Emissions Impacts of the Park-and-Ride Strategy: A Case Study in Shanghai, China

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Abstract

With the increasing interest in environment-friendly transportation strategies such as park-and-ride (P+R), evaluating transportation strategies’ emissions impacts is obtaining more attention. This study investigates the emissions impacts of P+R strategy through the case study of Song-Hong Road P+R Lot, the first P+R facility with rail transit connection in mainland China. The emissions impact evaluation approach is formulated using the sketch planning method. Using the data collected from two P+R lot surveys, the emissions impact of Song-Hong Road P+R Lot was estimated. The results showed that Song-Hong Road P+R lot has played an important role in reducing emissions due to high utilization rate, large percent of users who drove alone previously and the usage of the P+R lot by long-distance-trip travelers. The reduced emissions for pollutants CO, NOx and HC are 21.7 ton, 1.2 ton and 1.8 ton respectively for 250 work-days each year. Last, discussions, recommendations and concluding remarks are given.

1. Introduction

The park-and-ride (P+R) strategy, an environment-friendly transportation strategy, has been applied in many cities around the world. P+R related topics, such as facility location optimization, travel demand forecasting, user behavior modeling, and P+R strategy’s impacts on transportation network performance (for example, Vijayakumar et al., 2011; Holguín-Veras et al., 2012; Syed et al., 2009; Molin and Gelder, 2008; Faghri et al., 2002; Merriman, 1998; Tsang et al., 2005; Huang, 2002; Eaken et al., 2005), have been addressed by researchers.

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and practitioners. However, relatively fewer empirical studies on emissions impacts of real world P+R applications exist in the literature.

With the globally increasing concern about environment pollution and fuel shortage, the transportation community is more interested in assessing the emissions impacts of environment-friendly transportation strategies such as P+R strategies. Research on P+R strategies’ emissions impacts can facilitate better investment, design and operation of P+R facilities.

This paper will investigate the emissions impacts of P+R strategy through a case study of the first P+R facility with rail transit connection in mainland China—“Song-Hong Road P+R Lot” in Shanghai. Song-Hong Road P+R Lot is connected with a rail transit line.

The remaining of this paper is organized as follows. First, this paper gives a brief overview of emissions impacts of P+R strategy and presents the approach to evaluating emissions impacts of P+R strategy. Second, it describes the survey of Song-Hong Road P+R Lot. Third, it evaluates emissions impacts of P+R strategy using data collected from the survey. Last, discussions and concluding remarks are given.

2. The Emissions Impacts Evaluation Approach

2.1. Overview of P+R strategy

P+R facilities include the construction or expansion of parking lots where people can park their vehicles and then join a carpool, vanpool or transit service. The P+R strategy reduces emissions by decreasing the number of single-occupancy vehicles on the road.

P+R facilities reduce emissions of all pollutants associated with driving, such as PM-2.5, PM-10, CO, NOx, VOCs, SOx and NH₃, by encouraging drivers to reduce vehicle kilometers traveled (VKT) by sharing car trips or taking transit.

Factors affecting the level of emissions impacts (ICF International, 2007) include:

- The number of spaces available in the park-and-ride facility, and expected utilization.
- The form of transportation previously used by P+R facility users (i.e., extent to which people previously drove alone).
- The average length of carpool/vanpool or transit trips using the park-and-ride facility.

2.2. Emissions Impacts Evaluation Approach

Taking the above factors into account, the emissions impacts evaluation approach for a P+R facility with rail transit service like P+R lots in Shanghai can be formulated as follows. The evaluation method is in essence a sketch planning method which is suitable for evaluating a transportation strategy’s emissions impacts (e.g. Gan et al., 2010; International, 2007).

2.2.1 Notation

\( X1 \): Parking spaces added.
\( X2 \): Estimated utilization rate.
\( X3 \): Percent of users who previously drove alone.
\( X4 \): Estimated average round trip for driving alone between origin and destination. (km)
\( X5 \): Estimated average round trip for driving between origin and P+R lot. (km)
X6: Operating days of the P+R lot.
X7: Running emission factor. (g/km)
S1: Spaces used.
S2: Number of people reducing driving.
S3: Annual VKT reduction. (veh·km/yr)
Y: Annual emissions reduction.

2.2.2 Calculation Procedure

Step 1: Estimate expected lot use.
\[ = X1 \text{ (spaces added to lot)} \times X2 \text{ (estimated utilization rate)} \]
\[ = S1 \text{ (spaces used)} \]

Step 2: Calculate expected number of people reducing driving.
\[ = \text{(Spaces used } S1 \text{) } \times \text{(share who previously drove alone } X3 \text{)} \]
\[ = \text{(Number of people reducing driving } S2 \text{)} \]

Step 3: Calculate annual VKT reduction.
\[ = \text{(Number of fewer drivers per day } S2 \text{) } \times \text{(Estimated average round trip for driving alone between origin and destination } X4 \text{–Estimated average round trip for driving between origin and P+R lot } X5 \text{) } \times \text{(operating days } X6 \text{)} \]
\[ = \text{(annual VKT reduction } S3 \text{)} \]

Step 4: Calculate reduction in emissions.
\[ = \text{(Running emission factor } X7 \text{) } \times \text{(annual VKT reduction } S3 \text{)} \]
\[ = \text{(annual emissions reduction } Y \text{)} \]
(Note: step 4 can be executed for all the pollutants of interest.)

3. A Case Study

3.1. Background Information

Shanghai is the first city to use the P+R lot with rail transit connection in mainland China. Now there are totally eight P+R lots in Shanghai. Six of these P+R lots are all located in the fringe of downtown Shanghai while the other two are in the suburb (depicted in Figure 1). The locations of the eight P+R lots are plotted by red circle symbols and numbered in Figure 1.

Two of these P+R lots were put to operation in July 2009, while the other six were started after December 2010. The first two P+R lots are Song-Hong Road P+R Lot and Hong-Mei Road P+R Lot. Song-Hong Road P+R Lot is a single-purpose facility only for P+R users, while Hong-Mei Road P+R Lot is a mixed-usage one for
which only part of spaces serve P+R users. Thus the authors selected Song-Hong Road P+R Lot for the case study.

Figure 1 Locations of the P+R lots in Shanghai, China

3.2. Survey

Song-Hong Road P+R Lot (Figure 2) is a P+R lot with rail transit service (i.e. Metro Line 2). Two surveys in form of on-site questionnaire survey were conducted (II). The first one was done in September 7-9, 2009 about one and a half months after the opening of the P+R lot. The second survey was done in April 2010, about seven months after the first survey, to obtain information about possible changes in P+R facility utilization and P+R users’ trip characteristics.

Figure 2 Song-Hong Road Lot: (a) the multi-layer lot; (b) location of the lot

The first and second surveys collected 300 and 276 valid samples, respectively.
The collected data consist of two parts (Gan and Sun, 2011): (a) facility related data, such as parking spaces available, utilization rate, parking price, operating time, operating days; (b) P+R user related data, such as users’ socioeconomic attributes, form of transportation previously used, trip length for driving alone, trip length between origin and P+R lot, trip purpose, travel costs for driving alone and for P+R mode.

These data were processed (Gan and Sun, 2011; Gan et al., 2010) to derive the inputs of the emissions impacts evaluation approach introduced in Section 2.

3.3. Emission Impacts Calculation

3.3.1 Inputs

The inputs needed for emission impacts calculation are summarized in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>292</td>
<td>X2</td>
<td>90%</td>
<td>X3</td>
<td>80%</td>
</tr>
<tr>
<td>X4</td>
<td>12.45 km</td>
<td>X5</td>
<td>5.56 km</td>
<td>X6</td>
<td>250</td>
</tr>
<tr>
<td>X7(CO)</td>
<td>20.1 g/km</td>
<td>X7(NOx)</td>
<td>1.1 g/km</td>
<td>X7(HC)</td>
<td>1.7 g/km</td>
</tr>
</tbody>
</table>

Note: the text in X7(·) represents a specific pollutant. The value of X7(·) is referred to research results of Chinese Research Institute of Environmental Science (Wang, 2006).

3.3.2 Emission benefits calculation

Following the emissions impacts evaluation approach introduced in previous section, reduction in emissions can be calculated.

For the first survey, the estimated reduction in emissions follows.

\[ Y(CO) = 7.28 \text{ ton/yr} \]
\[ Y(NOx) = 0.582 \text{ ton/yr} \]
\[ Y(HC) = 0.899 \text{ ton/yr} \]

For the second survey, the estimated reduction in emissions follows.

\[ Y(CO) = 31.602 \text{ ton/yr} \]
\[ Y(NOx) = 1.730 \text{ ton/yr} \]
\[ Y(HC) = 2.682 \text{ ton/yr} \]

Table 2 gives a summary of emissions reductions for two surveys.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Emissions reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO (ton/yr)</td>
</tr>
<tr>
<td>First survey</td>
<td>7.28</td>
</tr>
<tr>
<td>Second survey</td>
<td>21.65</td>
</tr>
</tbody>
</table>
3.4. Discussions and Comments

Discussions and comments follow.

A. Facility utilization.

The P+R lot' utilization rates of the first survey and the second survey are 90% and 95% respectively. Given that a utilization rate of over 80% is usually considered to be satisfactory in traffic engineering practice, these utilization rates are quite satisfactory, indicating that Song-Hong Road P+R lot is operated efficiently and well accepted by travelers.

B. Share who previously drove alone.

Values of $X_3$ in the two surveys (see Table 1) are both 80%. This indicates that the P+R lot has succeeded in attracting a high proportion of drivers who previously drove alone to use the environment-friendly P+R travel mode. This indicates that the P+R lot has really changed many automobile users' travel mode choice decisions which in turn facilitate emissions reduction.

C. Reduced trip length.

The larger the reduced trip length (i.e. $X_4-X_5$), the more significant role the P+R lot has in reducing emissions. As shown in Table 1, $X_5$ in two surveys is similar (5.56 km vs. 5.6 km) while $X_4$ in the second survey is two times of that in the first survey (12.45 km vs. 25.01 km), thus the reduced trip length in the second survey is almost three times of that for the first survey, i.e. $(25.01-5.6)/(12.45-5.56) \approx 3.0$. This is an interesting and important observation obtained by our study including two surveys that were implemented at different time. This change of course could have not been observed if only one survey was conducted.

D. P+R users' trip characteristics.

First, given the fact that the values of $X_4$ for two surveys are similar (5.56 km vs. 5.6 km), it is concluded that the average driving distance between a P+R user’ origin and the Song-Hong Road P+R lot is about 5.6 km.

Second, given that the value of $X_5$ for the second survey (25.01 km) doubles relative to that for the first survey (12.45 km), it is indicated that great changes of P+R lot users’ trip characteristics have occurred. This shows that, after an ‘adjusting’ period, the P+R lot has attracted users whose average driving distance between trip origin and trip destination is 12.5 km (25.01/2). Moreover, the minimum and maximum of this driving distance (i.e. 12.5km) is 8.2km and 18.1km respectively (Gan and Sun, 2011). Thus, for the Shanghai situation, the Song-Hong Road P+R lot had attracted middle-to-long distance trip makers.

However, this study could not identify the exact reason for changes of P+R lot users’ trip characteristics, since the two surveys didn’t record respondents’ identity information due to privacy consideration. Usually, if a respondent is asked to provide his identity information, he will refuse to attend the survey. Consequently, we conjectured that possible reasons for changes of P+R lot users’ trip characteristics were (1) some non-commuter travelers may use the P+R mode to get to more distant destinations (i.e. destination change for old users), (2) some short-distance trip makers who used the P+R lot before decided not to use the P+R mode any more, and (3) the P+R lot attracted some new users who were long-trip makers.

E. Emissions reduction estimates.

As shown in Table 2, the amount of emissions reductions for the second survey is three times of that for the first survey. As shown in Table 1, this is mainly due to the drastic change of the reduced trip length ($X_4-X_5$) as discussed above.

F. Overall.
Putting all these above comments and discussions together, we can argue that Song-Hong Road P+R Lot has played an important role in reducing emissions due to the high utilization rate, large percent of users who drove alone previously and the usage of the P+R lot by long-distance-trip travelers.

4. Conclusions, Implications, and Recommendations

This study investigated the emissions impacts of P+R strategy through the case study of Song-Hong Road P+R Lot, the first P+R facility with rail transit connection in mainland China. The emissions impacts evaluation approach is formulated using the sketch planning method. Using the data collected from two P+R lot surveys, the emissions impacts of Song-Hong Road P+R Lot were estimated.

Our results showed that Song-Hong Road P+R Lot has played an important role in reducing emissions due to the high utilization rate, large percent of users who drove alone previously and the usage of the P+R lot by long-distance-trip travelers. The reduced emissions for pollutants CO, NOx and HC are 21.7 ton, 1.2 ton and 1.8 ton respectively for 250 workdays each year.

This study has practical implications for transportation engineering. With the increasing interest in environment-friendly transportation strategies such as the P+R strategy, evaluating transportation strategies’ emissions impacts is considered to be more and more important by government agencies. However, in many occasions government agencies (especially those in China) feel hard to fulfill the evaluation task in an effective way. Our study provided an easy-to-implement way and may be a useful technical reference for transportation planners and traffic engineers.

This study also has implications for data collection in emissions impacts evaluation. In practice, government agencies may ‘simplify’ the emissions impacts evaluation process by collecting data for analysis through only one survey due to practical considerations (e.g. saving monetary and human resources). The resulting emissions reduction estimate may be ambiguous. The emissions impacts may be under-estimated or over-estimated through only one survey. This of course will mislead the government to make inappropriate policy decisions. As reflected by our study, there may be significant changes in the inputs of emissions reductions evaluation (e.g. estimated average reduced trip length in this study). If only the data of the first survey were used, our analysis would have underestimated the emissions impacts of Song-Hong Road P+R Lot. Therefore, caution should be taken by the analyzer when evaluating emission benefits of a P+R facility. It is suggested that, at least two P+R lot surveys be conducted with the interval between two sequential surveys being reasonably long (e.g. half a year) if the budget permits so as to take a clearer picture of the P+R lot and obtain a more accurate estimate of emissions impacts.

Furthermore, it is suggested that government take measures to further target potential P+R users who previously drove alone thus facilitating the better use of P+R facilities in terms of emissions reduction. Feasible measures include driver training, education of the public through public media such as newspapers, internet, leaflet, TV and radio, etc.

In future, the study can be extended to address more P+R lots in Shanghai and other Chinese cities to obtain more general conclusions and reach more insightful results regarding emissions impacts as long as the budget permits. It is hoped this study will intrigue more researches into the emissions impacts of the P+R strategy.

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References


