Analysis of Public Transportation Travel Characteristics of the Elderly based on IC Card Big Data-Taking Qingdao as an Example

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Abstract: Due to technical limit, it is difficult to get the public transportation orient-destination (OD) data in Qingdao. In despite of limited data, the paper introduced a new way to conduct bus passenger flow analysis, taking trip characteristics of the elderly in Qingdao as an example. Based on the analysis of IC card data in various time slots, cluster analysis of typical bus lines, combined with urban population data and person trip survey data, the paper analyzed the passenger bus travel characteristics of the elderly, especially their utilization of public transportation resources.

1. Introduction
The bus IC card charging system provides low-cost, high-quality data for passenger bus travel analysis. For one-vote (single-swipe) bus lines, only when the correspondence between passenger IC card data and bus stops GPS data is established, can the IC card data be used to derive the bus travel OD data. However, restricted by current technical level, it is difficult to connect IC card data, vehicle running GPS data and site GPS data in most cities of China. Therefore, bus trip OD data is unavailable in many cases.

There is such a problem in Qingdao that the bus running GPS data is of low quality and cannot be corresponded to IC card data due to inconsistent data standard. As a result, the collection of bus passenger flow data is still heavily used by manual survey methods. With the absence of bus trip OD data, this paper analyzed passenger bus travel characteristics of the elderly, especially their utilization of public transportation resources, as well as introduced a new way to conduct bus passenger flow analysis based on limited IC card data.

2. Research Process
The research aimed to answer questions including whether the elderly has used too much public transportation resources, and whether it affects rigid public transportation demand of commuters and students, especially during peak hours. Based on the analysis of IC card data in various time slots, cluster analysis of typical bus lines, and combined with urban population data and person trip survey data, the research was conducted in the following way.
3. **Assumptions**

Since passenger volume of the elderly using cash could not be identified, the total passenger volume of the elderly was assumed to be the same as the number of the elderly (aged over 60) using IC cards. The reason is:

Citizens over 60 in Qingdao enjoy half-price or free discount when using IC cards. To get the most of the benefits, it is reasonable to assume that most of them will not pay by cash.

4. **Overall Bus Travel Characteristics**

4.1. **Overall Passenger Volume Distributions**

The following table compares passenger volumes and ratios of the elderly and other citizens from May 2016 to April 2017.

During this period, the passenger volume of the elderly over 60 was 167.94 million, accounting for 16.5% of all population. Among them, the passenger volume of the elderly aged 60-64 was 49.84 million, accounting for 4.9% of all population. The passenger volume of the elderly over 65 was 11.81 million, accounting for 11.6% of all population. The passenger volume of other citizens was 85.152 million, accounting for 83.5% of all population.

| Group                          | Bus Passenger Volume (million) | Proportion |
|--------------------------------|-------------------------------|------------|
| The Elderly aged 60-64 (Half-price Card) | 4.984                        | 4.9%       |
| The Elderly over 65 (Free Card)    | 11.810                        | 11.6%      |
| Subtotal                         | 16.794                        | 16.5%      |
| Subtotal of Other Groups         | 85.152                        | 83.5%      |
| Total of All People              | 101.946                       | 100.0%     |

4.2. **Passenger Volume Distributions in Typical Bus Lines**

The cluster analysis was conducted on all 361 bus lines in Qingdao, based on the ratio of passenger volume of the elderly over 60 to the total passenger volume.
4.2.1. Bus Lines with Highest Elderly Proportion
The following table demonstrates the 7 bus lines with the highest proportion of elderly volume to all passengers. The proportions of all 7 lines were over 50%, with the highest of 68.5%. Plus, all of them were branching lines.

Table 2. Bus Lines with the Highest Elderly Proportion (May 2016 - April 2017)

| Bus Line | Total Passenger Volume (Thousand) | The Proportion of the Elderly to the Total Passenger Volume | Rank | Line Type |
|----------|----------------------------------|----------------------------------------------------------|------|-----------|
| 675      | 87.2                             | 68.5%                                                    | 1    | Branching |
| 674      | 11.9                             | 64.5%                                                    | 2    | Branching |
| 466      | 16.4                             | 64.1%                                                    | 3    | Branching |
| 467      | 300.0                            | 63.0%                                                    | 4    | Branching |
| 463      | 67.0                             | 56.1%                                                    | 5    | Branching |
| 40       | 69.3                             | 51.4%                                                    | 6    | Branching |
| 618      | 221.1                            | 50.1%                                                    | 7    | Branching |

4.2.2. Bus Lines with Lowest Elderly Proportion
The following table demonstrates the 7 bus lines with the lowest proportion of elderly volume to all passengers. The proportions of all 7 lines were below 10%, with the lowest of 0.7%. And all of them were branching lines as well.

Table 3. Bus Lines with the Lowest Elderly Proportion (May 2016 - April 2017)

| Bus Line | Total Passenger Volume (Thousand) | The Proportion of the Elderly to the Total Passenger Volume | Rank | Line Type |
|----------|----------------------------------|----------------------------------------------------------|------|-----------|
| 776      | 2.1                              | 7.0%                                                     | 354  | Branching |
| 114      | 424.5                            | 4.8%                                                     | 355  | Branching |
| 770      | 137.7                            | 3.9%                                                     | 356  | Branching |
| 772      | 20.3                             | 3.2%                                                     | 357  | Branching |
| 38       | 194.4                            | 2.2%                                                     | 358  | Branching |
| 802      | 334.6                            | 1.8%                                                     | 359  | Branching |
| 805      | 304.2                            | 0.7%                                                     | 360  | Branching |

4.2.3. The Elderly Proportion in Express and Main Bus Lines
The proportions of elderly volume to all passengers varied widely in different express and Trunk Lines. Some were higher than 35%, as indicated in the following table.

Table 4. Express and Trunk Lines with Highest Proportion of Elderly (Over 35%) (May 2016 - April 2017)

| Bus Line | Total Passenger Volume (Thousand) | The Proportion of the Elderly to the Total Passenger Volume | Rank | Line Type |
|----------|----------------------------------|----------------------------------------------------------|------|-----------|
| 220      | 2563.2                            | 41.5%                                                    | 19   | Trunk     |
| 217      | 2677.4                            | 40.4%                                                    | 22   | Trunk     |
| 36       | 5276.8                            | 39.2%                                                    | 26   | Trunk     |
| 212      | 3139.8                            | 38.5%                                                    | 28   | Trunk     |
| 604      | 4106.8                            | 37.6%                                                    | 35   | Trunk     |
| 219      | 3828.2                            | 37.6%                                                    | 36   | Trunk     |
| 209      | 5276.5                            | 35.2%                                                    | 43   | Trunk     |

Contrarily, some were lower than 16.5%, as indicated in the following table.
Table 5. Express and Trunk Lines with Lowest Proportion of Elderly (Below 16.5%) (May 2016 - April 2017)

| Bus Line | Passenger Volume of the Elderly aged 60-64 (Thousand) | Passenger Volume of the Elderly aged over 65 (Thousand) | Passenger Volume of the Elderly aged over 60 (Thousand) | Total Passenger Volume (Thousand) | The Proportion of the Elderly to the Total Passenger Volume | Rank | Line Type |
|----------|------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|----------------------------------|------------------------------------------------------------|------|----------|
| 125      | 253.0                                                | 478.3                                                | 731.3                                                | 5509.6                           | 13.3%                                                      | 316  | Trunk    |
| 503      | 71.5                                                 | 171.6                                                | 243.0                                                | 1914.8                           | 12.7%                                                      | 326  | Trunk    |
| 28       | 162.7                                                | 318.1                                                | 480.8                                                | 4020.0                           | 12.0%                                                      | 335  | Trunk    |
| 502      | 181.3                                                | 387.7                                                | 569.0                                                | 4792.8                           | 11.9%                                                      | 336  | Trunk    |
| 102      | 161.4                                                | 294.5                                                | 455.9                                                | 3906.8                           | 11.7%                                                      | 337  | Trunk    |
| Tunnel 1  | 137.4                                                | 310.6                                                | 448.1                                                | 3846.8                           | 11.6%                                                      | 338  | Trunk    |
| 30       | 153.2                                                | 299.2                                                | 452.4                                                | 4140.7                           | 10.9%                                                      | 341  | Trunk    |
| 2        | 118.5                                                | 256.9                                                | 375.4                                                | 3570.0                           | 10.5%                                                      | 344  | Trunk    |
| 15       | 232.3                                                | 462.5                                                | 694.8                                                | 6967.9                           | 10.0%                                                      | 346  | Trunk    |

4.2.4. Bus Lines with Highest Elderly Volume

The following table indicates the top 10 bus lines with highest elderly passenger volume. Among them, 1 line had elderly passenger volume of over 3 million, 4 over 2 million, and 5 under 2 million. The proportions of elderly to total passenger volume in each bus line were between 20% and 28%, ranking between 26 and 112.

Table 6. Bus Lines with Highest Elderly Volume (May 2016 - April 2017)

| Bus Line | Passenger Volume of the Elderly aged over 60 (Thousand) | IC card Passenger Volume (thousand) | Total Passenger Volume (thousand) | The Proportion of Elderly Over 60 to Total Passenger Volume | Rank |
|----------|--------------------------------------------------------|-------------------------------------|----------------------------------|------------------------------------------------------------|------|
| 1        | 3300                                                   | 9550                                | 13540                            | 24.4%                                                      | 47   |
| 307      | 2210                                                   | 7570                                | 10730                            | 20.6%                                                      | 93   |
| 302      | 2160                                                   | 7710                                | 10920                            | 19.8%                                                      | 112  |
| 309      | 2080                                                   | 7270                                | 10310                            | 20.1%                                                      | 104  |
| 36       | 2070                                                   | 5280                                | 7480                             | 27.6%                                                      | 26   |
| 25       | 1960                                                   | 6760                                | 9590                             | 20.4%                                                      | 97   |
| 209      | 1860                                                   | 5280                                | 7480                             | 24.8%                                                      | 43   |
| 364      | 1850                                                   | 5760                                | 8170                             | 22.7%                                                      | 65   |
| 32       | 1820                                                   | 6470                                | 9180                             | 19.8%                                                      | 110  |
| 206      | 1780                                                   | 5710                                | 8090                             | 22.0%                                                      | 69   |

The following figure shows the distribution of 10 typical bus lines, mainly operating in Shinan District, Shibe District and Licang district.
The following table shows the number of featured area covered by typical bus lines, including hospitals, primary and secondary schools, parks and large residential districts in downtown. These places are commonly considered as the starting and end points for the elderly to go to hospitals, look after children, and relax, showing great attraction for senior citizens.

| Bus line | Number of Hospitals | Number of Primary and Secondary Schools | Number of Parks | Number of Large Residential Districts |
|----------|---------------------|----------------------------------------|----------------|--------------------------------------|
| 1        | 1                   | 1                                      | 0              | 0                                    |
| 307      | 2                   | 1                                      | 0              | 4                                    |
| 302      | 1                   | 2                                      | 2              | 1                                    |
| 309      | 2                   | 1                                      | 0              | 3                                    |
| 36       | 0                   | 1                                      | 1              | 4                                    |
| 25       | 0                   | 3                                      | 0              | 0                                    |
| 209      | 0                   | 1                                      | 0              | 1                                    |
| 364      | 2                   | 1                                      | 1              | 6                                    |
| 32       | 0                   | 2                                      | 0              | 2                                    |
| 206      | 0                   | 2                                      | 1              | 2                                    |

4.3. Comparison between Elderly Bus Passenger Volume and Population Proportion

The following figure shows that the proportion of the elderly passenger volume to the total passenger volume (16.5%) was higher than the proportion of the elderly population in the total population (13.6%). In the top ten bus lines with highest elderly passenger volume, all of them had the proportion of the elderly passenger volume to the total passenger volume over 19.8%, which was higher than the elderly population proportion.
5. **Bus Travel Characteristics during Different Time Slots**

5.1. **Comparison between the Elderly and Other Citizens**

5.1.1. **Passenger Volume Distribution in Peak Hours**

The following table shows the comparison of the passenger volume and proportion during peak hours between the elderly and other citizens. The passenger volume of the elderly over 60 was 47.66 million, accounting for 16.8% of all people. Among them, the passenger volume of the elderly aged 60-64 was 15.39 million, accounting for 5.4% of the total; the passenger volume of the elderly over 65 years old was 32.27 million, accounting for 11.4% of the total. The passenger volume of other groups was 230.64 million, accounting for 83.2% of the total.

In terms of passenger volumes in peak hours, the elderly over 60 was 26.82 million during morning peak hours, accounting for 18.9% of the total, and 20.84 million during evening peak hours, accounting for 14.7% of the total. Therefore, the proportion of the elderly passengers was higher in morning peak hours than that in the evening.

**Table 8. Passenger Volumes and Proportions of the Elderly and Other Citizens in Peak Hours (August 2016 - July 2017)**

| Group                        | Passenger Volume during Morning Peak Hours (Million) | Proportions to Total Passenger Volume | Passenger Volume during Evening Peak Hours (Million) | Proportions to Total Passenger Volume | Total Passenger Volume (Million) | Proportions to Total Passenger Volume |
|------------------------------|------------------------------------------------------|---------------------------------------|------------------------------------------------------|---------------------------------------|-----------------------------------|---------------------------------------|
| Elderly aged 60-64(half-price card) | 7.89                                                 | 5.6%                                  | 7.5                                                  | 5.3%                                  | 15.39                             | 5.4%                                  |
| Elderly aged over 65(free card)    | 18.93                                                | 13.3%                                 | 13.34                                                | 9.4%                                  | 32.27                             | 11.4%                                 |
| Subtotal                        | 26.82                                                | 18.9%                                 | 20.84                                                | 14.7%                                 | 47.66                             | 16.8%                                 |
| Sum of Other Groups             | 115                                                  | 81.1%                                 | 121.04                                               | 85.3%                                 | 236.04                            | 83.2%                                 |
| Sum of All People               | 141.82                                               | 100.0%                                | 141.88                                               | 100.0%                                | 283.7                             | 100.0%                                |

5.1.2. **Passenger Volume Distribution in Tourism Seasons and Other Seasons**

The following two figures compare the distribution of elderly passenger volume and proportion on 4/10/2017 (Monday) and 7/24/2017 (Monday). Generally Speaking, in terms of passenger volume,
4/10/2017 was higher than 7/24/2017 in usual period and evening peak hours, no significant difference in morning peak hours; in terms of passenger proportion, 4/10/2017 was higher than 7/24/2017 in usual period, no significant difference in both morning and evening peak hours.

5.1.3. Passenger Volume Distribution in Different Time of the Day

The following figure indicates the distribution of elderly passenger proportion on 4/10/2017. It can be concluded that the proportion varied a lot during different time slots of the day. Generally, the elderly had a higher proportion during the usual period, and much lower during peak hours.
5.2. Comparison between Peak Hours and All Day Elderly Proportion

5.2.1. The Elderly aged 60-64
During August 2016 – July 2017, the number of passenger volume in the morning and evening peak hours of the elderly people aged 60-64 was 8.57 million and 8.58 million respectively. The elderly passenger volume difference in the morning and evening peak hours was insignificant, accounting for 16.1% and 15.2% of the whole day. The average morning and evening peak hours elderly passenger volume in each month was 0.71 and 0.67 million respectively.

Generally, the number of 60-64 year senior citizens in the morning peak hours was greater than that of the evening peak.

In January and February, due to temperature, school break and spring festival, the elderly passenger volume was reduced by 0.1 million in the morning peak hours, and became lower than evening.

![Figure 7. Passenger Proportion of the Elderly aged 60-64 to the Whole Day](image)

5.2.2. The Elderly over 65
During August 2016 – July 2017, the number of passenger volume in the morning and evening peak hours of the elderly people over 65 was 20.7 million and 14.44 million respectively, accounting for 16.9% and 11.8% of the whole day. The average morning and evening peak hours elderly passenger volume in each month was 1.72 and 1.2 million respectively, with the morning higher than evening by 43%.

The travel characteristics of the elderly over 65 was similar as 60-64. The morning volume was lower in January and February, and morning volume was greater than the evening in most months.

![Figure 8. Passenger Proportion of the Elderly aged over 65 to the Whole Day](image)
5.3. Peak Hours Characteristics by Qingdao Person Trip Survey

According to Qingdao Person Trip Survey Report (2016), the public transportation travel proportion for all citizens during peak hours of the whole day was about 46%.

![Figure 9. Time Distribution of Different Trip Modes](image)

According to IC card data from August 2016 to July 2017, the average daily bus travel trips of citizens aged 60-64 and over 65 were 0.147 million and 0.339 million respectively, with 0.486 million in total. During morning peak hours, the average daily bus travel trips of citizens aged 60-64 and over 65 were 0.022 million and 0.04 million respectively, with 0.062 in total, accounting for 12.8% of the whole day. During evening peak hours, the average daily bus travel trips of citizens aged 60-64 and over 65 were 0.024 million and 0.057 million respectively, with 0.081 in total, accounting for 16.7% of the whole day.

Compared with peak hours proportion for all citizens (46%), peak hours proportion for the elderly (29.5%) is much lower.

6. Conclusions

6.1. Conclusion of the Elderly’s Overall Usage of Public Transportation Resources

The data analysis shows that the proportion of the elderly passenger volume to the total passenger volume in Qingdao (16.5%) was about 3% higher than the population proportion of the elderly people (13.6%), indicating that the amount of public transportation resources used by the elderly in Qingdao was higher than that of other citizens.

According to Qingdao Person Trip Survey Report (2016), the average daily bus travel trips of the elderly was 0.69 times per day, and the daily average bus travel trips of the all citizens was about 0.46 times per day, also proving that the elderly used public transportation resources more frequently than other citizens.

According to the analysis of typical express and trunk lines, the passenger proportion of the elderly was significantly different. The highest line was over 40%, and even the lowest line was more than 10%. In terms of top 10 lines with the highest elderly passenger volume, the elderly passenger proportions were all over 19%, higher than the proportion in all bus lines (16.5%). That is to say, the elderly had more intensive use of public transportation resources in express and trunk lines.

14 bus lines with the highest and the lowest elderly passenger volume proportion were all branching lines, showing that the use intensity of public transportation resources by the elderly was strongly related to the area covered by the line and might lead to significant differences.
6.2. Conclusion of the Elderly’s Usage of Public Transportation Resources during Peak Hours

The data analysis shows that elderly passenger proportion to all passing volume (16.8%) was higher than elderly population proportion (13.6%) by about 3%, with morning (18.9%) higher by about 5% and evening (14.7%) by about 1%. In other words, the use intensity of public transportation resources for the elderly was higher than other citizens, and especially during peak hours.

The analysis of passenger volume distribution during different time slots on 4/10/2017 shows that, the elderly passenger proportion to all day elderly passenger volume was higher during usual time on the day, and much lower during peak hours. Combined with Qingdao Person Trio Survey(2016), peak hours elderly passenger proportion to all passenger volumes (29.5%) is much lower than all citizens’ peak hours proportion to all day (46%). That is to say, the elderly were more likely to take bus during usual period.

In general, although the elderly were more likely to take bus during usual period, compared with the rigid demand of bus travel by commuters, the elderly’s usage of public transportation resources might be too much during peak hours, since their bus travel demand during peak hours was not considered rigid demand.

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