Expert System and Classical Probability for Setting up Hotel's Dynamic Price Level: A Case of Four-Star Hotel in Bali

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***Abstract*—Dynamic price in the hospitality industry is a term to indicate the selling prices of hotel rooms that can be changed at certain times dynamically. Based on the author's observation at Mercure Bali Nusa Dua Hotel, the process of deciding the dynamic price level in the hotel is greatly influenced by individuals hence highly subjective, therefore prone to inconsistent pricing mechanism and decision which in turn affects the revenue of the hotel. In this paper, the authors propose expert systems combined with classical probabilities to solve the problem. Fuzzy logic and forward chaining are used to form inference rules that produce a knowledge base of the system. Next, the classical probability is used to calculate the confidence level of the conclusion. The algorithms are tested with the price level of the hotel in 2018. The result shows an initial accuracy of 73.66% with average deviations of 0.36. By classifying the deviations with the rule-based classifier method, the accuracy increases to 90.77%. It is shown that the difference between the actual data is small. The proposed technique potentially increases the hotel's revenue. The usability score of the proposed system is 91.88, indicating the usability of the proposed system is grade A and excellent rating.**

***Index Terms*—Classical probability, dynamic price, expert system, forward chaining, fuzzy logic**

I. Introduction

Bali is a popular destination both for holiday and business purposes. In 2017, Bali was nominated as the world's best tourist destination by TripAdvisor, the world's largest travel sites [1] and had received numerous awards to recognize the excellence of the island offered for its visitors. In February 2019 alone, the total visitors reached 400,000 people [2]. Besides, Bali is also a popular venue for hosting international level meetings. For example, UNFCC, UN, IMF, ASEAN, to name a few, have conducted meetings in Bali. To accommodate this development, Bali has become a place with the rapid development of tourism facilities. For example, Bali has about 4,874 hotels [3], [4]. Such a high number of hotel rooms lead to tight competition among hoteliers. One strategy adopted by the hotel management to achieve sales is a dynamic pricing strategy. This strategy is effective to maintain its price to remain competitive [5], [6].

In the hospitality industry, dynamic price is a term to indicate the selling prices of hotel rooms that can be fluctuated at certain times dynamically. Dynamic prices are determined by taking into account hotel occupancy rates and customer demands, both current and future [7] to maximize the hotel revenue. The dynamic price of a hotel is represented in levels that widely known in the industry as rate level or price point. Based on our observations at Mercure Bali Nusa Dua Hotel, the process of deciding dynamic price level of the hotel was greatly influenced by individuals hence highly subjective and therefore prone to inconsistent pricing mechanism and decision which in turn affects the revenue of the hotel [8].

An expert system is a computer-based system intended to emulate expert knowledge in terms of decision-making abilities [9]-[14]. Expert system characteristics are making conclusions based on available information [9], [10], [14]-[20], generating consistent conclusions [13], and it serves as smart mentors who offer proper reasoning process [12], [13]. For instance, an expert system in [9] was implemented to identify diseases of chili plants. It provides farmers with information and instructions on how to recognize and handle chili plant diseases based on expert knowledge. The expert system in [10] was used to identify bean plant diseases. The system assists farmers to diagnose the disease, which attacks their plants and provides information to handle it. Also, the expert system was used to diagnose the damage of city car common in Indonesia [15]. The system provides information and instructions to assist the reparation of the damaged vehicles. These papers show that the expert system has been widely used in decision-making problems. It provides information and assistance to solve problems based on the knowledge of an expert. Moreover, since it is a computer-based, the conclusions generated by the systems are consistent.

One of the key aspects of the expert system is the inference engine, which contains the reasoning mechanism and the thinking pattern of an expert to analyze problems and to obtain the best possible conclusion. Forward chaining is one of inference method

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of the expert system [9], [10], [15], [17]-[20]. The method is effectively a search method or forward tracking technique, which starts with existing information and rules to produce a conclusion or goal [9]-[11], [15]. Forward chaining is a data-driven method; hence, suits the requirement of an expert system which relies on conditions or facts.

The conditions or facts faced by an expert system may be hard to define. For instance, age and temperature could not be determined with yes or no answer. Therefore, this type of facts needs a different approach when implemented with an expert system. Fuzzy logic is an approach to represent values or data that cannot be represented precisely in firm value (crisp) or into a Boolean value (true or false) [16], [21], seemingly can be used to manage those kinds of facts. By using fuzzy logic, conditions, or facts can be grouped into a fuzzy set that contains a specific range of value. For example, the age of people could be divided into a fuzzy set of young and old.

The certainty of the conclusion generated by the expert system is measured using a term called the confidence level. The parameter is based on a probability method with a classical approach, known as classical probability. This technique has been implemented in [9] and [20]. The method has been used along with the forward chaining method to calculate the certainty of conclusions obtained from the forward chaining inference [22], [23].

When developing an expert system, it is useful for both user and software developer to get some ideas on whether the expert system being developed can be considered good or bad. One approach to this assessment is to perform a system usability test. A usability test is used to gather user opinion regarding the usability offered by the system. One standard method for this purpose is the system usability scale (SUS). System’s usability score is calculated based on the questionnaire presented to the prospective users [24]–[26]. At the end of the test, the score is compared with the SUS assessment chart to find out the acceptability range, grade scale, and adjective rating of the proposed system.

This study proposes an expert system using forward chaining and fuzzy logic to assist the determination of the dynamic price level of hotel and concept of classical probability to assess confidence level of the conclusion generated by the proposed system. The objective of this paper is to develop an expert system as a decision support system to assist the management of the hotel in setting up a dynamic price level consistently and facts-based in improving the hotel’s revenue.

II. Research Methods

This section explains the systematic plan of the research and flowchart of the proposed system.

A. Research Schematic Plan

The research reported here is conducted in several stages, as described in Fig. 1.

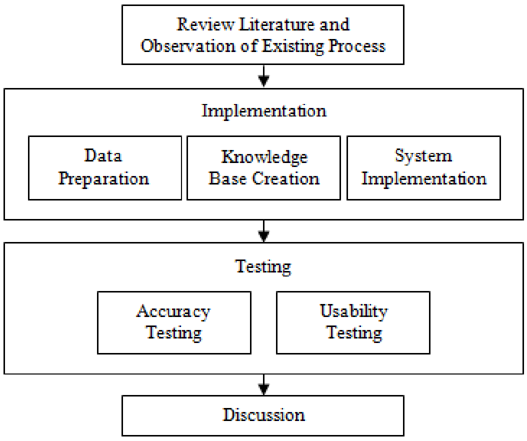

Fig. 1. Schematic of methodology

The first stage is to review the existing process of the dynamic price level of the hotel, including documents reviews. The reviews find that the determining factors of dynamic price level at Mercure Bali Nusa Dua Hotel are occupancy rate, pickup public, weekend, event period, public holiday, competitor occupancy, and competitor price. Occupancy rate represents the percentage of rooms that already occupied. Pickup public represents walk-in guest reservations or direct booking on the hotel's official sites. Weekend means the weekend determined by the hotel. Event period represents whether a special event or events take place in the hotel or Nusa Dua area. Public holiday stands for a public holiday period determined by the hotel’s management. Competitor occupancy means a comparison of hotel occupancy rate with competitors. Competitor price represents a comparison of the hotel's room rate with competitors.

The implementation stage consists of three main processes; the first is data preparation. Here, the datasets and codes representing parameters and conclusions are compared, and the fuzzy logic technique is applied to produce fuzzy sets for parameter’s conditions and conclusions. The second is the knowledge base creation; here, the inference rules are created. Since forward chaining is used, the rules are made based on parameters and its fuzzy sets conditions to achieve a conclusion. Further, the classical probability is used to calculate the confidence level of the conclusions using the following equation [9].

$$\text{Confidence Level} = \frac{\sum \text{"Yes" Answer}}{\sum \text{Total Questions}} \times 100\% \quad (1)$$

The confidence level is a term used to indicate the certainty of the system’s conclusion. Finally, the third is the system implementation; here, a graphical user interface is developed to enable the user of the system to interact with the proposed system.

The next stage is testing the proposed expert system. The test consists of two parts, accuracy test and usability test. The accuracy of the system is measured by comparing the results with datasets. In this test, there are two parameters: the percentage of accuracy and the mean absolute deviation (MAD) value. The percentage of accuracy indicates how many percent of the system's results are matched with actual data in datasets. The MAD value shows the deviations that occur between the system's results and real data in datasets.

System usability is measured by using the SUS method. A set of questionnaires is designed to collect the feedback of prospective users. The answer is processed by using simple statistics parameters. The result is compared with the SUS assessment chart, as shown in Fig. 2.

In the final stage, we discuss the test results of the proposed system. The system's result and the actual hotel price level will be compared to find whether the proposed systems affect the hotel's revenue. The usability test is compared with the SUS assessment chart to find out the acceptability range, grade scale, and adjective rating of the proposed system [24]-[26].

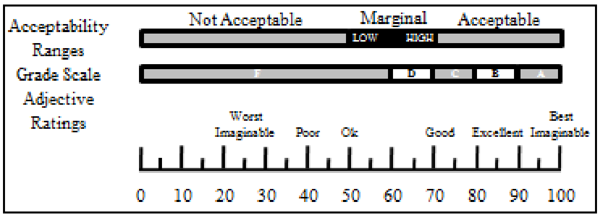

Fig. 2. SUS method assessment chart

B. System Flowchart

The flowchart of the proposed expert system is described in Fig. 3.

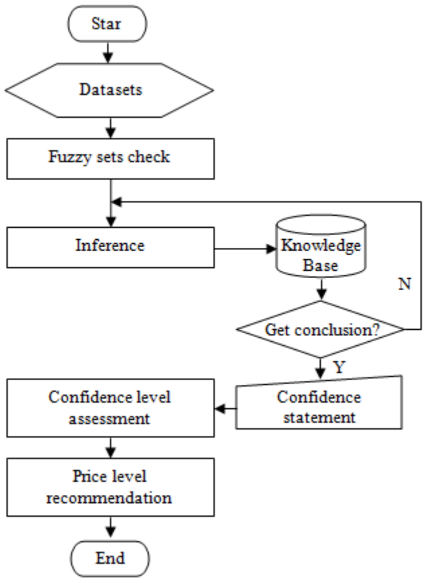

Fig. 3. System's flowchart

The algorithm starts with the preparation of data for each of the parameters and then follows by fuzzy sets check. Next is the inference process; each known condition of the parameter is checked on the knowledge base to find conclusion based on the conditions. When a conclusion is obtained, the system displays some must-answered questions to measure the confidence of each of the known conditions. Then based on the answers, the system will display price level recommendation. It contains the conclusion obtained through the inference process along with the confidence level of the conclusion.

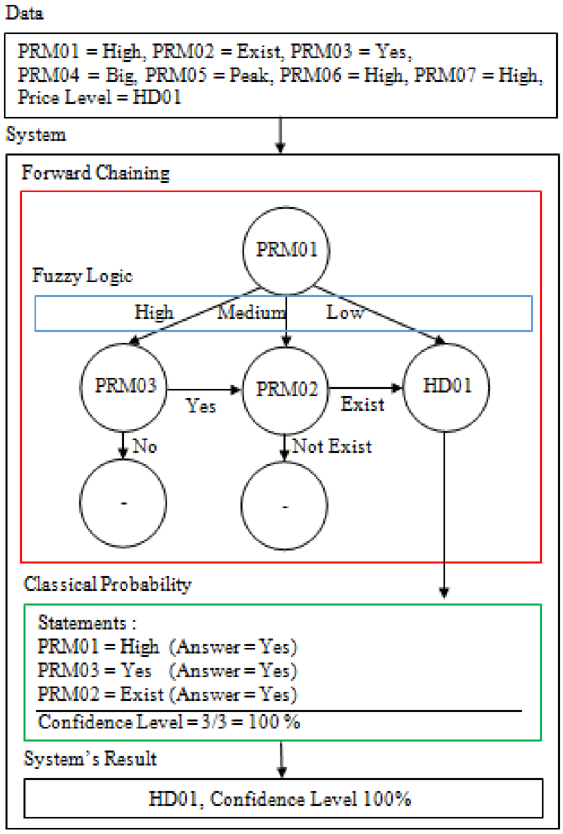

Fig. 4. System's plan

Fig. 4 shows three methods that we propose to implement the expert system. First, the fuzzy sets are produced by applying the concept of fuzzy logic to the data of each parameter. Next, the forward chaining method is used to obtain a conclusion based on the parameter's fuzzy set and inference rules. Finally, the classical probability method is used to calculate the confidence level of the conclusion.

III. Implementation

This section explains the implementation of the proposed expert system, which consists of data preparation, knowledge base creation, and system implementation.

A. Data Preparation

Datasets used for this implementation is obtained from Mercure Bali Nusa Dua Hotel. The data is sourced from the hotel's reservation reports of 2018, which consists of 322 datasets. The parameters are listed in Table I.

TABLE I. PARAMETERS

No.	Parameter
1	Occupancy
2	Pick up public
3	Weekend
4	Event period
5	Public holiday (PH)
6	Competitor occupancy
7	Competitor price

TABLE II. FUZZY SETS OF PARAMETERS

Parameter	Code	*Fuzzy Set*	Scale
Occupancy	prm01	High	> 86 %
		Medium	65% > Occ > 86%
		Low	< 65%
Pick Up Public	prm02	Exist	There is pick up public
		Not Exist	No pickup public
Weekend	prm03	Yes	Friday and Saturday
		No	Sunday – Thursday
Event Period	prm04	Big	International *event*
		Medium	National *event*
		Small	No *event*
Public Holiday (PH)	prm05	Peak	Christmas and new year
		High	Chinese New Year and Eid
		Low	Another PH
		Not PH	Not PH
Comp. Occupancy	prm06	High	> Competitor
		Medium	2.1% > Comp. > 2.1%
		Low	< Comp.
Comp. Price	prm07	High	> Comp.
		Low	< Comp.

TABLE III. FUZZY SETS OF CONCLUSIONS

Description	*Fuzzy Set*	Scale
Conclusion	I	Price Level 1 – 3
	II	Price Level 1
	III	Price Level 2 – 4
	IV	Price Level 4 – 6
	V	Price Level 2
	VI	Price Level 5 – 7
	VII	Price Level 7
	VIII	Price Level 8

The possible conditions of each parameter are grouped by using fuzzy logic to produce fuzzy sets, as shown in Table II. The same process is applied to the conclusion used, which is the price level used by the Mercure Bali Nusa Dua Hotel. The fuzzy set of the conclusion is shown in Table III.

B. Knowledge Base Creation

The reasoning process is implemented by using forward chaining method in which the inference rules are formed based on conditions of each parameter. There are 144 inference rules to accommodate all fuzzy set conditions from the parameters shown in Table II. One example of the rule is as follows:

"If prm01=High and prm02=Exist and prm04=Medium and prm05=Peak Then I."

This rule shows that if the occupancy rate is more than 86%, and there is pick up public, and there is a national level event being held and coincides with public holidays during a peak season, then the price level is the price level of group I. The next step is to obtain an exact conclusion from the price level group based on the occupancy rate. For instance, in the rule above, if the actual occupancy rate is between 91% and 95%, then the system recommends the price level 2.

Table IV shows the occupancy rate conditions which are used to obtain an exact conclusion from a price level group.

The confidence level of the conclusion is calculated based on the answers given by users. The questions are listed in Table V. For instance, in the rule above, the system has recommended price level 2 while showing the following questions:

TABLE IV. THE SCALE OF CONCLUSION FUZZY SETS

Fuzzy Set	Condition	Scale
I	Occ > 95%	Price Level 1
	91% < Occ < 95%	Price Level 2
	86% < Occ < 90%	Price Level 3
II	N/A	Price Level 1
III	Occ > 97%	Price Level 2
	95% < Occ < 97%	Price Level 3
	86% < Occ < 94%	Price Level 4
IV	81% < Occ < 86%	Price Level 4
	73% < Occ < 80%	Price Level 5
	65% < Occ < 72%	Price Level 6
V	N/A	Price Level 2
VI	81% < Occ < 86%	Price Level 5
	73% < Occ < 80%	Price Level 6
	65% < Occ < 72%	Price Level 7
VII	N/A	Price Level 7
VIII	N/A	Price Level 8

TABLE V. QUESTIONS FOR CONFIDENCE LEVEL ASSESSMENT

Questions	Answer
Are you sure the occupancy rate is high?	Yes/No
Are you sure there is pick up the public?	Yes/No
Are you sure there is a national event held?	Yes/No
Are you sure the public holiday is in peak season?	Yes/No
Are you sure the actual occupancy rate between 91%-95%?	Yes/No

For example, let us assume from those five questions presented to the user, the total number of "Yes" answer is three, then using equation (1) the confidence level is obtained as follows:

$$\text{Confidence Level} = \frac{3}{5}100\% = 60\%$$

Therefore, for conditions which meet the inference rule, the occupancy rate, and the answers of questions in Table V, the system recommends the price level 2 with 60% confidence level.

C. System Implementation

The system graphical user interface (GUI) is created by using the PHP programming language with Laravel 5.8 framework and MySQL database. The GUI is designed to directly show the question and answer pages as the home page.

Fig. 5 shows parts of the questions given to users. The answer to each question will be the basis for the inference process to find the most suitable rule to obtain the conclusion.

Fig. 6 shows temporary conclusions generated based on the user's answer. Here, users are prompted with Yes/No questions. Fig. 7 shows the conclusion and confidence level.

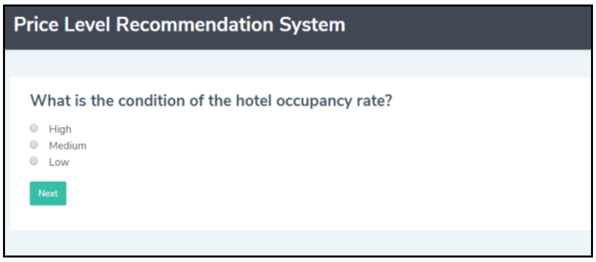

Fig. 5. GUI for question and answer page

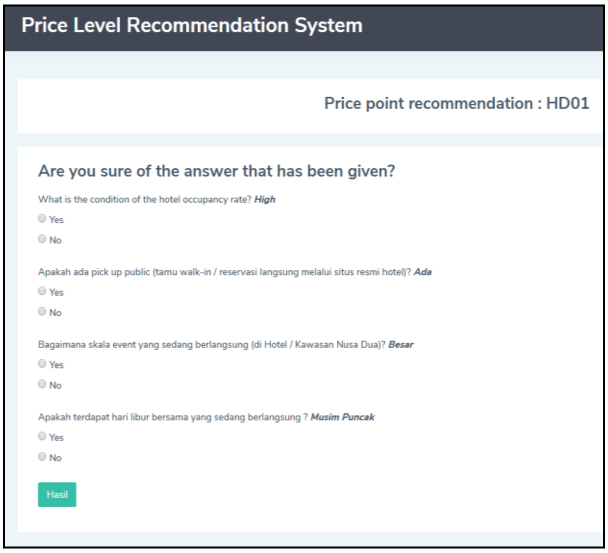

Fig. 6. GUI for temporary conclusion and question for confidence level assessment page

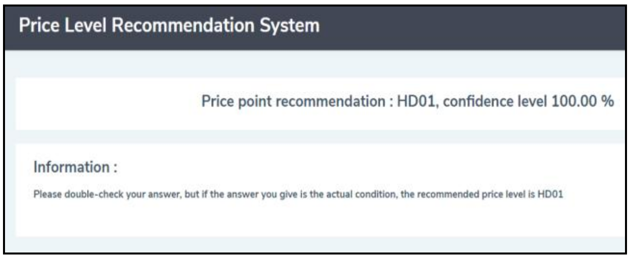

Fig. 7. GUI for conclusion page

IV. Testing

Tests were conducted to assess the accuracy and usability of the proposed system. The accuracy test consists of two stages; the system's accuracy and deviation tests. Details of the tests are described below.

A. Accuracy Test

Accuracy tests were conducted in two stages; the first stage is the system's accuracy test, and the second stage is the deviation test. The deviation test uses the rule-based classifier method. The classification rule is applied if the system's results are similar or deviating by one level above or below the actual data. For example, if the system's result is price level 5 while in the datasets shows actual price level 4, 5 or 6, then that result is still considered matched. The results of the first stage and second stage tests are shown in Table VI and Table VII.

TABLE VI. SYSTEM'S ACCURACY TEST

Month	Dataset	Match	Not Match	% ACC	MAD
Jan	26	18	8	69.23	0.39
Feb	20	16	4	80.00	0.25
Mar	26	25	1	96.15	0.04
Apr	20	15	5	75.00	0.50
May	31	22	9	70.97	0.39
June	28	22	6	78.57	0.21
July	28	16	12	57.14	0.61
Aug	31	24	7	77.42	0.29
Sep	25	20	5	80.00	0.28
Oct	29	19	10	65.52	0.59
Nov	27	17	10	62.96	0.41
Dec	31	22	9	70.97	0.32
Total	322	236	86	73.66	0.36

TABLE VII. DEVIATION TEST

Month	Datasets	Match	Not match	% ACC
Jan	26	24	2	92.31
Feb	20	19	1	95.00
Mar	26	26	0	100.00
Apr	20	15	5	75.00
May	31	28	3	90.32
Jun	28	28	0	100.00
Jul	28	23	5	82.14
Aug	31	29	2	93.55
Sep	25	23	2	92.00
Oct	29	22	7	75.86
Nov	27	26	1	96.29
Dec	31	30	1	96.77
Total	322	293	29	90.77

Table VI and Table VII consist of many data. The datasets column shows the monthly total amount price level in the datasets. The match column shows the monthly total number of system results which matched with actual data. The not-match column shows the monthly total number of system results which was not matched with actual data. The % Acc column shows the percentage of the system's accuracy.

Moreover, the MAD column shows the deviation between the system's results and actual data. The system's accuracy test shows that 236 datasets out of 322 datasets are identified as a match and 86 datasets as not-match. Therefore, the average accuracy rate of the proposed system is 73.66% with a mean average deviation of 0.36.

Using classification rule shows that the accuracy rate increases by 17.11% to become 90.77%. These results indicate that 17.11% of the data which was initially identified as not match has a small deviation. For example, in January, the initial result showed there were 8 data identified as not match with the system. However, after the classification rule was applied, the total number of not match decreased to only 2 data. This shows there are 6 data which has a small deviation within one level range.

B. Usability Test

A usability test was conducted by using SUS, as described by Brooke in [24]. The usability score of the proposed system was calculated based on questions presented to the respondents. The questions are shown in Fig. 8. User's answers are calculated by following the SUS standard scoring procedures, and the result is compared with the SUS usability chart shown in Fig. 2, to determine the system's usability.

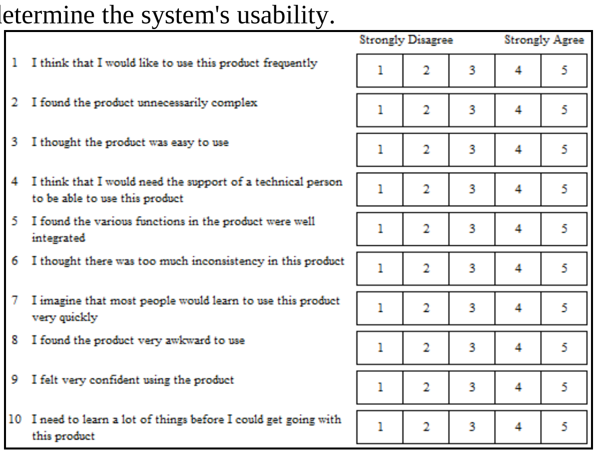

Fig. 8. Assessment instrument of SUS method

Fig. 8 shows a questionnaire sheet presented to respondents. The questionnaire contains ten questions with five answers ranging from strongly disagree to strongly agree [24]-[26]. The results of the questionnaire were tabulated and then converted by using SUS procedures. The standard SUS procedures are, to sum the score of each respondent, to multiply each of them by 2.5, and finally averaged out to obtain the final system's usability score. The usability score is then compared with the SUS chart shown in Fig. 2. The usability test was carried out on four respondents who were part of Mercure Bali Nusa Dua Hotel reservation team. Respondent#1 was revenue managers, Respondent#2 reservation managers, Respondent#3 senior reservation staff, and Respondent#4 reservation staff. The results of the test are shown in Table VIII to Table X.

The results shown in Table VIII were converted using SUS procedure. For each odd-numbered question, the answers of the respondent were subtracted by one. For each even-numbered question, subtract the answer from 5. For example, if on the 1st question respondent answer is 5, since 1 is an odd number, then the conversion score is to subtract 1 from 5, which gives 4. If on the 2nd question respondent answer is 5, because 2 is an even number, then the conversion score is to subtract 5 from 5, which equals to 0. The full conversion results are shown in Table IX. The next step is, to sum the converted score of each respondent. Finally, each of the total scores is multiplied by 2.5. The final results are shown in Table X. Here, the usability score of the proposed system is found at 91.88.

TABLE VIII. USABILITY TESTING RESULT

Statement	Respondent #1	Respondent #2	Respondent #3	Respondent #4
1st	5	5	5	5
2nd	1	1	1	1
3rd	5	5	5	5
4th	1	1	1	1
5th	4	4	4	4
6th	1	2	2	2
7th	5	5	5	5
8th	1	1	1	1
9th	4	4	4	4
10th	1	1	2	2

TABLE IX. THE CONVERSION VALUE OF USABILITY TEST RESULT

Statement	Respondent #1	Respondent #2	Respondent #3	Respondent #4
1st	4	4	4	4
2nd	4	4	4	4
3rd	4	4	4	4
4th	4	4	4	4
5th	3	3	3	3
6th	4	3	3	3
7th	4	4	4	4
8th	4	4	4	4
9th	3	3	3	3
10th	4	4	3	3

TABLE X. SYSTEM'S USABILITY SCORE

Statement	Respondent #1	Respondent #2	Respondent #3	Respondent #4
Total	38	37	36	36
Total x2.5	95	92.5	90	90
Result	91.88			

C. Discussion

Based on the accuracy-test described in the previous section, it is shown that the initial accuracy of the proposed system is 73.66%. By applying classification rule that if the system's results are similar or deviating by one level above or below the actual data, then the system's result is still considered matched. With this rule, the accuracy of the system increases to 90.77%. This indicates that the deviation of the system's result from the actual data is small.

Discrepancies occurred between the system's results and the current manual process highlight the inconsistent and subjective nature of human-made decision as illustrated next. Table XI shows four sets of data in the datasets. The datasets have inconsistencies between the conditions of the parameters and the conclusions taken by the management team.

TABLE XI. EXAMPLE OF INCONSISTENCY IN DATASETS

No.	Date	Prm01	Prm02	Prm03	Prm04	Prm05	Prm06	Prm07	Price Level
1	18-Jan-18	Low	Exist	No	Small	Not PH	Low	High	HD07
2	25-Jan-18	Low	Exist	No	Small	Not PH	Low	High	HD08
3	12-Feb-18	Low	Not Exist	No	Small	Not PH	Low	High	HD07
4	26-Feb-18	Low	Not Exist	No	Small	Not PH	Low	High	HD08

As seen in Table XI, there are two different parameter conditions from those four data. However, there are four different conclusions taken. Let us say, the first and the third row are the right decisions for the given conditions; consequently, the second and the fourth row indicate the inconsistency of the decision. The proposed system is developed to prevent such inconsistency. By using predetermined inference rule, the system determines an appropriate conclusion based on the parameter conditions given consistently.

Furthermore, we compared the system's result with actual data to find whether the proposed system affects the hotel's revenue. The comparison showed that the total sum of the price level of the proposed system was lower than the total sum of the actual data. Because a lower price level has a greater nominal value than the higher price level, this indicates the proposed system could potentially increase the hotel's revenue.

The results of the comparison are shown in Table XII. The actual-data column shows the total monthly price level of the actual data. The system column indicates the total monthly price level of the proposed system. The actual data (IDR) column gives the total monthly actual hotel revenue data in Indonesian currency IDR. And, the system (IDR) column shows the total monthly hotel revenue generated by the system. Table XII indicates that the proposed system generates a lower total amount of price level than that of actual data. However, it generates a higher revenue of IDR 2,196,000. This table shows that the proposed system could potentially increase the hotel's revenue by 0.88%. Although the increase is not very high, with the consistency provided by the system, it shows a promising start. A system that can provide a consistent decision leads to steady improvement. Furthermore, the usability score is 91.88, which, according to SUS assessment chart, is in an acceptable range with grade A and excellent rating. This system can be used as tools for decision-makers to keep them on the right track in deciding the dynamic price levels.

TABLE XII. COMPARISON OF PRICE LEVEL RESULT

Month	Actual data	System	Actual data (IDR)	System (IDR)
Jan	182	184	18,422,000	18,470,000
Feb	107	104	15,957,000	16,056,000
Mar	197	196	18,023,000	18,048,000
Apr	123	113	14,751,000	15,066,000
May	161	157	24,584,000	24,733,000
Jun	156	156	21,718,000	22,345,000
Jul	129	112	21,849,000	22,443,000
Aug	107	114	26,586,000	25,364,000
Sep	128	125	19,262,000	19,353,000
Oct	125	110	25,711,000	26,587,000
Nov	198	189	18,904,000	19,170,000
Dec	191	183	24,624,000	24,952,000
Total	1804	1743	250,391,000	252,587,000

V. CONCLUSION

This paper has presented an expert system as a decision support system which uses forward chaining, fuzzy logic and classical probability to assist hotel management in setting up a consistent mechanism to decide dynamic price level of their room rates.

The proposed system showed an accuracy rate of 73.66% with a deviation of 0.36. When combined with rule-based classifier, the accuracy increased to 90.77%, which indicates the system's result deviation was small. Comparison between price level generated by the expert system and actual data showed the proposed technique could potentially increase the hotel’s revenue by 0.88%. Further, the usability test found that the proposed system score was 91.88. The value indicates that the system's usability was perceived as a good decision support system.

CONFLICT OF INTEREST

The authors declare no conflict of interest

AUTHOR CONTRIBUTIONS

The contributions given by each writer in this research are as follows: I. W. S. Pramana conducted the research, observation and data collection at the Mercure Bali Nusa Dua Hotel; I. W. S. Pramana and M. Sudarma analyze the data and determine the approach we used to solve the problems found; I. W. S. Pramana, M. Sudarma and I. N. S. Kumara all together carry out the system development and system testing; I. W. S. Pramana and I. N. S. Kumara wrote the paper. All authors had approved the final version.

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