ISSN: 0974-5823 Vol. 7 No. 2 February, 2022

International Journal of Mechanical Engineering

Ranking Of Airports Based On Operational Efficiency Using PROMETHEE and CRITIC Methods

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Abstract - The operational efficiency of the airports has become vital of the sustainability of airports. This helps the airports to be recognised as best in terms of facilities for the passengers and also facilitates to increase the revenue by reducing the cost of operations. This paper deals with the ranking of international busiest airports. It has adopted the PROMETHEE GAIA method and CRITIC method for ranking of international airports and for the weights given to alternatives. It takes into consideration a sample of 50 international airports and the 9 comprehensive essential criterions like operational cost, accidents and incidents, distance from city centre , no. of runways etc to rank for the sustainability and efficiency of the airports .The result of the study ranks Dallas/Fort Worth International Airport (Dallas), Hartsfield–Jackson Atlanta International Airport (Atlanta), O'Hare International Airport (Chicago), the best among the sample with regard airport facilities. The results can be used the decision makers of the airport authorities to have an insight over the criterion important for the sustainability and efficiency airports for in near future

Index Terms - International Airports, PROMETHEE -GAIA Approach, CRITIC.

INTRODUCTION

Airlines business engages with recreation services and has a significant part in elevating the economy of world over its individual actions and also influence on other associated businesses. Nowadays, the administrators are putting their efforts to increase income and reduce losses through continuous improvements. Airports has a important influence in economic growth of a country due to movements of passengers and cargos global. An airport can be well-defined by means of a multifaceted d establishment consisting of runways, No. of Terminal, operational expenditure etc. (Humphreys and Francis, 2002) [16]. It turns by way of a transport hub and encounters several requirements of travel. Passengers and cargo all over the world.

Due to the LPG (liberalisation, privatisation and globalizing) these needs turn out to be vital meant for the airports to deliver an outstanding value of amenities for the customers and withstand with the existing extremely competitive environment. Due deregulating and privatization of the airports, air costs drastically declined and paved the way for the low-cost airlines, empowering the cost-conscious individuals to benefit from the air transport service

Consequently, constant assessment of performance through suitable tools is of greatest importance for successful managing the airports. Accordingly as per report of World Bank data (Air transport statistics,1970-2015) [29], during these current years international aviation industry has enjoyed a significant progress, as a result many airports worldwide were either enhanced or constructed, henceforth, airport authorities are compelled to meet the global procedures and also revamp the performance of airports.

Taking into consideration the above scenario the airport ranking is a fruitful resolution which can put forward the best and worst amongst the 50 international airports taken for the study in this paper. It is done through the evaluation of criterions as no. of passengers, operational expenditure, accidents and incidents, etc. It becomes difficult to apply a suitable method to evaluate performance of airports. The efficient performance of airports assessment structure eventually assists for recognizing effectiveness of airports to deliver sustained air transport facilities, assisting the administrations to keep track on investment utilization, reducing the cost of operations, in addition of increased market share also return on investment, also assisting the authorities of the airport through valued understanding the comparative merits and demerits in accordance of other rival airports (Barros and Dieke, 2008[7]; Perçin, 2018)[35].Competent airports deliver non-stop air traffic services, help governments control the use of investment, reduce operating costs, and help airport management provide valuable insights into the relative advantages and disadvantages among similar airports in competition (Barros and Dieke, 2008; Perçin, 2018)[35].

Therefore, the problem of evaluating the efficiency of the airport by assessing the efficacy of the airports in the order of efficiency evaluation and selecting the airport with the best characteristics could expressed with (MCDM) Multicriteria Decision Making. There are several alternative standards, which usually have the opposite nature. Some research has been conducted to solve the problem of airport efficiency and productivity, but only a few studies have been conducted on related issues. Ranking some competitive airports helps in making decisions regarding (travellers, airport administrators, government, stakeholders, etc.) making in time decisions (Tovar and Martín-Cejas, 2010). The correlation method between the two MCDM methods (CRITIC) [208-211] standards recommended by Diakulaki, Mavrotas and Papayannakis in 1995[15] is largely applied in determining weights of the attribute. The method, attributes do not contradict each other, and a decision matrix determines attributes weight. The main goal of the mentioned PROMETHEE method helps participants understand it as simply as possible. Decision makers. It is based on an extension of the concept of guidelines. The highest ranked chart is represented by the preference index. In order to solve the ranking problem with the help of the ranking map, PROMETHEE II is considered. PROMETHEE II provides the total amount of pre-orders in many possible promotional methods. Therefore, a real-time smart method to measure performance would be more appropriate. Provide information to airport staff towards identifying vital reasons of poor performance of airports and propose ways to improve problem spots (Pandey, 2016) [35].

DESCRIPTION CRITIC METHOD

I. Normalization of the Decision Matrix

In order to balance favourable and non-favourable attributes of the decision matrix, Equation. (1) & (2) is applied, correspondingly.

$$x_{ij} \frac{r_{ij} - r - r_i^-}{r^+ - r_i^-} i = 1 \dots \dots m, j = 1, \dots \dots, n \quad (1)$$

$$x_{ij} \frac{r_{ij} - r - r_i^+}{r^+ - r_i^+} i = 1 \dots \dots m, j = 1, \dots \dots, n \quad (2)$$

wherever x_{ij} signifies a standardised decision value of the matrix for *i*th alternative in *j*th element and $r_i^+ = max\ (r_1, r_2 \dots\dots\dots\dots; r_m)$ and $r_i^- = min\ (r_1, r_2 \dots\dots\dots\dots; r_m)$

II. *Correlation Coefficient*

The coefficient of correlation amongst attributes is determined by Eq (3)

$$p_{jk} = \sum_{i=1}^{m} (x_{ij} - \bar{x}_j)(x_{ik} - \bar{x}_k) / \sqrt{\sum_{i=1}^{m} (x_{ij} - \bar{x}_j)^2 \sum_{i=1}^{m} (x_{ik} - \bar{x}_k)^2} \quad (3)$$

wherever $\bar{x}_j$ and $\bar{x}_k$ show the mean of jth and kth traits. $\bar{x}_j$ is calculated from Eq. (4). Correspondingly, it is obtained for $\bar{x}_k$: As well, p_{jk} is the coefficient correlation amongst *j*th and *k*th traits

$$\bar{x}_j = \frac{1}{n} \sum_{j-1}^{n} x_{ij} \ i = 1, \dots \dots \dots, m \quad (4)$$

III. The Index

Primarily, the standard deviation of respectively trait is assessed by Eq

$$\sigma = \sqrt{\bar{x}_j = \frac{1}{n-1} \sum_{j=1}^{n} (x_{ij} - \bar{x}_j)^2}; \ i = 1, \dots \dots \dots, m \quad (5)$$

$$C_j = \sigma_j \sum_{k=1}^{m} (1 - p_{jk}); j = 1, \dots, n \quad (6)$$

(iv)The Attributes Weight

The attributes weights are shown by Eq. (7)

$$w_j = \frac{c_j}{\sum_{j=1}^{m} c_j} \quad (7)$$

(v) The Concluding Attributes Ranking

The weight of attributes is organized in descending order aimed at concluding ranking of attributes.

LITERATURE REVIEW

The competition between the airports is mostly classified on the basis of distance from the airport, its infrastructure and nearness of airports from the urban areas (Postorino, 2010b) [37]. The method adopted for this paper is (CRITIC) [208-211] standards proposed by Diakulaki, Mavrotas and Papayannakis in 1995[15] for weights of the criterions. PROMETHEE-GAIA methodology is adopted for the outrankingThe PROMETHEE-II (Preference Ranking Organization Method for Enrichment Evaluation) GAIA (Geometrical Analysis of Interactive Aid). PROMETHEE-I is for incomplete ranking while PROMETHEE-II is for comprehensive ranking and it is preferred over PROMETHEE-I were developed by J.P. Brans and presented for the first time in 1982[8]. The other methods like DEA (Decision envelopment method) are a quantitative method. GAIA is the best method for the objective of this paper. It shows the comprehensive rankings of the alternatives. The GAIA is a pictorial graphic representation of the alternatives along with its values. GAIA displays the best alternative and also the criteria which represents that alternative.

Criteria used for performance evaluation	Criteria Paper
Passenger Throughput	Alodhaibi, S., Burdett, R. L., & Yarlagadda, P. K. (2017, Loo, B. P. Y. (2008)
All Departure	Jr., R. A. A., Bongo, M. F., Ocampo, L. A., N. J. (2018), Sidiropoulos, S., Majumdar (2015)
All direct routes	H. (2012), Yang, C.-W., Lu, J.-L., & Hsu, C.-Y. (2014), Lieshout, R., & Matsumoto, H. (2012)
No. of Runway	Lu, W., Park, S. H., Huang, T., & Yeo, G. T. (2019, Farhadi, F., Ghoniem, A., & Al-Salem, M. 2014). Turskis, Z., Antuchevičienė, J., Keršulienė, V., & Gaidukas, G. (2019)
Aircraft Area	Setiawan, M., Surjokusumo, S., Ma’soem, (2018), Suzuki, Y., Crum, M. R., & Audino, M. J. (2003)
No. of Terminal	Schultz, M., Schulz, C., & Fricke, H. (2009), Manataki, I. E., & Zografos, K. G. (2010).
Operational expenditure	Gudiel Pineda, P. J., Liou, J. J. H., Hsu, C.-C., & Chuang, Y.-C. (2018), Lai, P., Potter, A., Beynon, M., & Beresford, A. (2015)
Distance from city	Damacena, E. F., Wanke, P. F., & Correa, H. L. (2016). Suzuki, S., Nijkamp, P., Rietveld, P., & Pels, E. (2010)
Accidents and Incidents	Wilke, S., Majumdar, A., & Ochieng, W. Y. (2015), Kharoufah, H., Murray, J., Baxter, G., & Wild, G. (2018)

Author	**Method(s) Applied**	**Findings**
Santonab Chakraborty, Sayantan Ghosh , Baneswar Sarker , Shankar Chakraborty	(BWM) (MABAC)	Findings founded cohesive exploration, Indira Gandhi International Airport and Surat International Airport correspondingly appear to be the favourable and the least favourable acting international airports in India.
S¸ an Kılkıs¸ , S¸ iir Kılkıs	Sustainability Ranking of Airports Index	The viability Position of Airports is evolved by means of a combined criterion to deliver a primary resource of comparation between the airports position based on elements that consider the Feasible change of energy, water, and environment systems.
Milan Janic* and Aura Reggiani	SAW, TOPSIS, AHP	Multi criteria methods are adopted for the ranking by assigning the weights to the criterions and the results concluded are the same.

Young-Hyo Ahn , Hokey Min	DEA, Malmquist	The analysis of the competence of the key international airports for the specific year, 2006 and 2011 by means of the DEA and the Malmquist efficiency.
Anne Graham	Total Factor productivity (TPF), Data Envelopment Analysis, DEA	various airports have adopted benchmarking techniques but Europe is emerged as the best one. Along with the airports the airline industry is increasing its efficiency in relation with international and global norms.
Murat Kucukvar, Khalel Ahmed Alawi, Galal M. Abdella, Muhammed Enis Bulak, | Nuri C.	Data Envelopment Analysis DEA	The observation through the statistical methods adopted shows that that San Francisco, Hong Kong and Hamad International Airports stand as the utmost well planned airports in relation of comprehensive feasible achievement in performance.
Payam Shojaei, Seyed Amin Seyed Haeri, Sahar Mohammad	VIKOR, BWM, Taguchi loss function	The suggested framework suggests the customers preferences on the basis of criteria, also the airports are ranked on this basis.
Augusto Voltes-Dorta a, Héctor Rodríguez-Déniz , Pere Suau-Sanchez	Marketing Information Data Transfer (MIDT	This assessment specifies that the most fault-finding airports in the European network during the sample period were Heathrow, Istanbul, and Barcelona the worst performers regarding delays per passenger were Moscow-DME, Barcelona, and Stockholm.
Sarkis, J., & Talluri, S.	DEA. Clustering	It recognizes the suitable benchmark criterions for responsible for the poor performance airports.
Oum, T. H., Yu, C., & Fu, X.	Regression Models & (TEP) Total Factor Productivity	(TEP) Total Factor productivity performers stand as Seoul, Sydney, Boston, Kansai, Vancouver, Calgary, Minneapolis-St. Paul, Newark, Miami and Seattle .

SAMPLE COLLECTION

The sample for the study of airports performance is based on 2019 Yearly Airports Traffic Flow Statement of United States: Port Authority of New York and New Jersey. 2020[1]. The airports performance criterions in table 1 are Passenger Throughput, All departures, All direct routes, No. of Runway, No. of Terminal, Airport Area (Acres), operational expenditure(million), Distance from city(ml), accidents and incidents.

RESEARCH OBJECTIVES

The paper focuses on three key research objectives to support the

framework such as;

1.To rank the airports on their best-in-class operational performance that others can follow

2. The analysis of the airports on the crucial pointers considered as most important factors such as distance from city center and no. of accidents.

3. To provide assistance to airport authorities of having a defined evaluation system for sustainability of airports

The first section is of introduction of aviation industry followed by literature review later the sample collection of the airport based 2019 Yearly Airports Traffic Flow Statement of States: Port Authority of New York and New Jersey. 2020 represents a assessment on the Global Report. This section is supported by the part that involves the CRITIC Method adopted for the weight of the criterions and PROMETHEE GAIA approach for ranking of the international airports on the basis of nine criterions.

Moreover, the data collection presents the details of the comprehensive information collected of international airports. It is relating to its operational performance on the basis of criterions identified to quantify the operational airports performance. The study concludes with the suggestions for the policy makers in the area of reducing the incidents and accidents and also lowering the operational expenditure of airports.

The analysis of the airports on the crucial pointers of 50 alternatives and nine criteria, as listed in Table no.1, their weights (relative importance are determined employing CRITIC Method (Intercriteria Correlation),which was proposed by Diakoulaki, Mavrotas, and Papayannakis in 1995 [208–211]. It is being observed that citreria C8 (Distance from city(ml) is considered as the utmost vital criterion while evaluating the best airport among the alternatives taken, along with criteria C9 and C4 (accidents and incidents, No. of Runway)Among the these 9 criterions (C1, C2, C3.C4, C5and C6) present as beneficial traits , while (C7, C8 and C9) are non-beneficial criterias where higher values are preferred .

Table: -1 The Weights of measured Criteria's

Criteria	Symbol	Criteria Type	Weight
Passenger Throughput	C1	Beneficial	0.111
All departures	C2	Beneficial	0.097
All direct routes	C3	Beneficial	0.106
No. of Runway	C4	Beneficial	0.117
No. of Terminal	C5	Beneficial	0.102
Airport Area (Acres)	C6	Beneficial	0.096
operational expenditure(million)	C7	Non-Beneficial	0.093
Distance from city(ml)	C8	Non-Beneficial	0.162
accidents and incidents	C9	Non-Beneficial	0.117

The decision matrix Table no. 2 is decision matrix for the performance of international airports. It is being observed that (ATL) Hartsfield–Jackson Atlanta International Airport remains the highest number of passengers. The maximum number of flight departures from O'Hare International Airport (ORD). maximum number of direct routes are from Frankfurt Airport (FRA). The highest number of runways belongs to(DFW) Dallas/Fort Worth International Airport and also O'Hare International Airport (ORD) . The highest number of airport terminals outrightly of (LAX) Los Angeles International Airport . The maximum airport in (acres) if of Indira Gandhi International Airport (DEL). The airport with the least operating expenditure is (B0M) Chhatrapati Shivaji International Airport. The airport with the least distance from city center is Dubai International Airport (DBX). The least number of accidents and incidents are in Xi'an Xianyang International Airport (XIY).

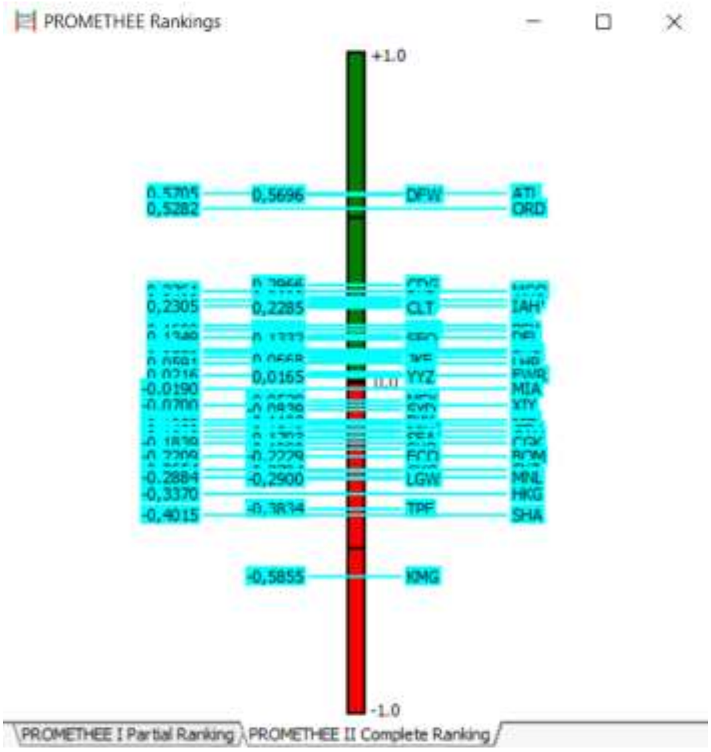

Figure:-1 Ranking of International Airports

From the figure 1, presents the airports that have being placed alongside a vertical scale arranged according to values .It is divided into two halves respectively, it denotes favorable and non- favorable rankings of the airports. The alternative getting the highest ranking is considered as the outmost in performance airport it becomes clear that Dallas/Fort Worth International Airport (DFW), city in U.S. state of Texas, Hartsfield–Jackson Atlanta International Airport (ATL) and O'Hare International Airport Chicago (ORD), in U.S. is the best with regard airport facilities. On the other hand, (KMG) Kunming Changshui International Airport Yunnan Province, China. has performed negatively and it is lagging behind their counterpart in the airport facilities

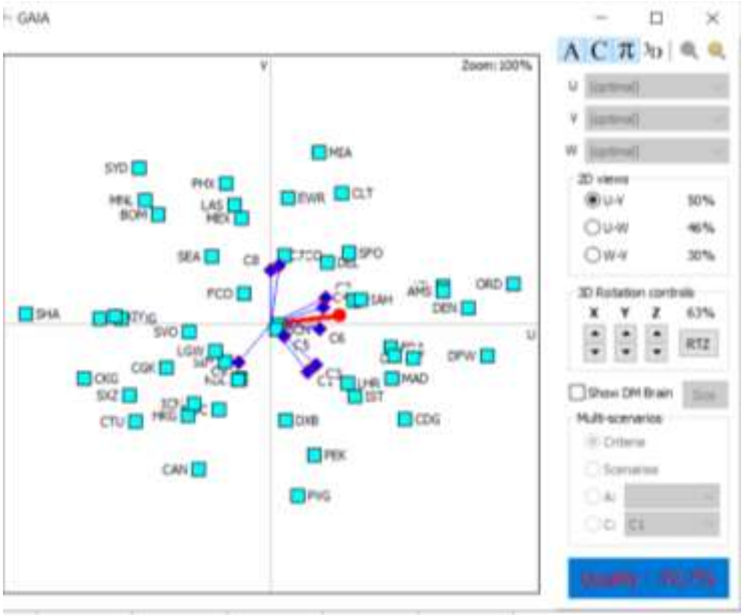

Figure:-2 GAIA plane of international airport wise facility assessment

In order to get improved awareness of the international airport wise facility assessment dilemma, the related GAIA plane is developed in Fig 2. The situation shows that Dallas/Fort Worth International Airport (DFW),(0RD) O'Hare International Airport Chicago, U.S also the (DEN) Denver International Airport Denver, U.S. are very far after the source of GAIA plane towards path of π-axis is considered to be superior among the others with respect to airport facility measures. On the other hand, (KMG) Kunming Changshui International Airport Yunnan Province, China and (SHA) Shanghai Hongqiao International Airport, Shanghai China are the farthest from π axis in the opposite direction. It therefore recognized as the worst performing airports with respect to facilities. In this GAIA plane, criterions, i.e., C7, C8 (non- beneficial),(operational expenditure(million) and (Distance from city) are close to each other in the same direction. Criterions C2, C4 (All departures and No. of Runway) form a cluster. criterions C3 and C5 (All direct routes and No. of Terminal) are highly corelated along with criterion C1(Passenger Throughput) . Miami International Airport (MIA) located at U.S. state of Florida is strong with criteria C2& C3. Chengdu Shuang Liu International Airport Shuang Liu District, Southwest China having favorable criteria C9.It is also observed that the position of criterion C6 (Airport Area (Acres) is close towards the starting point of the GAIA plane showing its least significance regarding the performance of this airport.

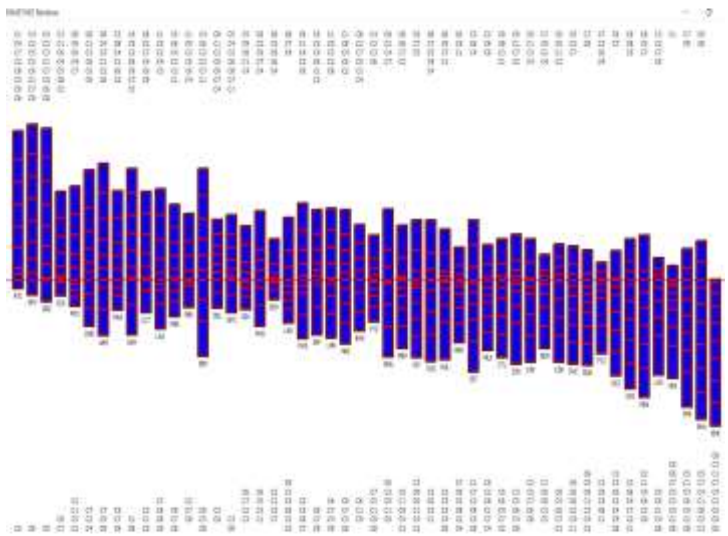

Figure:-3 PROMETHEE rainbow diagram International Airport wise evaluation of performance

The Fig 3 shows the PROMETHEE rainbow diagram. The diagram is showing the ranking obtained in relation to International Airport wise evaluation of performance of all the 50 International Airports that are placed from left to right. The perpendicular bar drawn contains of many parts. The slice thickness inside the bar shows the impact that each criterion on the performance for that specific airport performance. The slices positioned above the horizontal line are considered to be favorable and those below denote as weak criteria.

Therefore, from this PROMETHEE rainbow diagram, it makes feasible to predict the performance of the international airports. In this figure, (ATL) Hartsfield–Jackson Atlanta International Airport Atlanta U.S. is at the top position with strong in criterion1(Passenger Throughput). While (ORD) O'Hare International Airport Chicago, in U.S. and (DFW) Dallas/Fort Worth International Airport ,Dallas U.S. state of Texas are strong at criterion 4(No. of Runway) and weak at criterion 8 & 9 (Distance from city(ml and accidents and incidents) correspondingly . The Table no.2 depicts that the (ATL)Hartsfield–Jackson Atlanta International Airport that (operational expenditure and Distance from city) which was minimum among all the international airports. The (KMG) Kunming Changshui International Airport Yunnan Province, China occupies last place in ranking list. It has merely criteria C8 & C9 Distance from city (ml and accidents and incidents) in its favor.

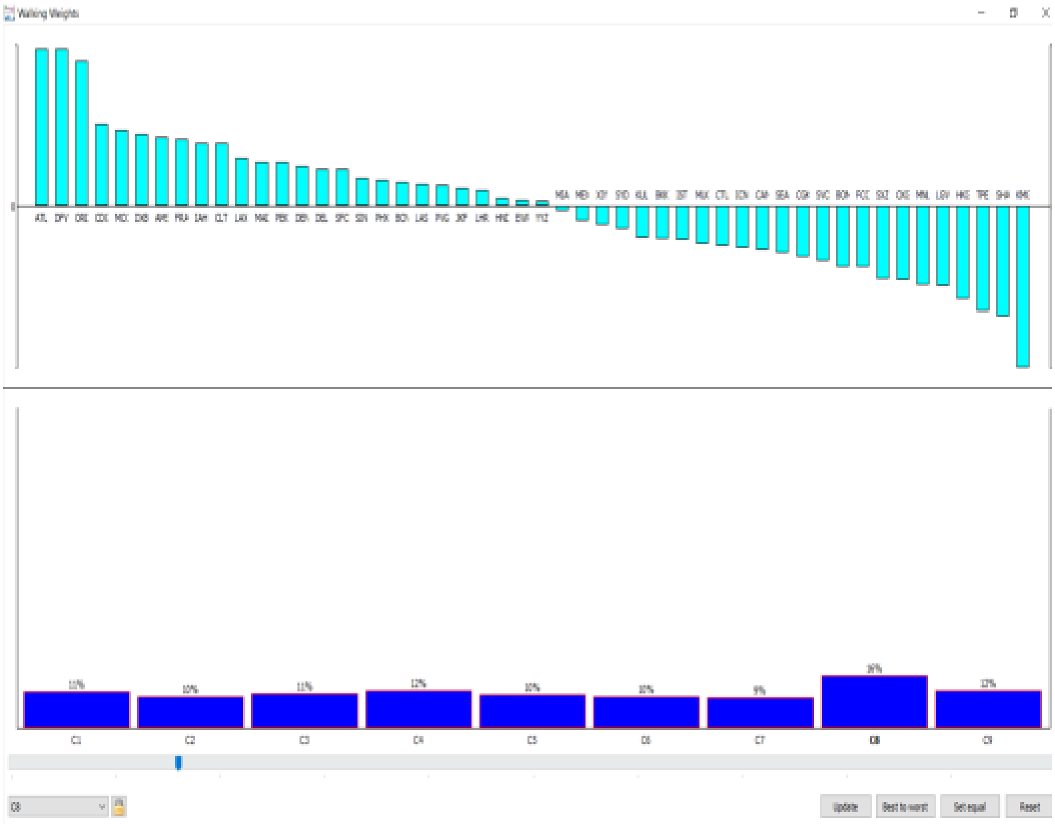

Figure:-4 Walking weights is allocated to the evaluation criteria

The PROMETHEE software has the special feature of “Walking Weights” Fig. 4 which permits the airport managers use the all the criteria weights and then see the changes in alternatives ranking of PROMETHEE II. Fundamentally it acts as a self-communicating sensitive weight tool for analysis. Any change in the criteria weight will result in the changes in the π-axis, but alternatives position is unaltered. Figure 4 reveals the performance of the airports from the best to the worst ranking orders depending upon the different weight allocation for the assessment criteria. Fig.4 shows that ATL, DFW, ORD, CDG, MCO, DXB, AMS, FRA, IAH, CLT, LAX, MAD, PEK, DEN, DEL, SFC, SIN, PHX, LAS, PHX, LAS, PUG, JKF, LHR, HNC, EWK, YYZ form a group ranking identifying good performing airports. While on the other hand MIA, MEX, XIY, SYD, BKK, IST, MUC, CTL, ICN, CAN, SEA, CGK, MAL, LGW, HKG, TPE, SHA and KMG are having negative ranking indicating unsatisfactory performing among the international airports

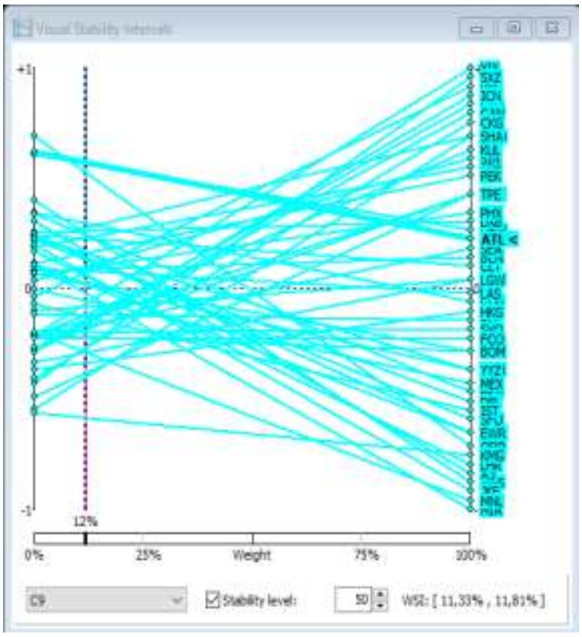

Figure5: - Visibility Stability intervals for the utmost vital criteria

The Fig.5 of visibility stability intervals shows the crucial criterion(C9) i.e. (Distance from city in miles). The figure shows the in what way the flows of net ranking changes by means of the weight of C9 criterion. The Weight of C9 criterion is shown on the horizontal axis , while the ranking is on the vertical axis. Each International Airport is represented by a line is drawn indicating its net flow as function of C9 criterion weight. Thus, C9 signifies, Hartsfield–Jackson Atlanta International Airport (ATL), Atlanta United States and Miami International Airport, Florida, United States as the top and the least in performance among the sample of 50 international airports performing states respectively. The range of weights for C9 criterion is amid at 11.33% and 11.81%, this indicates the topmost ranking of airports within this range at the current position.

CONCLUSION

This paper has focused on the operative effectiveness of the international airports as air travelers has increased. This indeed mandates for the all the international airports to focus on the reduced cost of operations. The PROMETHEE GAIA approach is adopted for ranking the sample of 50 airports and the CRITIC method is used for allocation of weights to the 9 criterions. The paper concludes with the top ranking for the outmost operational performance achieved by Dallas/Fort Worth International Airport (DFW), (ATL) Hartsfield–Jackson Atlanta International Airport, Atlanta and (ORD) O'Hare International Airport Chicago. On the other hand, (KMG) Kunming Changshui International Airport, China performed negatively, and it is lagging behind their counterpart in the airport facilities. This paper provides a view for the decision makers the focus on the criterions vital for the performance of the international airports in the near future in consideration of the increasing air traffic along with the safety of the passengers.

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