An Illustrated Example of DEMATEL within the Context of Analytics

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Abstract

To deal with considerable number of parameters in an optimal solution, determining the impact-relations map and analyzing casual influences work out complex problems in decision-making process. The aim of this study is to find out which of the many meaningful parameters revealed in the aviation sector, is influential. The concept of descriptive and prescriptive analytics is introduced in civil aviation sector.The secondary data was taken from one flag carrier airlines. In addition, interviews were conducted with 10 different experts to compare the interaction between 8 different attributes. The interviews were structured around the DEMATEL Model.Descriptive analytics results have set a precedent implication of multidimensional reports for service sector. Decision making with the variety of combinations of multidimensional reports has a complex nature. Thanks to prescriptive analytics, displayed results supported by DEMATEL. The results of the study will be supportive for strategic levels of decision making for all service sectors, especially for civil aviation.

Keywords: Business analytics, Prescriptive analysis, DEMATEL .

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Motivation and Background

Making a good decision and forecasting the outcome of the available options are based upon both methodical exploration of an organization's data and the mathematical modeling of problem. Mathematical programming models like business analytics tools have made major additive to decision-making as they facilitate the model to capture the structure of the problem. Business analytics can be defined as a process that involves the use of statistical techniques, information system software and operations research methodologies to explore, visualize, discover and communicate patterns or trends in data (Schniederjans, Schniederjans and Starkey, 2014).

Business analytics is used to acquire insight that notice business decisions and can be used to optimize and automate business operation and process. Business analytics, as an emerging space of research, strives to bring together interested fields and disciplines overlaying diverse aspects in terms of technological innovations, quantitative/numerical methods, and decision-making (Heilig, Lalla-ruiz and VoB, 2017). Recent years, developed technologies have increased the matter of data analytics and extended the potential of using data-driven tools in decision-making processes.

Business analytics include the three main type of analytics which are descriptive, predictive and prescriptive (Hsinchun Chen, 2012). Descriptive analytics examine in detail into data to pick out details such as the frequency of cases, the cost of processes, and the base cause of collapse (IBM, 2013). It ensures meaningful insight into activity performance and facilitate users to better follow up and operate their work processes (Lustig et al., 2010). Predictive analytics uses a sort of models and techniques to estimate forthcoming results based on historical and streamed data (Gandomi and Haidar, 2014). In predictive analysis, the statistical model is prepared, forecast is made, and the pattern is confirmed as supplementary data becomes existing (Gartner IT Glossary. n.d). Prescriptive analysis in business making process offers suggestions on how to act and take advantage of forecast (Perugini and Perugini, 2014). Prescriptive analysis uses a variety of algorithms and data modelling practices to get a complete understanding of the environment and build up activity's performances (Delen and Demirkan, 2013).

The aim of the prescriptive analytics is to find an alternative or set of alternatives which is best acceptable by the group of decision makers as a whole (Cabrerizo et al., 2016). The main objective would be one where all the decision makers could convey their options on the alternatives in a certain way by means of prescriptive.

Research shows that the nature and content of business decision making has hardly changed and that managers operate by a majority descriptive analytics, some predictive analytics, and a few of prescriptive analytics (Appelbaum et al., 2017). Generally, descriptive analysis compasses two or multidimensional reports and predictive analysis includes alternatives or alternative set of solution. Indeed, managers do not know what they want and analysts do not understand what they need or can accept; a necessary action should define the structure of problem and determine the parameters that take part in optimal solution by using prescriptive analysis.

In this paper, a novel business analytics approach is proposed for aviation optimization and getting a grip on flight occupancy rate taking into consideration all perspective, such as time, location, class type and aircraft capacity with addressing important research method, mentioned by Tazaki and Amagasa (1979), is DEMATEL. The decision-making trial and evaluation laboratory method (DEMATEL) with the expert feedbacks are then used to construct the new evaluation and assessment system. This study investigates the DEMATEL to determine the impact-relations map as prescriptive analytics using flight occupancy rate.

Methodology and Analysis

The main research question is how can impact-relations map be determined to identify influencer parameters in optimal solutions. The aim of this study is to find out which of the many meaningful attributes revealed in the aviation sector that is one of the remarkable service sectors, is influential. Furthermore, the concept of prescriptive analytics in civil aviation industry decision-making is introduced.

Descriptive Analysis

The methodology of this study has two main stages, first stage includes descriptive analytics by using multidimensional reporting and the second stage contains DEMATEL. Taking secondary data from airlines has comprised different types of attributes. The attributes are flight dates, flight month, flight season, flight class, flight region, flight distance, aircraft capacity and flight type. In descriptive analysis stage, hundreds of multidimensional tables are obtained at the strategic level. One of the examples of multidimensional table is shown in Figure 1.

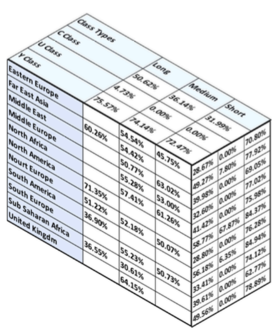

Figure 1. Multidimensional reporting outcomes example.

The descriptive analyzes produces considerable number of reports; therefore, decision makers are forced to decide which parameters they should focus. At this point the following commissioning is taking place: the criteria to be evaluated are considered based upon expert interviews.

Prescriptive Analysis

DEMATEL technique can convert the interrelations between criteria into an intelligible structural model of the system and divide them into a cause group and an effect group (Chen Shyu and Huang, 2017). DEMATEL is a practicable and beneficial tool to analyze the interdependent relationships among elements in a complex framework and grade them for decision making. Thus, this technique can be used in prescriptive analysis.

The formulating steps of the classical DEMATEL (Fontela and Gabus, 1976) can be summarized as follows;

Step 1: Generating the direct-relation matrix. For example, four scales for measuring the relationship among different criteria are used: 0 (no influence), 1 (low influence), 2 (high influence), and 3 (very high influence). Decision makers prepare sets of pair-wise comparisons in terms of effects and direction between criteria. The initial data can be obtained as the direct-relation matrix which is a n × n matrix A where each element of is denoted as the degree in which the criterion i affects the criterion j.

Step 2: Normalizing the direct-relation matrix. Normalization is performed using the following formula,

$$X = k \times A \qquad (1)$$

$$k = \frac{1}{max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}}. \ i, j = 1,2\ldots, n \qquad (2)$$

Step 3: Attaining the total-relation matrix. Once the normalized direct-relation matrix X is obtained, the total relation matrix T can be acquired by using Eq. (3), where I is denoted as the identity matrix,

$$T = X(I-X)^{-1} \qquad (3)$$

Step 4: Producing a causal diagram. The sum of rows and columns are separately denoted as vector D and vector R through equations (4-6). The horizontal axis vector (D + R) named as "prominence" is made by adding D to R, which reveals the relative importance of each criterion. Similarly, the vertical axis (D - R) called as "relevance" is made by subtracting D from R, which may divide criteria into a cause and effect groups (Chen, 2012). Generally, when (D - R) is positive, the criterion belongs to the cause group, (D - R) is negative, the criterion represents the effect group. Therefore, the causal diagram can be obtained by mapping the dataset of the (D + R, D - R), providing some insight for making decisions.

$$T = [t_{ij}]_{n \times n} \quad i, j=1, 2, \ldots, n \qquad (4)$$

$$D = \left[\sum_{j=1}^{n} t_{ij}\right]_{n \times 1} = [t_i]_{n \times 1} \qquad (5)$$

$$R = \left[\sum_{i=1}^{n} t_{ij}\right]_{1 \times n} = [t_j]_{1 \times n} \qquad (6)$$

where vector D and vector R denote the sum of rows and columns in total-relation matrix $T = [t_{ij}]_{n \times n}$.

Step 5: Obtaining the inner dependence matrix. In this step, the sum of each column in total-relation matrix is equal to 1 by the normalization method, and then the inner dependence matrix can be acquired.

In this study to explain DEMATEL steps, attributes impact values have already asked to 10 different experts working in this field. The impact value, which is from 0 to 4 has collected from each different specialist. They are asked to identify the degree of influence between the parameters (criteria) to calculate the average matrix of influence matrix in Table 1. In step 1, the experts adopted the eight attributes as evaluation criteria.

Table 1. Average matrix.

Conditional Attributes	A1	A2	A3	B1	C1	C2	D1	E1
A1. Flight Dates	0.000	1.110	1.010	1.410	1.660	0.500	1.600	2.000
A2. Flight Month	1.430	0.000	2.220	2.000	2.400	1.200	1.660	1.330
A3. Flight Season	0.820	1.000	0.000	2.050	2.440	1.650	2.650	1.880
B1. Flight Class	1.920	0.800	1.820	0.000	2.750	3.500	3.330	3.100
C1. Flight Region	2.200	3.110	1.250	0.750	0.000	2.250	2.660	1.750
C2. Flight Distance	1.010	1.310	1.450	1.200	1.440	0.000	0.750	3.000
D1. Aircraft Capacity	3.500	3.200	2.950	3.330	2.880	1.850	0.000	1.400
E1. Flight Type	0.500	1.250	1.400	3.660	1.000	2.000	3.330	0.000

In step 2, the normalized initial direct-relation matrix is calculated by using average matrix. Normalized initial matrix is obtained as shown in Table 2.

Table 2. Normalized initial direct-relation matrix.

Conditional Attributes	A1	A2	A3	B1	C1	C2	D1	E1
A1	0.000	0.058	0.053	0.074	0.087	0.026	0.084	0.105
A2	0.075	0.000	0.116	0.105	0.126	0.063	0.087	0.070
A3	0.043	0.052	0.000	0.107	0.128	0.086	0.139	0.098
B1	0.100	0.042	0.095	0.000	0.144	0.183	0.174	0.162
C1	0.115	0.163	0.065	0.039	0.000	0.118	0.139	0.092
C2	0.053	0.069	0.076	0.063	0.075	0.000	0.039	0.157
D1	0.183	0.167	0.154	0.174	0.151	0.097	0.000	0.073
E1	0.026	0.065	0.073	0.192	0.052	0.105	0.174	0.000

In step 3, the total-relation matrix is acquired by formula X(I-X)-1. Values higher than the threshold value are presented in bold, for example, the fourth column and the seventh row in Table 3 is 0.478, which means that D1 will affect B1.

Table 3. The total-relation matrix.

Conditional Attributes	A1	A2	A3	B1	C1	C2	D1	E1
A1	0.146	0.206	0.202	0.249	0.257	0.191	0.275	0.268
A2	0.255	0.191	0.297	0.318	0.34	0.267	0.329	0.288
A3	0.239	0.254	0.203	0.335	0.352	0.3	0.384	0.323
B1	0.343	0.305	0.348	0.31	0.431	**0.443***	**0.487***	**0.449***
C1	0.308	0.356	0.274	0.289	0.125	0.326	0.388	0.325
C2	0.196	0.218	0.227	0.25	0.252	0.172	0.248	0.324
D1	0.433	0.424	0.418	**0.478***	**0.469***	0.39	0.364	0.398
E1	0.242	0.276	0.29	0.427	0.311	0.337	0.434	0.256

The total influence matrix is defined as the sum of the rows and the columns separately which can be denoted as vector d and r. Let and ; the horizontal axis vector (di+ri) is made by adding di to ri, which illustrates the importance of the criterion. Similarly, the vertical axis vector (di-ri) is made by deducting di from ri, which separates criteria into a cause group and an affected group. In prominence-relevance maps whether (di-ri) is positive, the criterion is part of the cause group or (di-ri) is negative, the criterion is part of the affected group (Li and Tzeng, 2009). Therefore, a causal graph can be achieved by mapping the dataset of (di+ri , di-ri), providing a valuable approach for decision-making. The sum of influences is given and received on criteria will be shown in Table 4.

Table 4. Causal influence level summarized table of criteria.

Conditional Attributes	D	R	D+R	D-R
A1. Flight Dates	2.800	3.163	5.957	-0.368
A2. Flight Month	3.300	3.230	6.515	0.055
A3. Flight Season	3.400	3.260	6.649	0.130
B1. Flight Class	4.100	3.656	7.774	0.461
C1. Flight Region	3.500	3.660	7.176	-0.145
C2. Flight Distance	2.900	3.426	6.312	-0.540
D1. Aircraft Capacity	4.400	3.911	8.285	0.463
E1. Flight Type	3.600	3.629	7.202	-0.056

The direction of influence between dimensions and criteria can be visualized as in Figure 2. It can be inferred from figure that Aircraft Capacity (D1) is the most effective attributes. As a result of the DEMATEL method, the conditional attributes' degrees of impacts have been identified.

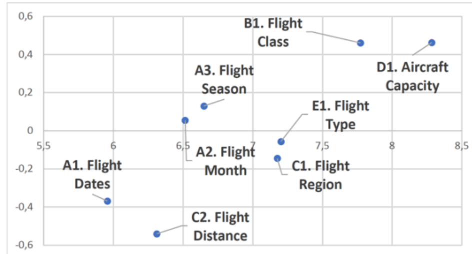

Figure 2. The Causal Diagram.

Moreover, descriptive analytics results such as multidimensional reports have been supported with DEMATEL technique. All those outcomes would give advices for decision makers with meaningful results.

Conclusion and Discussion

DEMATEL is an exhaustive method for setting up and analyzing an organic model involving casual correlations among complicated criteria. DEMATEL technique has two main advantages: It effectively analyzes the mutual influences which are direct and indirect effects among separate criteria and understands the complicated cause and effect relations in the decision-making problem. DEMATEL can be used not only to determine the ranking of alternatives, but also to find out critical evaluation criteria and measure the weights of evaluation criteria.

The total relation matrix consists of direct and indirect effects. (D+R)i provides an index of strength of influences given and received, that is, (D+R)i shows the degree of criteria i that plays in the decision making process. The quantity of (D+R)i indicates the importance degree of each criteria. If (D-R)i is positive that belongs to cause group or else (D-R)i is negative that belongs to effect group. In this study, "D1 Aircraft Capacity" and "B1 Flight Class" represent the linkage of (D+R), which are crucial in total assessment of criteria associated with making strategic decisions on air transportation. These decisions are important so as to make a decision profitable, to combine all airlines data effectively and appropriately, to organize the output such as flights planning and arrangement of aircraft types and to develop the civil aviation in Turkey. The degrees of (D-R) affect two criteria with positive value "A1 Flight Dates" and "C2 Flight Distance" that can be affected by other criteria. Taking (D+R) and (D-R) combination into account, the key criteria for higher critical degree and positive and higher influence degree are "D1 Aircraft Capacity" and "B1 Flight Class". Therefore, the manager should pay attention to the aircraft capacity, aircraft internal layout and class types when taking a strategic decision in their planning in terms of the development strategy.

Civil aviation as a notable part of transportation is a growing and a highly competitive sector. The aviation industry has adapted several business intelligence and analytics implementations in order to support decision-making activities. Regarding the developing technology, business analytics process monitoring aims at forecasting potential problems during process execution before they occur so that these problems can be handled proactively.

Since DEMATEL method may create the impact-relations map to determine cause and effect relationships, it is supportive for strategic levels of decision making for all service sectors.

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