Siphon effect among main airports in Beijing-Tianjin-Hebei region

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***Abstract*—Based on passengers' travel itineraries of domestic flights provided by the Umetrip, this study analyzes the siphon effect among four main airports(PEK、NAY、SJW and TSN) in the Beijing-Tianjin-Hebei Region, which is also named the Jing-Jin-Ji (JJJ) area. In this paper, we find that Beijing's two airports (PEK and NAY) have the most substantial siphon effect among these four airports, while SJW has the weakest siphon effect. It can be seen that Tianjin has narrowed its gap with PEK in attracting nonresidential passengers. However, the gap between SJW and others is still getting larger. Compared with the data of the Yangtze River Delta (YRD) region, passengers' distribution of the JJJ has presented a more seriously imbalanced status. Overall, this study points out that the situation of SJW is still far from optimistic. We suggest that SJW should take full advantage of short-distance transportation tools to attract passengers from Beijing and Tianjin, but the most important thing is to slow the trend of brain-drain through strengthening the competitiveness of the province itself.**

Keywords—the Beijing-Tianjin-Hebei Region Integration; Regional Development; Airports; Siphon Effect

I. INTRODUCTION

The integrated development of the JJJ area has gained much attention from society since the Beijing-Tianjin-Hebei Integration Plan was put forward in 2014. It is known that transportation is the foundation of the development of the JJJ area, whose imbalance, to a great extent, will restrict the progress of integration. As one of the significant roles in transportation, civil aviation also contributes largely to the JJJ Integration Plan. Therefore, the positions and functions of regional airports need to be further explored both in theory and practice. However, researches on airports in JJJ area are still rare, and most of them are traditional case studies. The opening of the new airport in Daxing(PKX) and the closure of Nanyuan(NAY) would bring uncertainty to the development of the JJJ airport group. To better understand the conditions and relationships of the JJJ airport group and to offer some theory and decision support for airports in future, this study quantitated the siphon effect of the JJJ airport group. Supported by the combination of big data technology and statistics methods, the relationship of airports in JJJ area is clarified. Reliable sample data in this study outbreaks regular case study and qualitative analytical method in the field of siphon effect. It is hoped that this study can provided support to the future research in this field and other relative fields.

In order to make it clear, some special expressions in this study were listed and explained as below.

Overall airlines: all airlines that all of the four airports have.

Fully competed airlines: if one airline starts from the four airports for the same destination, it is regarded as a fully competed airline.

Unique airlines:

PEK: the ITAT code of Beijing Capital Airport

NAY: the ITAT code of Beijing Nanyuan Airport

TSN: the ITAT code of Tianjin Binhai Airport

SJW: the ITAT code of Shijiazhuang Zhending Airport

II. LITERATURE REVIEW

Siphon effect is a physical phenomenon that takes advantage of different pressure in the liquid level. After filling a tube with liquid in an inverted u-shaped structure, the end with a high opening is placed in a container filled with liquid. The liquid in the container will continue to flow from the opening to a lower position through the siphon tube. Which is similar to regional development, the advantaged area usually makes use of the resource tube to consume the resource elements of the surroundings.

The academic world has not reached a consensus on its exact definition in regional development, but there are some similar concepts which are sometimes used as the siphon effect such as the backwash effect and the spread/the negative spillover effect. The development economists Myrdal G (1957)[1] is the first one to use the spread effect and backwash effect as tools to describe the circular cumulative causation between two neighbor areas, which provides a practical tool to further analyze the relationship among neighbor areas during the development period. It mainly focuses on the dynamic process. Gaile G L (1980)[2] explains the backwash effect as the negative influence that the central area brings about to the surroundings. Chiang S (2018)[3] claims that the spillover refers to the positive effect, and the backwash effect refers to the detrimental effect, which is similar to Gaile GL's explanation [2]. Fan etc. (2018) [4] use the negative spillover effect to describe the influence that developed area has brought about to its surroundings. In their study, the negative spillover effect is regarded as the same with the siphon effect. However, they

did not consider about whether the decreased resource has returned back to the advantageous area or not, the negative spillover in their study does not cover the back process, which will be considered in this study. Therefore, the siphon effect is not exactly equal to the negative spillover effect from such a perspective. Liu etc. (2013) [5], Yan etc. (2018) [6] and Feng (2018) [7] mention that the siphon effect is a phenomenon that the central city or advantageous city attracts the resources from its surroundings and bring about an adverse effect, which is much similar to the definition in this paper. In order to measure the relatively static status of the effect among airport groups, further description will be explained in this paper.

As for the researches of siphon effect in the regional development area, many researchers have a focus on case study and descriptive research, but only several of them have done quantitative studies. Zhu (2018) [8] tries to explore siphon effect with quantitative method. However, with the expert evaluation method and logit regression model to measure the siphon effect, the study is still more subjective when confirming the regression parameters. Which may bring about significant bias to verify the siphon effect.

III. Research Methods and Assumptions

A. The siphon effect of the airports

Based on the study of other scholars, the airport siphon effect in this study is defined and described as below. That is due to the existence of advantaged airports, passengers are attracted to change their original departing choice and contributes to an increase of passenger volume in advantaged airports. It is a relatively static perspective different from the backwash and the negative spillover effect as these two effects are more dynamic while siphon effect in this study is a comprehensive and static measurement. Which is more suitable to be used to present the overall interactive relationship among regional areas.

As one of the components of transportation, airport cluster play a very important role. The resources of each airport, such as the size, location, ticket price, flight frequency, as well as the number of airlines and popularity of city tourism, are not always the same. These differences would generate a resources' gap among airport cluster, which forms the different level as shown in the physical phenomenon of siphon effect, making some passengers choose to take flights from their neighbor airports rather than their native airports where they were born.

The change of passenger volume and its structure reflects the final status of an airport after being influenced by other airports. Based on the study of Liu etc. (2013) [5], Yan etc. (2018) [6] as well as Zhang and Xu (2007) [9], The major factors that influence the number of passengers is summarized as two part in this paper. One part comes from the city itself, such as the GDP, the employment capability, the education level and the population of residents. These resources usually tend to lead an increasing of the volume of residential passengers. Another part comes from the airports themselves, such as the location, the size, the price of the flights as well as the service. Therefore, the overall siphon effect of the airport could be reflected from these two parts and presented by the volume of passengers. We choose the volume of passengers as a comprehensive indicator to measure the siphon effect. Due to the spatial distance, the nearby airport clusters usually have stronger influence on each other than remote airports. When several airports are inter-effected, the mechanism of is getting more complicated. Therefore, we would like to better present the relationship of airport cluster with the support of a visual chart which shows the distribution of passengers and their choice.

B. Data and Sample

Among the nine airports in the JJJ region, we only select the four main airports (the PEK, the NAY, the TSN and the SJW) as our research airports and their passengers as the sample. According to the annual throughput of these nine airports. The total volume of other five airports in Hebei Province in 2018 are less than a million (see Fig 1), whose influence is relatively limited. In order to simplify this model, above four main airports are selected for further analysis. No direct airline exists between the three areas, except one flight destined to TSN stopping at SJW with an annual volume less than 4000 passengers which could be ignore in this study. Therefore, the influence between their tourism resources on civil aviation's passenger volume can be ignored.

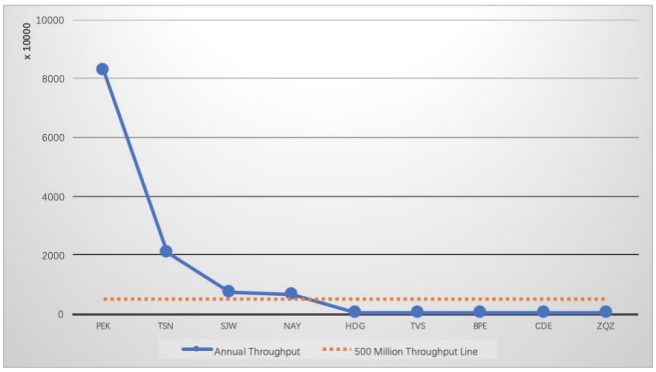

Fig. 1. The throughput volume of nine airports in JJJ area in 2018

The original data comes from the records of those passengers who has chosen to depart from above four airports in 2017 or 2018 with the support of the Umetrip. The international flights were excluded in this study. Passengers' residential information is identified through their ID numbers.

The change of passengers' volume brought by advantageous resources from the city itself can be reflected by the change of residential population from other places, which to some extent represents the siphon effect from the city or province itself. This part of effect could be estimated from the 6th population census carried out by the National Bureau of Statistics in 2010[10]. Table I presents the structure of residential population immigrated from other provinces. The total number of residents of Beijing, Tianjin and Hebei are 19.6 million,12.9 million and 71.8 million in 2010. And among these residents, Hebei natives account for about 7.95% and Tianjin natives account for 0.42%. Resident here in the national statistics is counted when a person has been stayed in a city over six months, as well as in countryside, town and city street. While native province is the place where a person was born. If one airport attracts more non-native passengers than others, these passengers could be the residents or non-residents. With the data from National Bureau of Statistics, the probability of non-residents could be easily estimated. And the gap between total volume and the volume of residents will be the siphon effect brought by the airport itself in the JJJ area.

TABLE I. THE RATIO OF RESIDENTS' DISTRIBUTION FROM THE JJJ AREA (BY 10THOUSANDS) SOURCE FROM :HTTP://WWW.STATS.GOV.CN/TJSJ/PCSJ/RKPC/6RP/INDEXCH.HTML

No. of Residents from other provinces	Residents in Beijing	Residents in Tianjin	Residents in Hebei
Total No. of Residents	1961.24	1293.82	7185.42
No. of Residents of Beijing Natives		2.27(0.18%)	7.47(0.10%)
No. of Residents of Tianjin Natives	8.305(0.42%)		6.50(0.09%)
No. of Residents of Hebei Natives	155.9(7.95%)	75.45(5.83%)	

To sum up, the research assumptions and hypotheses of this study are as follows:

A. Residents in the JJJ area are most likely to take flights in their own region, so the influence of other city's airports in the neighborhood on passengers' choice is not taken into consideration in this study.

B. If there is no relative advantages or disadvantages among these airports, or the advantages and disadvantages maintain a balance and backwash effect equals to spread effect, the structure of passengers from native or non-native in each airport should be randomly and not significantly different. When making departure choices, in theory, passengers will try to maximize their benefits. Thus, the larger the proportion of non-native passengers grow, the more significant the siphon effect of this airport is.

C. Under the same condition in 2017 and 2018 and if there is no obvious change of siphon effect from the airport or the city, there should be no significant differences in the structure of native and non-native passengers departing from these airports.

To verify the existence of siphon effect and its influence from more dimensions, this paper focus on all native passengers' data of the JJJ area who has departed from these four airports in 2017 and 2018, and test or make analysis under different conditions. To avoid the disturbance of abnormal data, airlines with an annual flight volume less than 12 are filtered out.

Overall, 32 fully competed airlines of the four airports in the JJJ area in 2017 are selected. In 2018, the number was 27 (Fig 2). Fig 3 displays overall airlines departing from four airports and the volume of JJJ passengers.

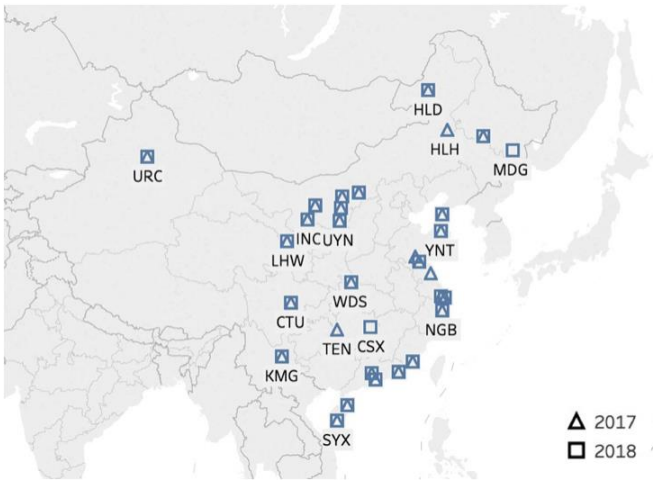

Fig. 2. The destinations of overall airlines opened by four airports in 2017 and 2018.

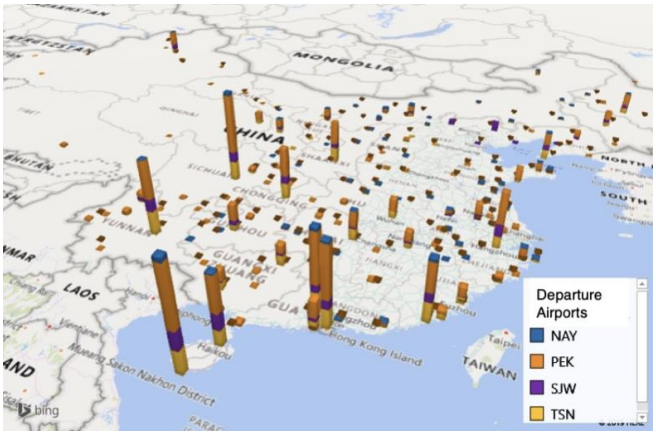

Fig. 3. The throughput of overall airlines by departure airports in 2018.

Samples in Table II were selected to explore the structure of passengers of the four airports in different period and different airline scopes. Samples in Table III were selected to explore the change of siphon effect of different airports.

TABLE II. THE NUMBER OF SAMPLES IN TWO AIRLINE SCOPES IN 2017 AND 2018.

Year / Airline Scope	Y2017	Y2018
Fully Competed Airlines	sample A1 7787664	sample A2 8453415
Overall Airlines	sample A3 12929918	sample A4 13850827

TABLE III. THE NUMBER OF SAMPLES IN TWO SCOPES AND FOUR AIRLINES IN 2018.

Airline Scope / Airports	Overall Airlines	Fully Competed Airlines
NAY	sample B1 662235	sample B2 1072222
PEK	sample B3 9358904	sample B4 15297479
TSN	sample B5 3943501	sample B6 6671005
SJW	sample B7 2276439	sample B8 3740039

At the same time, on the basis of the research above, to further explore the attraction of the four main airports in the JJJ Region to passenger volume, this study made a comparative analysis of each airport's unique airlines with the data of 2018, taking passengers in Beijing, Tianjin and Hebei as three groups of samples.

In order to further explore the siphon effect of the four main airports in the JJJ area on the basis of the research above, chi-square test analysis was made. A Chi-square statistic test is a measure of how different the data we observe are to what we would expect to observe if the variables were truly independent.

The formula is as below:

$$\chi^2 = \sum \frac{(f_O - f_E)^2}{f_E}$$

$f_O = observed\ frequencies$

$f_E = expected\ frequencies$

IV. Anslysis of Siphon Effect

A. Analysis of the structure of passengers of the four airports

Table IV presents the structure of passengers group by ID cards and airports with the samples come from overall domestic airlines. And table V shows the structure of passengers group by ID cards and airports with the samples come from fully-competed airlines.

TABLE IV. The Structure of Native and non-native Passengers with the sample of overall domestic airlines in 2017 and 2018

Year	Passengers' ID	PEK	NAY	TSN	SJW
2017	local	5010981 (66. 3%)	282244 (55. 0%)	1967490 (62. 4%)	1676777 (98. 1%)
	non-local	2544094 (33. 7%)	230681 (45. 0%)	1185766 (37. 6)	31885 (1. 9%)
2018	local	5075592 (65. 6%)	307342 (55. 0%)	2095789 (59. 6%)	1990786 (98. 0%)
	non-local	2666812 (34. 4%)	251955 (45. 5%)	1421958 (40. 4%)	40591 (2. 0%)

TABLE V. The Structure of Native and non-native Passengers with the sample of the fully-competed airlines in 2017 and 2018

Year	Passengers' ID	PEK	NAY	TSN	SJW
2017	local	3059465 (66. 8%)	186624 (55. 7%)	1138617 (62. 7%)	1036884 (98. 3%)
	non-local	1522103 (33. 2%)	148704 (44. 3%)	677510 (37. 3%)	17757 (1. 7%)
2018	local	3159477 (66. 1%)	181846 (55. 6%)	1270626 (59. 7%)	1198568 (98. 1%)
	non-local	1617859 (33. 9%)	145061 (44. 4%)	856748 (40. 3%)	23230 (1. 9%)

This study divided the groups by the airport and the year respectively. The samples A1- A4 from table II are grouped by the airport, and the samples B1-B8 from table III is grouped by the year. The significance threshold was set at .05, and the method of chi-square is adopted to test the difference of passengers' structure of the airport. The null hypothesis is that there is no significant difference in the ratio of native and non-native residents in four airports.

The result shows that all P values in group A1-A4 are less than 0.01, which is statistically significant. For the groups of B1-B8, the P value of the NAY airport is statistically not significant(p=0.8209), while for the others, P value is larger than 0.01 and is statistically significant (Table VI). It means that we have about 99% probability to think that no matter what the airline scope is, the four main airports have a significantly different attraction for native passengers and non-native passengers rather than the random choice. During the year of 2007 and 2008, the structure of passengers departing from NAY is stable and its ratio is approaching 1:1. While the passengers' structure of passengers in other three airports have been statistically significantly changed.

TABLE VI. Chi-square test of the structure of each airports in 2018 (the *** means significantly less than 1%.)

Departure Airports	Year	local	non-local	Chi-square	P value
NAY	2017	55.65%	44.35%	0.0513	0.8209
	2018	55.63%	44.37%		
PEK	2017	66.78%	33.22%	433.66	<2.2e-16
	2018	66.13%	33.87%		***
TSN	2017	62.69%	37.31%	3629.2	<2.2e-16
	2018	59.73%	40.27%		***
SJW	2017	98.32%	1.68%	151.46	<2.2e-16
	2018	98.10%	1.90%		***

As for the airports in the JJJ area, the ratio of the JJJ non-native residents departing from an airport presents the degree of the airport's attractiveness. The amount of non- native passengers in NAY airport accounts for about 44% while the percentage is only 2% in SJW. According to the statistics data in 2010 from the statistic bureau, the non- native residents in Hebei account for only 1.9%. To some extent, it could be estimated that the siphon effect mainly comes from the city itself. If the siphon effect from the city itself is excluded, the influence of SJW seems quite limited.

B. Anslysis of the passengers' choice about departure airports in fully competed airline

In order to compare the differences of siphon effect among four main airports in the year of 2017 and 2018, this study visualized the siphon effect as is shown in Fig 4 based on the data of table VII.

TABLE VII. The departed choice of passengers of the JJJ area in 2017 and 2018.

Year	Selected Airports	Beijing Origin	Tianjin Origin	Hebei Origin
2017	PEK	92. 7%	14. 7%	42. 6%
	NAY	5. 6%	1. 0%	4. 3%
	TSN	1. 4%	83. 8%	20. 3%
	SJW	0. 3%	0. 5%	32. 8%
2018	PEK	92. 7%	14. 2%	45. 5%
	NAY	5. 4%	0. 9%	4. 3%
	TSN	1. 6%	84. 6%	26. 0%
	SJW	0. 3%	0. 4%	24. 1%

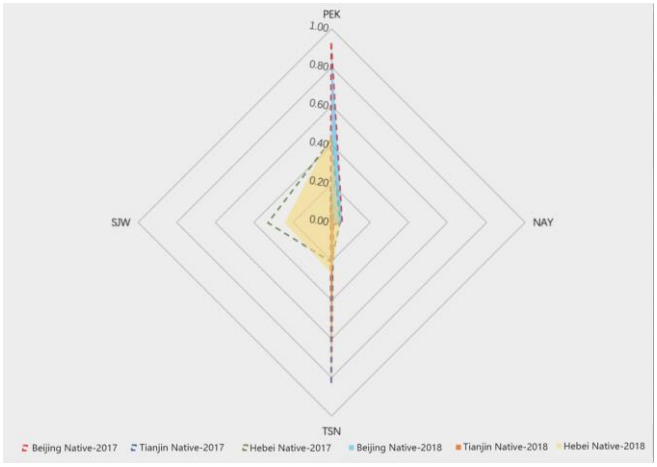

Fig. 4. The distribution of departed choice of passengers of JJJ the area in 2017 and 2018

Fig 4 presents that passengers from three places make different decisions when faced with the choice between the local airport and the neighbor airport. Those Beijing natives mainly choose the two airports in Beijing, with less than 2% of them choose TSN or SJW. Compared to that,15%

of Tianjin natives preferred to take planes in Beijing and 67% of Hebei natives chose to take flights from Beijing and Tianjin, which is more diversified.

Compared with the data in 2017, 75% of passengers chose neighbor airport in 2018.Among them,45.5% of passengers chose to go to PEK and 26% of them chose TSN. There is a significant increase of Hebei natives who depart from Tianjin, which is about 6%. Although PEK has the most significant siphon effect, the attraction of TSN cannot

be ignored. For the siphon effect, the gap between PEK and TSN is becoming smaller; Both of them attracted passengers from Hebei, which results in a lack of siphon effect of SJW.

Based on airport choices of residential passengers, to better clarify the differences of siphon effect among the four airports in 2017 and 2018, this study constructs the airport siphon effect chart (Fig 4) under shared airlines according to statistics in Table VII.

Fig 4 indicates that when passengers from different places are making choices with local and remote airports, their decisions are not similar. Instead, they show a distinct regional difference. Native passengers from Beijing mainly choose the two airports in Beijing, with less than 2% of them taking planes in TSN and SJW. About 15% of residential passengers in Tianjin show a preference to leaving from PEK. What is more, native passengers from Hebei show a distinguished diversity. Over 67% of them take planes in Beijing and Tianjin. Compared with data of 2017, the tendency is more evident in 2018, reaching 75%. 45.5% of Hebei native passengers take planes in Beijing, and 26% in Tianjin. However, the rate of Tianjin rose significantly in 2018, increasing about 6 percentage point. The siphon force of Tianjin Airport to Hebei residents strengthened remarkably. Although Beijing is equipped with stronger siphon effect, that of Tianjin is increasing with a faster trend. The difference of siphon effect between Beijing and Tianjin airports keeps narrowing, while Hebei Zhending Airport is experiencing a loss of passengers.

Take the airlines which departing from the JJJ area to Shanghai as an example (Fig 5), when considering about Hebei natives, from 2017 to 2018, SJW has experienced a decrease of passenger's origins from Hebei, while the amount of the decreased passengers has chosen to depart from TSN. Overall, over 65% of Hebei passengers has chosen the PEK and TSN to Shanghai.

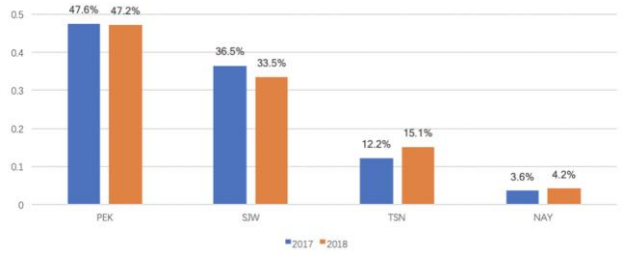

Fig. 5. The distribution of Hebei natives from the JJJ area to Shanghai in 2017 and 2018

When considering about fully competed airlines, residents in the Beijing-Tianjin-Hebei Region also show great differences, which to some extent shows the imbalanced effect among the airports. Between Beijing and Tianjin, Beijing also shows the siphon effect to the native residents of Tianjin. Based on the statistics in Fig 1, the siphon effect among airports are much stronger than that of cities themselves. So, we can conclude that besides the siphon effect brought city resources, advantages of PEK and TSN airports also bring significant siphon effect.

C. Anslysis of the passengers' choice about departure airports in unique airline

The unique airlines in this study can be also regarded as the compete-less airlines. In order to further explore the siphon effect, this study chooses the unique airlines as the scope and makes an analysis on passengers' decisions making behavior. The special airlines of each airport and the passengers' decision are shown in Fig 6 and Fig 7 respectively. For the passengers of SJW, the id cardholders who come from Beijing and Tianjin account for less than 3%. The Hebei id cardholders account for 34%、40% and 38% respectively in PEK、NAY and TSN.

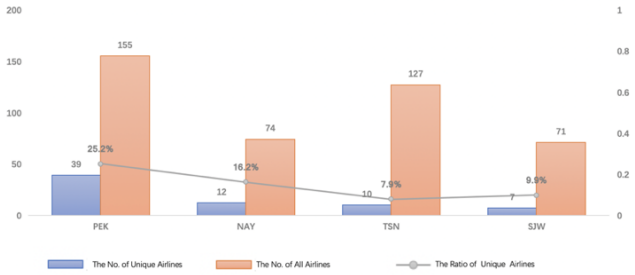

Fig. 6. The Ratio of Unique Airlines.

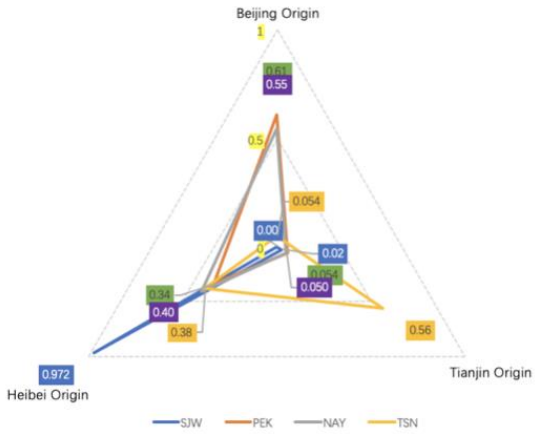

Fig. 7. The Distribution of departed choice of passengers.

For the scope of special airlines, the relative advantages are not that significant as shared airlines. However, as the proportion of passengers in special airlines of each airport is less than 0.5%, the influence on the overall siphon effect is quite limited.

With the analysis on 7 main airports which has the passenger throughput more than 5 million of the Yangtze River Delta Area, the relationship is presented in Fig 8. Compared to airports in Shanghai, Zhejiang, and Jiangsu, the airport of Anhui(HFE) has encountered a larger challenge from its neighbor airports. However, when compared with the group of airports in Yangtze River Delta Area, the Beijing-Tianjin-Hebei Region seems more imbalanced. As for SJW airport, the effect from Beijing and Tianjin is quite significant, and the imbalance of capital circle areas is becoming more and more serious.

It is necessary to reconsider the orientation of each airport and the function of each city to solve the imbalanced development and achieve the goal of the "Beijing- Tianjin-Hebei Integration Plan."

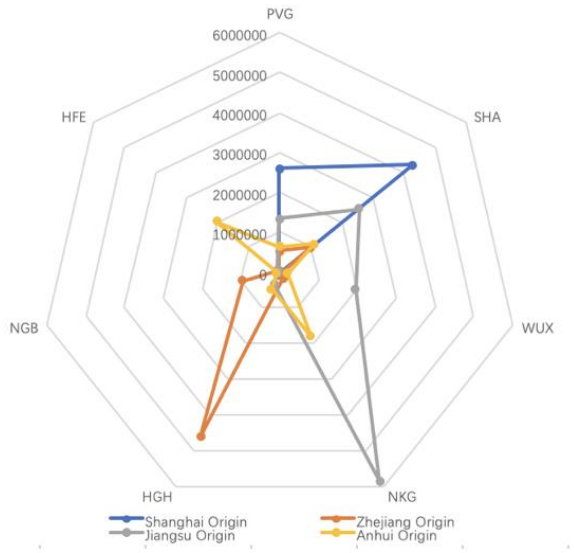

Fig. 8. The Siphon Effect of the YRD area.

V. Conclusion

In conclusion, this study firstly selected passengers' data in different airline scopes as samples and verified that the siphon effect exists among airports according to the definition of siphon effect. The scopes of the samples are listed as below:

The first scope is the analysis on all airlines starting from four airports; the second scope mainly focusing on the airlines with the same destination, which can be regarded as the fully competed airlines, and the third is the analysis from relatively unique airlines that not all neighbor airports have. The sample includes nearly 30 million passengers who reside in the JJJ area and depart from the four airports in the year of 2017 and 2018.

Secondly, the relationship among four airports was analyzed, and the siphon effect was visualized. In terms of fully competed airlines, both of the TSN airport and SJW airport saw a significant increase of 12% and 15% respectively in the volume of local natives in 2018 compared with 2017.

Finally, it is pointed out that the SJW almost has no siphon effect on the other three airports while the TSN has experienced a sharp rise in the attraction to Hebei passengers. As the passengers' structure is quite stable in 2017 and 2018, and Tianjin passengers account for only 1%, it can be predicted that the passengers from Tianjin will be less influenced when compared with passengers from Beijing and Hebei province.

The research on the siphon effect within different economic regions is also an important direction in future's research. With the establishment of Daxing airport and the closeness of NAY in 2019, the siphon effect among these airports may change soon. How the siphon effect between airport clusters change and how it affects the transportation decisions among different groups worth further discussion and exploration.

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