Analysis of the Key Points for Increasing Passenger Traffic Efficiencies Based on Measurements of Traffic through Ticket Gates in 3 Cities.

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Abstract — By 2012, the passenger traffic capacity for rail transport in Guangzhou reached the highest level of all the cities in China. A questionnaire survey of commuters revealed that 42% of those interviewed in Guangzhou thought the ticket Automatic Gate Machine (AGM) was the most time-consuming aspect of the rail transport system, and its capacity could not meet commuter demand. Therefore, this research focused on the ticket gate machine and its effect on passenger traffic. In addition, concentrating on the sensor area of the ticket gate machine and investigating the machines in Guangzhou, Shenzhen and Hong Kong regions, the optimized key points for increasing passenger traffic efficiencies were found. These were whether the sensor areas lay flat or oblique and whether raised or not, and the color design of the sensor area.

Keywords- Railroad transportation; Traffic ability; Metro devices and systems; Public security; Ticket gate machine; Sensor area

I. INTRODUCTION

Line 1 of the Guangzhou (GZ) rail transport system was opened to traffic on June 28th, 1997. Ten routes are now in operation, including the Guangfo and APM lines. Guangzhou rail commuter numbers increased more rapidly than expected in recent years. The data show that the average daily traffic of the metro has grown by 64% annually [1], 1.85 million in 2009, 3.92 million in 2010, 4.5 million in 2011, and reached nearly 5 million in February 2012. The above data showed that the intensity of passenger flow in the Guangzhou rail transit system reached the highest level in China, and reflected the congestion level of Guangzhou rail transit traffic [2].

Taking this into consideration, we carried out questionnaire surveys of Guangzhou commuters on their subjective views on the current status of the rail transport system and analyzed the data. Of the 96 recovered questionnaires 65% of the respondents considered that the Guangzhou rail transport system was very crowded and 22% that it was crowded. These top two factors constituted 87% of the research results (Fig.1). 42% said they spent too much time at the automatic gate machines (Fig.2) and 40% spent too much time on the platforms. To resolve the problem of spending too much time on the platforms we needed to optimize the transit operation and to resolve the problem of spending too much time at the rail transit gates we needed to analyze the effect of the ticket gates on passenger flow.

However according to the survey carried out in Hong Kong (HK), we found that public satisfaction with the rail transit system was generally higher than that of Guangzhou, although both cities are international financial centers, and are subjected to high rail transit passenger flow. In particular, on the problem of time delays at peak times on rail transit, only 28% of HK citizens encountered a "gates jam" problem.

Ticket gates are the interface points between paid areas and free areas in a metro station, and form the narrowest point in the passenger flow lines [3]. Aiming at free flowing passenger-flow lines without disastrous holdups the research focused on automatic gate machines following the results of the questionnaire surveys. According to these and comparing the automatic gate machines in Guangzhou, Shenzhen and HK, we analyzed the advantages and disadvantages of a variety of automatic gate machines, and proposed optimum strategies for increasing passenger traffic efficiencies.

Figure 1. Opinions about GZ Rail Traffic Congestion

Figure 2. Opinions of the Retention Time in GZ Rail Traffic
II. DATA COLLECTION AND ANALYSIS

A. Analysis of Rail Traffic Gates Use

The design of the station level equipment of an automatic gate machine (AGM) in the rail transit automatic fare collection system (AFC), requires ease of use by commuters, effective guidance of passenger flow and the important objective of the rapid evacuation of passengers in cases of emergency [4].

The methods of passengers going through ticket gates can be divided into:

1) "normal access", a passenger handing a valid ticket can be quickly identified and released normally by an AGM.
2) “non-normal access”, any situation except “normal access” (such as holding a damaged ticket or insufficient payment, not knowing how to use the gate machines or carrying oversize or overweight objects). These situations will result in a passenger not being able to access in time and having to return to attempt to pass through the gate a second time [5].

Because this study focuses on the effects of AGM design in enabling normal access by a passenger in a non-disaster mode [6,7], “non-normal access” situations are not dealt with in this study[8,9].

An investigation into access conditions in rush hours can illustrate the effects of the AGM design on traffic flow most clearly when there are large flows of passengers who must line up to pass through the gates. The action sequence of accessing a gate machine is:

1) Find the card reader
2) Confirm the validity of the previous passenger swiping a card before check-out
3) Place a card on the sensor area (swiping a card)
4) Wait for the gate to release
5) Pass through the gate.

The initial action of finding a card reader (sensor area), plays a leading role in the whole sequence of actions[10]. The following analyses focus on the effects of the design of the AGM in the action sequence.

B. Data Collection and Analysis Methods

1) Investigation objective types


Shenzhen rail transit AGM: Luohu station on the Luobao line.

HK rail transit AGM: Tsim Sha Tsui Station and Central Station of the Tsuen Wan Line.

2) Investigation time and steps

During metro traffic peak hours (17:30–19:00), we initially counted and took videos for one minute when passengers passed through the AGM smoothly and continuously after each rail transit. 2–3 sets of each type of AGM were selected for investigation, and the average of 2–3 sequences was taken for each set of AGMs.

3) Parameters and index calculations

By playing the video frame by frame, the data on passengers reaching the AGM port and passing through normally were established. The number of passengers passing through in each one minute sequence was identified as the traffic efficiency and summary tables of the data were created. A method of taking average values from several sequences was adopted in this study. Each type of AGM was investigated at 2–3 stations, 2–3 sets of each type of AGM were investigated at each station, the statistics were repeated 2–3 times for each set of AGMs, and average values were taken finally to reduce errors.

The traffic efficiency of an AGM (statistical average values taken from several investigation sets) can be expressed as: (numbers of passengers/set · min)

\[
\bar{f} = \frac{\sum n}{mt}
\]

where \( m \) is the number of AGM sets, \( n \) is the number of passengers passing through the gates per minute (number of passengers/min), \( t \) is the measurement frequency, \( t = 2–3 \) numbers of measurements taken at the same measuring point, \( f \) is the traffic efficiency of an individual AGM port for one set of measurements and \( \bar{f} \) is the traffic efficiency of an AGM (average value).

III. DATA ANALYSES

A. Factors Affecting AGM Traffic Efficiency

Of the five actions taken by a passenger passing through a gate, the first three are connected with swiping cards and the last two are connected with the AGM, especially the method of passing through the gate. Based on the investigations and analyses, we found that the method of passing affected traffic efficiency: a wing door type was used in new AGMs, while a rotating bar type was used in older AGMs. Subject to a wing door type AGM, the factors affecting traffic efficiency mainly concerned the design of the sensor areas.

In field investigations, we first investigated the methods of passing through AGMs, after which the differences in sensor area designs were investigated. The following factors affected the traffic efficiency of an AGM:

1) Wing door type and rotating bar type
2) Sensor area:
   - Horizontal and sloping types
   - Raised and non-raised types
3) Color design of AGMs (including induction sensors)

In addition, some inevitable objective factors, such as choice of observation times for peak flows, flow densities at the observation sites, and quantities and sizes of passengers" luggage at the observation stations, all affect the traffic efficiency of AGMs [8]. We controlled these non-primary factors as much as possible, and obtained results from several field measurements.

B. Measurement Results:

1) Wing door type and rotating bar type
The data in Tables 1 and 2 indicated that the access efficiency of the wing door type was $\bar{f}_{e,w} = 8.5 \text{ persons/set} \cdot \text{min}$ and that of the rotating bar type was $\bar{f}_{e,h} = 6.16 \text{ persons/set} \cdot \text{min}$. The access efficiency of the wing door type was greater than the rotating bar type, $\bar{f}_{e,w} > \bar{f}_{e,h}$ ($\Delta \bar{f}_{e} = 2.34 \text{ persons/set} \cdot \text{min}$).

This was because in an access process there was an additional manual step for the rotating bar type gates, compared with wing door types. The speed of passenger movement, operation efficiencies, and quantities and sizes of luggage affected this step and slowed down the overall efficiencies. In contrast, the access efficiencies of wing door type gates were greater because of the absence of the manual rotating step and full machine control [10].

### TABLE I. WING DOOR TYPE GATES ACCESS EFFICIENCIES

<table>
<thead>
<tr>
<th>Station</th>
<th>Video No.</th>
<th>Passenger Numbers</th>
<th>AGM sets</th>
<th>Direction</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway east</td>
<td>1</td>
<td>33</td>
<td>4</td>
<td>Gate out</td>
<td>8.25</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>35</td>
<td>4</td>
<td>Gate out</td>
<td>8.75</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>30</td>
<td>6</td>
<td>Gate out</td>
<td>5.0</td>
</tr>
<tr>
<td>Wing door type gates access efficiencies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.5</td>
</tr>
</tbody>
</table>

### TABLE II. ROTATING BAR TYPE GATES ACCESS EFFICIENCIES

<table>
<thead>
<tr>
<th>Station</th>
<th>Video No.</th>
<th>Passenger Numbers</th>
<th>AGM sets</th>
<th>Direction</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gong yuan qian</td>
<td>1</td>
<td>40</td>
<td>6</td>
<td>Gate out</td>
<td>6.67</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>29</td>
<td>5</td>
<td>Gate out</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>30</td>
<td>5</td>
<td>Gate out</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Rotating bar gates access efficiencies = 6.16

### TABLE III. SLOPING TYPE SENSOR AREA ACCESS EFFICIENCIES

<table>
<thead>
<tr>
<th>Station</th>
<th>Video No.</th>
<th>Passenger Numbers</th>
<th>AGM sets</th>
<th>Direction</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gang ding</td>
<td>1</td>
<td>75</td>
<td>6</td>
<td>Gate in</td>
<td>12.50</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>41</td>
<td>6</td>
<td>Gate in</td>
<td>6.83</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>47</td>
<td>7</td>
<td>Gate out</td>
<td>6.71</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>118</td>
<td>7</td>
<td>Gate out</td>
<td>16.86</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.73</td>
</tr>
</tbody>
</table>

### TABLE IV. HORIZONTAL TYPE ACCESS EFFICIENCIES

<table>
<thead>
<tr>
<th>Station</th>
<th>Video No.</th>
<th>Passenger Numbers</th>
<th>AGM sets</th>
<th>Direction</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway east</td>
<td>1</td>
<td>37</td>
<td>6</td>
<td>Gate out</td>
<td>10.40</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>80</td>
<td>7</td>
<td>Gate out</td>
<td>8.50</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>38</td>
<td>4</td>
<td>Gate out</td>
<td>9.50</td>
</tr>
</tbody>
</table>

Horizontal type sensor area access efficiencies = 9.45

2) Sensor area (assuming the same situation of a wing door type AGM)

a. Sensor area of the horizontal and sloping types

The traffic efficiency for the sloping type sensor areas of the AGMs was $\bar{f}_{s,h} = 9.7 \text{ persons/set} \cdot \text{min}$, and for the horizontal type $\bar{f}_{s,h} = 9.45 \text{ persons/set} \cdot \text{min}$. The former had a higher traffic efficiency than the latter, $\bar{f}_{s,h} > \bar{f}_{s,h}$ ($\Delta \bar{f}_{s} = 0.25 \text{ persons/set} \cdot \text{min}$, see Tables 3 and 4).

One of the main reasons for this is that people separated by the same distance find it easier to identify a sloping type sensor area than a horizontal type. Through questionnaire surveys of the Guangzhou rail transit passengers, 64% of the passengers in the Gangding station thought that a card sensor area at a 5–7 m distance could be easily identified. In contrast, 78% of the passengers in the East Railway Station could identify a card sensor area at a 2–5 m distance. Therefore, the sloping type sensor area of an AGM enables passengers to more easily identify a sensor area from a greater distance, allowing preparatory action for accessing a gate.

### TABLE V. RAISED TYPE ACCESS EFFICIENCIES

<table>
<thead>
<tr>
<th>Station</th>
<th>Video No.</th>
<th>Passenger Numbers</th>
<th>AGM sets</th>
<th>Direction</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
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<td>Central</td>
<td>1</td>
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<td>6</td>
<td>Gate out</td>
<td>6.17</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>80</td>
<td>7</td>
<td>Gate out</td>
<td>11.43</td>
</tr>
</tbody>
</table>

Risen type access efficiencies = 8.80

### TABLE VI. NON-RAISED TYPE ACCESS EFFICIENCIES

<table>
<thead>
<tr>
<th>Station</th>
<th>Video No.</th>
<th>Passenger Numbers</th>
<th>AGM sets</th>
<th>Direction</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway east</td>
<td>4</td>
<td>33</td>
<td>4</td>
<td>Gate out</td>
<td>8.25</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>35</td>
<td>4</td>
<td>Gate out</td>
<td>8.75</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>30</td>
<td>6</td>
<td>Gate out</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Non-raised type access efficiencies = 8.5

### TABLE VII. COLOR EMPHASIS ACCESS EFFICIENCIES

<table>
<thead>
<tr>
<th>Station</th>
<th>Video No.</th>
<th>Passenger Numbers</th>
<th>AGM sets</th>
<th>Direction</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway east</td>
<td>1</td>
<td>37</td>
<td>6</td>
<td>Gate out</td>
<td>10.40</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>80</td>
<td>7</td>
<td>Gate out</td>
<td>8.50</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>38</td>
<td>4</td>
<td>Gate out</td>
<td>9.50</td>
</tr>
</tbody>
</table>

Color emphasis access efficiencies = 9.45

On inquiring about the color of the card sensor area at the Guangzhou Rail Transit AGM, 42% of the passengers responded positively to the question, but only 36% of the passengers in the East Railway Station correctly answered the question. This result also reflected that at the same distance, identifying a sloping type sensor area for an AGM is easier than identifying a horizontal type. Passengers were more aware of the sloping type sensor area.

b. Sensor area raised and non-raised

The traffic efficiency of an AGM with a raised sensor area was $\bar{f}_{e,r} = 8.8 \text{ persons/set} \cdot \text{min}$, while the traffic efficiency of an AGM with a non-raised sensor area was $\bar{f}_{e,n} = 8.5 \text{ persons/set} \cdot \text{min}$. The access efficiency of the type with a raised sensor area was greater than the type with a non-raised type, $\bar{f}_{e,r} > \bar{f}_{e,n}$ ($\Delta \bar{f}_{e} = 0.3 \text{ persons/set} \cdot \text{min}$, see Tables 5 and 6).

Because the raised sensor area is more visually obvious, passengers are more aware of it from a greater distance [10].

c. Sensor area with colors emphasized and not emphasized

Similar to the horizontal and non-raised sensor areas, the traffic efficiency of AGMs with a sensor area and color was $\bar{f}_{e,c} = 9.45 \text{ persons/set} \cdot \text{min}$, while the traffic efficiency of AGMs with color emphasis was $\bar{f}_{e,c} = 4.72 \text{ persons/set} \cdot \text{min}$.
Based on the investigation of the traffic efficiency of AGMs in rail transport systems in Guangzhou, HK and Shenzhen, we first found that the new wing-door AGMs were more efficient than the old rotating bar AGMs. The key points for improving passenger traffic efficiency of the wing-door AGMs, focused on the sensor area:

1) Sloping and horizontal sensor areas: A sloping type was more easily located than a horizontal type, and had a more ergonomic angle for passengers to swipe cards. Referring to ergonomic data [11], an AGM sensor area tilted at 8–15% is more convenient for passengers to use.

<table>
<thead>
<tr>
<th>Station</th>
<th>Video No.</th>
<th>Passenger Numbers</th>
<th>AGM sets</th>
<th>Direction</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luohu</td>
<td>1</td>
<td>34</td>
<td>6</td>
<td>Gate out</td>
<td>5.67</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>21</td>
<td>7</td>
<td>Gate out</td>
<td>3.50</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>35</td>
<td>7</td>
<td>Gate out</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.72</td>
</tr>
</tbody>
</table>

2) Raised and non-raised sensor areas: A raised sensor area was more obvious to passengers, making it easier to find a location to swipe a card. Referring to ergonomic data [11] and the design experiences of the HK rail transit system, a raised height within 5–8 cm was the most suitable.

3) The color design of an AGM sensor area: A sensor area can be emphasized by bright colors such as yellow, orange, or green, forming a sharp contrast to the general steel silvery appearance, so passengers can quickly swipe their cards and pass through. However, bright red or green should be avoided, because they are special colors used for evacuation signage.

The preliminary conclusions which can be drawn and need further special investigation, are: The passenger traffic efficiencies of the new wing-door AGMs are much greater than the old rotating bar AGMs. Similar to the wing-door AGMs, the passenger traffic efficiencies were improved by the color design of the AGM sensor areas much more than the factors associated with sloping or horizontal and raised or non-raised sensor areas.

IV. CONCLUSION

Rail transportation in HK developed earlier than in Guangzhou and Shenzhen, and the technologies and experiences are more mature, which can be used to guide the Rail Transit design in the Pearl River Delta. However, because local rail transit here started earlier, some station equipment such as the AGMs are aging and need a timely update. Conversely, because of the rapid economic development of modern society, the number of people using high-speed transport, such as the rail services, is increasing, and the demand for comfort and efficiency is also increasing. Therefore, updating the styles of rail transit AGMs will ensure safety and greater efficiency, and also meet the modern demand for ergonomic design.

Based on the results of the studies in the field of rail transportation, we found the efficiency of a wing door AGM was superior to a rotating bar AGM. Assuming a wing door AGM, the key points for increasing passenger traffic efficiencies focused on the sensor area:

1) Sensor areas of the sloping and horizontal types: the slope of the sensor area needs to be considered;
2) Sensor area of the raised and non-raised types: a raised sensor needs to be considered to emphasize the sensing area;
3) The color design of the sensor area: An AGM is usually made of stainless steel. The sensor area needs to be emphasized by bright and primary colors.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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