].

There are several challenges that DCSC have to face to maximize its profit, which include: online pricing, conventional store pricing, and wholesale pricing [3]. A conceptual model of DCSC is shown in Fig. 1. Supplier may cooperate with intermediary store (offline channel) to sell his products and services or take the advantage of internet features to directly fulfil customers' demand (online channel). Some customers may have different sensitivity to switch between online and offline channel as each channel appeals in a distinct way [4].

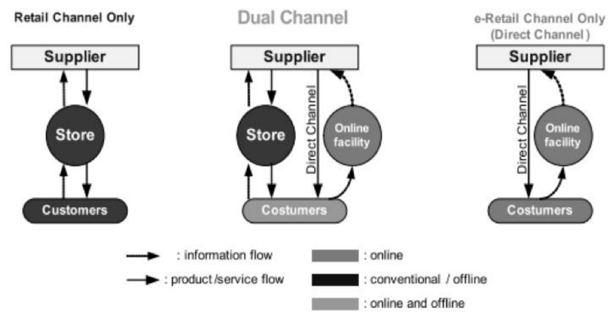

Figure 1. DCSC Structure Compared to Retail Only (left) and E-Retail Only (right)

A game theory approach with two scenarios, namely Stackelberg Leadership and Vertical Nash, is applied to determine the dual-channel price. Stackelberg Leadership is a non-cooperative game where the price is decided sequentially without collaboration between players, while Vertical Nash is a cooperative game where the price is decided jointly between companies. In this study, capacity is used as one of the main constraints. Also, changes in transportation modes will be added to be one of the

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variables in determining parking demand in the dual-channel service supply chain.

Based on the explanation above, this study aims to obtain optimal parking prices for car and motorcycle on the online and offline channels by comparing prices obtained from the Stackelberg Leadership and Vertical Nash scenarios. Scenarios that provide a lot of profit will be selected and used as a reference for pricing.

II. Literature Review

A. Dual-Channel Supply Chain

Dual-channel marketing allows companies to build relationships with customers for a long time because it can offer a variety of information, products, services, and support to customers through dual-channel so that companies can find out the company's strategy and tactics to help customers get information [5]. The dual-channel strategy outperforms the single-channel strategy and manufacturers benefit from a strategy of having higher margin and mark-up profits. On the other hand, retailers' profits are shown to decrease due to decreased demand because customers switch from offline to online channels so offline channels require better service [6]. Dual-channel management involves competition between channels, pricing strategies, and supply chain coordination in dual-channel [7]. The demand function in DCSC is assumed to be [8]:

$$D_o = \rho\, D_{max} - \beta_o\, P_o + \gamma_{os}\, P_s \tag{1}$$

$$D_s = (1-\rho)\, D_{max} - \beta_s\, P_s + \gamma_{so}\, P_o \tag{2}$$

where Do is customer demand in the online channel and Ds is customer demand in the offline channel. ρ is the percentage share of customers who prefer to purchase online channel and D max is maximum demand when the price is set near unit cost. β o is denoted price sensitivity constant in the online channel and β s is price sensitivity constant in offline channel. In the dual-channel supply chain, there is cross channel, γ os is cross-price sensitivity for online channel to offline channel and γ os is cross-price sensitivity for offline channel to online channel. Ps is the price in the offline channel and Po is the price in the online channel.

B. Pricing Decision

Pricing must decide appropriately to get optimal feedback as well as taking into account the needs and abilities of consumers as the main target. The pricing strategy has the goal of setting optimal prices by maximizing profits, maximizing the number of units sold, and others [9]. The profitability and cost-effectiveness of companies are very much attached to the pricing strategy regarding the internal capacity, skills, and advantages of their company towards competitors. Determination of a lower price can reduce profits because a large sales volume may not necessarily get a large profit margin as well [10]).

Companies that look for prices based on customer value and set prices high logically in the context of their markets still operating, tend to generate large profits than their competitors who adopt competitive pricing strategies by setting lower prices. The higher the use of value-based pricing strategies that companies add innovation to new products so that the greater the possibility of increasing the company's profit margins [10]).

C. Game Theory

Game theory is a mathematical study of interactions between independent agents or strategic interactions between rational individuals [11]. Game theory is used as a model of decision making with multiplayer situations that choose strategy [12]. The characteristics of the game are divided into two, namely cooperative and non-cooperative games. Cooperative game allows players to communicate and coordinate to choose the best strategy, therefore the solution may not be optimal for each player but the benefits for each player are more than his ability. Non-cooperative game means there is no communication and interaction between players. Game theory scenarios used in this research are:

a. Stackelberg Leadership Scenario Stackelberg's scenario, this model is considered as one of the producers whose position is quite strong in the market, thus making its competitors to follow all the rules that have been set. Stackelberg Leadership Scenario is a scenario in which the determination of the value of variables is sequential. The follower determines the price in advance for profit maximization then the leader passes the price determination by referring to the follower price which is used as a parameter for determining prices. In the Stackelberg scenario, the leader is a company that has been in the market for a long time or a strong company position, while the followers are new companies or new players in the market.
b. Vertical Nash Scenario This scenario is different from the Stackelberg Leadership scenario because the pricing is decided simultaneously by several players both online and offline channel. The price determination is decided together to get the maximum profit.

III. Materials and Methods

The development of the model to find the optimal price uses two scenarios, namely Stackelberg's leadership and Nash's vertical scenario. The development phase of the model begins with the preparation of a model framework consisting of demand functions for online and offline channels, constraint functions, and objective functions aimed at maximizing profits in online and offline channels after the model is verified and validated at LINGO. If it is not verified and validated, then review the model that was created.

A. Model Structure

The dual-channel supply chain structure generally consists of sellers, multiple channels, and buyers for manufacturing. In this study, the double channel is developed into a double channel service supply chain for parking management managed by the Department of Transportation and the Sidoarjo Regency Government which will be called Parking Management. Developed dual-channel services namely offline and online channels. This study uses two modes of transportation consisting of two-wheeled vehicles (motorcycles) and four-wheeled vehicles (cars). The research begins by solving problems that are carried out by reviewing journals that discuss preexisting problems.

After that, develop a model that starts with parking management which is divided into online and offline channels that have parking fees. Determination of the rate decision will see the movement of lost demand and move the price compilation up and down for each channel. Also, observe changes in motorcycle users and compilation of cars that are changing about large requests that are lost and moved.

Next, use two scenarios in game theory, namely Stackelberg Leadership and Vertical Nash Scenarios to determine the price of parking online and offline channels by looking at the demand to switching channels. Scenarios that provide benefits that will be chosen to be taken as a basis in setting parking prices. Profits from the second channel will be incorporated into the total Regional budget revenue from the Sidoarjo Government from the parking sector. Structure model for car shows in Fig. 2 and for motorcycle shown in Fig. 3.

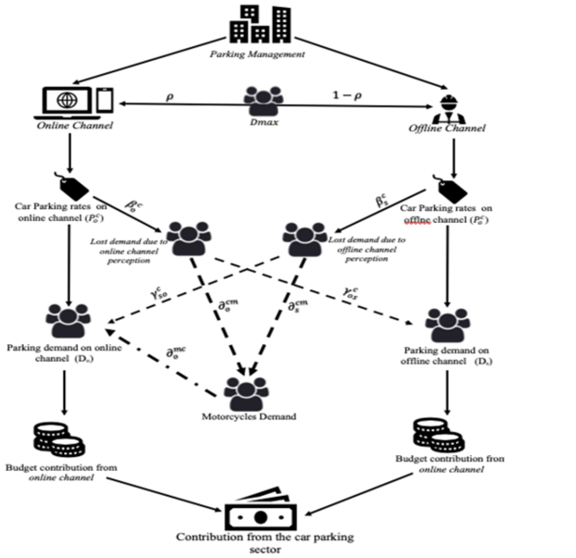

Fig. 2. Structure model for cars

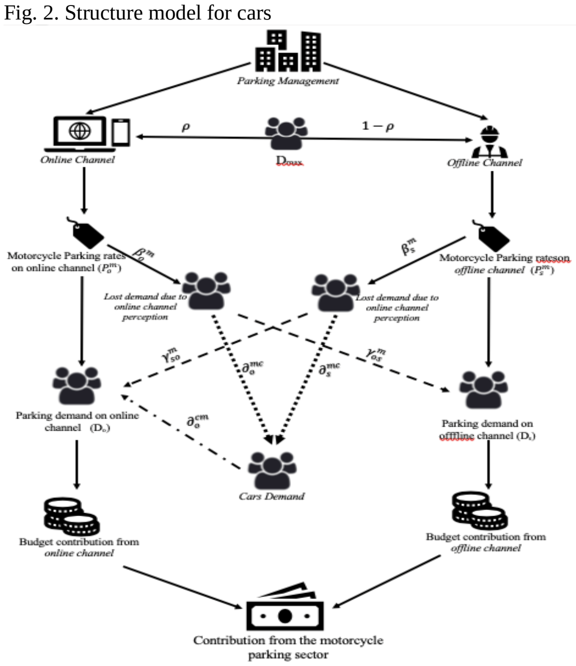

Fig. 3. Structure model for motorcycle

B. Demand Function

Car demand on the online channel

$$D_o^c = \rho D_{max} - \beta_o^c P_o^c + \gamma_{so}^c P_s^c + (\delta_o^{cm} + \delta_s^{cm}) P_o^m \quad (3)$$

Car demand on the offline channel

$$D_s^c = (1-\rho) D_{max} - \beta_s^c P_s^c + \gamma_{so}^c P_o^c \quad (4)$$

Motor demand on the online channel

$$D_o^m = \rho D_{max} - \beta_o^m P_o^m + \gamma_{so}^m P_s^m + (\delta_o^{mc} + \delta_s^{mc}) P_o^c \quad (5)$$

Motor demand on the offline channel

$$D_s^m = (1-\rho) D_{max} - \beta_s^m P_s^m + \gamma_{so}^m P_o^m \quad (6)$$

C. Objective Function

Online Channel Profit

Online Channel Profit

$$\pi_o=(P^c_o.D^c_o+P^m_o.D^m_o) - (LC+MC) \quad (7)$$

Offline Channel Profit

$$\pi_s=(P^c_s.D^c_s+P^m_s.D^m_s) - (LC+MC) \quad (8)$$

Dual Channel Supply Chain Total Profit

$$\pi_s=\pi_o+\pi_s \quad (9)$$

For scenario of Stackelberg Leadership using two objective functions, there are equation (7) dan (8) because the determination of the value of variables is sequential. Vertical Nash using equation (9) because the determination of the value is simultaneous.

D. Constraint Function

Prices on the online channel (P^c_o dan P^m_o) must be smaller or equal to the Prices on the offline channel (P^c_s dan P^m_s).

$P^c_o \leq P^c_s$ (10)

$P^m_o \leq P^m_s$ (11)

Online and offline channel parking demand must be smaller than the maximum parking space capacity (C^{max}_c & C^{max}_m) which has been provided for each channel.

$D^c_o+D^c_s \leq C^{max}_c$ (12)

$D^m_o+D^m_s \leq C^{max}_m$ (13)

Online channel demand for motorcycles and cars (D^m_o & D^c_o) must be greater or equal to demand for offline channels for motorcycles and cars (D^m_s & D^c_s).

$D^m_o \geq D^m_s$ (14)

$D^c_o \geq D^c_s$ (15)

The maximum price for each decision variable is limited so that the price obtained is not far from the prices that have been circulated.

$P^c_o \leq 4.000$ (16)

$P^m_o \leq 2.000$ (17)

$P^c_s \leq 5.000$ (18)

$P^m_s \leq 3.000$ (19)

Demand for all types of vehicles in offline and online channels must be integers.

@gin (D^c_o) (20)

@gin (D^m_o) (21)

@gin (D^c_s) (22)

@gin (D^m_s) (23)

E. Variable Notation

In the Dual-Channel Supply Chain (DCSC), there are two channels namely online (o) and offline (s) channels and there are also two types of vehicles namely motorcycles (m) and cars (c). π is denoted as profit, ρ is denoted as the percentage of customers who choose the online channel, D is denoted as demand, and (1- ρ) is the number of customers who choose the offline channel. P is the price. In DCSC there is a variable β which means sensitivity when there is a perception of price changes from online and offline channels. Also, there is a variable γ which means cross-channel sensitivity when the customer moves from online to offline (os) or from offline to online channel (so).

The difference between DCSC and this research is to consider changes in transportation modes by consumers so that they can determine consumer preferences in the use of a car or motorcycle. Changes in transportation modes are denoted by δ where the customer moves from the motorcycle to the car (mc) and car to the motorcycle (cm). In addition, the main barrier is Capacity (C). Each type of vehicle has a maximum capacity, 200 for cars (c), and 250 for motorcycles (m). Profit calculation will be reduced by MC which is Maintenance and utility cost (variable cost) and LC is Labor cost (fixed cost).

IV. Result

The parameters used in the model are obtained from the results of data collection through online and offline questionnaires. Table 1 and Table 2 are the demand for motorcycles and car parking. Values of β, γ, and δ are obtained from demand divided by price. Table 3 is the research parameter and table 4 and table 5 are price and demand for dual channel after using the parameter in table 3.

TABLE 1. Motorcycles Parking Demand Based on Price

Harga	D^m_o	D^m_{os}	D^{mc}_o	D^m_s	D^m_{so}	D^{mc}_s
2.000	21	15	6	9	7	2
3.000	35	27	8	18	13	5
4.000	5	5	0	2	2	0
5.000	38	29	9	15	11	4
6.000	2	2	0	1	1	0

TABLE 2. Cars Parking Demand Based on Price

Harga	D^c_o	D^c_{os}	D^{cm}_o	D^c_s	D^c_{so}	D^{cm}_s
2.000	2	2	0	2	2	0
3.000	2	2	0	1	1	0
4.000	43	40	3	19	14	5
5.000	4	3	1	3	3	0
6.000	13	10	3	4	3	1
7.000	4	4	0	1	1	0
8.000	1	1	0	0	0	0
9.000	30	15	15	15	13	2
10.000	2	2	0	2	2	0

TABLE 3. Research Parameter

No	**Parameters**	**Value**	**No**	**Parameters**	**Value**
1	ρ	0,6917	10	γ^m_{so}	0,00433
2	D_{max}	200	11	γ^c_{os}	0,00143
3	C^{max}_c	200	12	γ^c_{so}	0,00280

4	C_m^{max}	250	13	δ_o^{cm}	0,00267
5	β_o^c	0,00860	14	δ_o^{mc}	0,00167
6	β_s^c	0,00380	15	δ_s^{mc}	0,00150
7	β_o^m	0,01160	16	δ_s^{cm}	0,001
8	β_s^m	0,00600	17	MC	10.000
9	γ_{os}^m	0,00125	18	LC	17.500

Before conducting a numerical experiment, data verification and validation are performed. The results are appropriate so that it can proceed to numerical experiments. Table 2 and table showed the price and demand for motorcycles and cars in the dual channel when using parameters in Table 1.

TABLE 4. PRICE FOR DUAL-CHANNEL

Scenario	P_o^m (Rp)	P_o^c(Rp)	P_s^m(Rp)	P_s^c(Rp)
Stackelberg Leadership	2.000	4.000	2.887	4.963
Vertical Nash	1.906	3.974	2.819	4.943

TABLE 5. DEMAND FOR DUAL-CHANNEL

Scenario	D_o^m	D_o^c	D_s^m	D_s^c
Stackelberg Leadership	136	116	53	54
Vertical Nash	137	116	53	54

TABLE 6. DUAL-CHANNEL SUPPLY CHAIN PROFIT

Scenario	π_o (Rp)	π_s (Rp)	π_{DCSSC} (Rp)
Stackelberg Leadership	708.500	393.504	1.102.004
Vertical Nash	694.606	388.829	1.083.435

Table 6 shows the results of the profit calculation for both scenarios. Numerical experiments have been carried out and sensitivity analyzes done by changing the values of β, γ dan δ by the data obtained using two scenarios. Results that provide optimal values will be used as new parameters to find other optimal values. Thus, getting two new parameters from the Stackelberg Leadership Scenario (P1) and Vertical Nash (P2).

TABLE 7. PRICE FOR DUAL-CHANNEL USING P1

Scenario	P_o^m (Rp)	P_o^c(Rp)	P_s^m(Rp)	P_s^c(Rp)
Stackelberg Leadership	2.000	4.000	2.640	4.573
Vertical Nash	1.992	3.825	2.574	4.914

TABLE 8. DEMAND FOR DUAL-CHANNEL USING P1

Scenario	D_o^m	D_o^c	D_s^m	D_s^c
Stackelberg Leadership	159	114	69	66
Vertical Nash	155	116	69	65

TABLE 9. DUAL-CHANNEL SUPPLY CHAIN PROFIT USING P1

Scenario	π_o (Rp)	π_s (Rp)	π_{DCSSC} (Rp)
Stackelberg Leadership	746.500	456.500	1.203.000
Vertical Nash	725.082	469.559	1.194.641

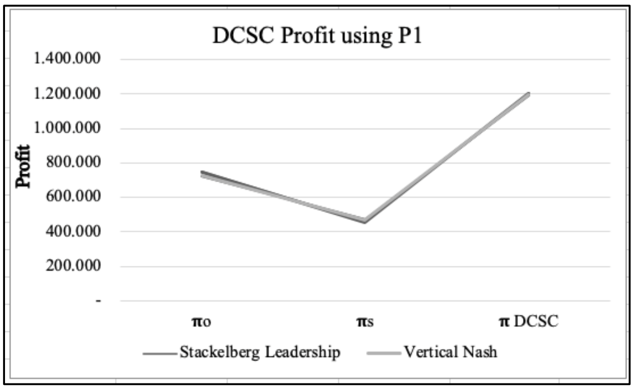

Fig. 4. Dual channel supply chain profit using P1

Table 9 is obtained from multiplications table 7 and table 8 which consist of motorcycles and cars for online and online channels. Then the online channels profit (π_o) consisting of motorcycles and cars are added up and *subtracted* by labour cost of Rp 15.000 and the maintenance cost of 10,000 as well as by the offline channel. Figure 4 is a visualization from table 9.

TABLE 10. PRICE FOR DUAL-CHANNEL USING P2

Scenario	P_o^m (Rp)	P_o^c(Rp)	P_s^m(Rp)	P_s^c(Rp)
Stackelberg Leadership	2.000	4.000	-	-
Vertical Nash	1.942	3.940	2.912	4.462

TABLE 11. DEMAND FOR DUAL-CHANNEL USING P2

Scenario	D_o^m	D_o^c	D_s^m	D_s^c
Stackelberg Leadership	181	116	-	-
Vertical Nash	181	116	67	66

TABLE 12. DUAL-CHANNEL SUPLLY CHAIN PROFIT USING P2

Scenario	π_o (Rp)	π_s (Rp)	π_{DCSSC} (Rp)
Stackelberg Leadership	798.500	-	798.500
Vertical Nash	781.045	462.095	1.243.140

Table 12 is obtained from the multiplication table 10 and table 11 which consists of motorcycles and cars for online and online channels. Then the profits of online channels consisting of motorcycles and cars are added up and reduced by labor costs of IDR 15,000 and maintenance costs of 10,000 as well as by offline channels. Fig. 5 is a visualization of table 12.

Table 9 and Table 12 are compared to see which parameters and scenarios provide the biggest profits. The results obtained are parameter 2 has the highest return from the Vertical Nash Scenario with the price of motorcycle and car parking in the online channel are Rp 1.942 and Rp.3.940. The price for the offline channel for motorcycles and cars is Rp 2.912 and Rp 4.462. Demand for motorcycle and car parking in the online channel are 181 and 116, while in the offline channel are 67 units dan 66 units with DCSC profit Rp 1.243.140.

V. Discussion and Conclussion

This study has a difference because it considers changes in transportation modes in the dual-channel supply chain and in the Stackelberg Leadership scenario. Generally, followers in the Stackelberg Leadership scenario have a higher price than the leader because parking on the online channel will be used as a substitute for parking on the offline channel. Therefore, the price of the online channel must be cheaper than that of the offline channel as the attraction of the people switching channels.

The results of numerical experiments show that the Vertical Nash scenario has more profit than the Stackelberg Leadership scenario. In dual-channel, online channels have more profit than offline channels. This is because the demand for the online channel is more than the offline channel. The price generated by the online channel is smaller than the offline channel. Also, the prices in the Stackelberg Leadership scenario are almost always higher when compared to the Vertical Nash scenario. Demand generated by online channels is always greater than offline channels for both scenarios.

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