Research on the Performance of Mobile Barricades
Based on Fuzzy-AHP Method

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Abstract: Generally, barricades are fixed and they separate roads into two symmetric parts. However, the traffic of two lanes is different by time, which means that the road is not made fully use of. Consequently, reallocating roads in different time could moderate tide traffic and improve road efficiency by adjusting the vertical and horizontal location of barricades. Based on engineering technology and achievements as well as field research, this paper designed a kind of mobile barricade which could moderate tide traffic. Analyses of the feasibility of this kind of mobile barricade are also made from the view of traffic, speed, investment, occupied space, speed standard deviation and road utilization. This paper also made an appraisal of it with AHP-Fuzzy method. Results show that the use of mobile barricades not only improves land utilization and traffic sustainable development, but also increases traffic capacity and cuts down energy consumption, which helps a lot in building good traffic environment.

Keywords: Mobile barricades, Engineering technology, Tide traffic, AHP-Fuzzy method.

1. Introduction

Distribution is becoming to an important mean to realize the use value of commodities with the fast development of economy. Moreover, high efficient urban logistics distribution could improve customer satisfaction effectively. While reducing distribution costs and improving customer service are contradictory from the aspect of economy, in order to find the equilibrium positions between the two applications, most scholars used modern information technology means to delve deep into distribution center site selection, logistics distribution vehicle routing problem, joint distribution center building and so on. But according to the growth situation of cities, such methods have been restricted by all kinds of constraints. They are facing more and more serious urban traffic problems which would finally cause that goods could not be delivered to customers in time, even if the vehicles are driving on optimal distribution routes. Consequently, easing traffic pressure needs a new construction method of road traffic to achieve sustainable development. This article tries to solve this kind of urban logistics distribution vehicle congestion problem by designing a kind of new mobile barricade and evaluating its performance.
2. Introduction of Mobile Barricades
Planning Research Based on Logistics Engineering Technology

Presently, the key problem is how to improve traffic capacity. Vehicles are carriers, and thus their traffic capacity is of great significance. Traditionally, enhancing the traffic capacity is often attributed to road design, which caused the dilemma of city traffic tide. If we could expand the traffic means of urban distribution to moderate their restraints by introducing advanced logistics engineering technique, the urban distribution traffic capacity would be largely elevated.

In traditional traffic concept, vehicles are dynamic while the roads are static. Consequently, it is hard to allocate resources dynamically according to the requirement. Taking some roads in Beijing as example, as is shown in Fig. 1, the tide traffic caused uneven utilization of two–way lanes resources [8]. In fact, the road can also be dynamic by using auxiliary facilities to fully utilize the road resources. This kind of design combines the static character of roads and dynamic, moving character of traffic together, increasing the diversity of transportation system and finally bringing convenience to the resident's journey.

3. Design of Mobile Barricades
in the Road Resource Allocation
and its Feasibility

Nowadays, we have several kinds of barricades which divide road into evenly or unevenly parts, such as fixed railings, green belts, lifting barricades. The defect of fixed railings is serious two-way traffic efficiency imbalances, which would cause that the up lanes may be of congestion, while the down lanes are idle. And the green belts occupy too much road space, which reduces the efficiency of road traffic. Although the ordinary lifting barricades can effectively solve the imbalance between the up and down lanes tide traffic problem, the bottom of the lifting barricades are pinned underground [4], which destroyed the roadbed and caused a great deal of damage to the road surface.

If we designed a mobile barricade to solve the above problem, the congested roads would be "broaden" and the idle path would be "narrowed" by adjusting the vertical position and horizontal position of barricades, to achieve maximum use of roads to solve tide traffic phenomenon. When the vehicles are running on the optimal planning of distribution route, it can also deliver the goods to the customer on time even if facing serious tidal traffic in a large degree.

3.1. Design of Mobile Barricades in the Road Resource Allocation

By lots of analyses and research, we designed a new kind of mobile barricade. This mobile barricade includes road locks, left mobile devices and right mobile devices, while the left mobile devices and right mobile devices have the same structure, and along the direction parallel to the installation, as shown in Fig. 2. The left mobile device consists of guide rail device and moving trolley and the guide rail device crosses the road and fixed on both sides of the road. Four wheels of moving trolley run on the beam of the guide rail device, while the barricades connects drum in the moving trolley by the movable pulley.

In addition, the traditional carriageway between the upper and lower is generally unconnected and existed independently, which reduced the connection degree of horizontal road resources and wasted the building of horizontal resources. Therefore, in order to change the present situation of the urban traffic congestion, we should change road systems design concept with modern logistics engineering technique. We can change the traditional static road and the dynamic traffic mode of vehicle with the new logistics engineering technique to form a new traffic method with dynamic configuration of vehicles and roads, to extend the design means of city road [7] and realize the optimal allocation of traffic road resources.
Moving trolley consists of elevating motor, lifting reducer, level traveling motor, traveling reducer, steel cables, and movable pulley as well as drums which are all fixed in the body of the moving trolley. Two elevating motors are connected to the two corresponding lifting reducers. Output shafts are connected to the corresponding axis of drums and two drums synchronous rotation in opposite direction, while steel cables and movable pulley are constitutive of pulley structure. Drums, steel cables and movable pulley are constitutive of lifting mechanism whose two ends of steel cables are respectively connected with the drums after bypass movable pulley. Movable pulley is connected with the rail of barricades, while level traveling motor is connected with traveling reducer and output shaft of traveling reducer is connected with wheel axles of the moving trolley. Wheel axles of the moving trolley is connected with the body of moving trolley and moving trolley running on the beam orbit of guide rail device. Mobile devices of left and right moving trolley moves synchronously.

Mobile devices of left and right moving trolley moves synchronously, in which the number of lanes and lifting of steel cables are auto controlled by PLC (Programmable Logic Controller). Mobile devices of left and right moving trolley moves synchronously could be accomplished by inverter, encoder and PLC, inverter installed in the body of moving trolley; encoder is coaxial connected with level traveling motor. The speed of level traveling motor can be converted into digital signal by encoder which provides digital signal to PLC and PLC gives the inverter order to control the speed of level traveling motor; two level traveling motors apply frequency converted motor whose speed is used for inverter control [10], and two inverters can be directly controlled by PLC. In closed-loop control, speed of right moving trolley is adjusted through right inverter aim for the speed of level traveling motor of left moving trolley to realize left and right moving trolley synchronous running. Two incremental rotary encoders are coaxial connected with level traveling motor, and they are used for acquiring each pulse signal of level traveling motor, and send pulse signal to PLC; trading these two speed signal data as control input to proportional - integral (PI) control arithmetic [2]. The result of operation as output signal delivery analog quantity module of PLC is sent out by PLC as control signal to right inverter which controls the speed of right moving trolley, ensuring the speed of right level traveling motor could follow up the speed of left level traveling motor.

In order to have a good sight for the traffic, the mobile barricades should be set up on the straight road and at least 50 meters from the turning point and the position of barricades can be adjusted to traffic conditions [1]. Normally, it should be put in the middle of the road. Taking eight-lane for example, the barricades could be put in the white lane-line between fast and slow lanes, controlling the position of the barricades according to traffic flow and dividing six lanes of up and down carriageways into 2.6 lanes or 3.5 lanes.

The height of the guide way device is set to 6 m, and the length of barricades is 0.8 m. When the barricades rise to the top position, pavement height is 5.2 m away from the barricades, which would not affect the passage of other vehicles.

Operating process of barricades is set according to traffic volume and time period to adjust the position of barricades. Normally, we place barricades in the middle of road so that up and down driveway have the equal lanes. When the tidal traffic jams, ground staff issue command to move barricades and send to PLC, then elevating motor in the body of moving trolley turns the drum to rotate movable pulley, and then lifting the barricades; When barricades rises to the set time, the lifting motor stops, moving trolley starts to left or right run from the yellow line above the middle of the road, the car moves in place and stops. At the same time, lifting motor begins to reverse, and then land the barricades in place and finally barricades movement is completed.

Rise and fall of the barricades are controlled by pre-computed. Taking falling process as example, when the barricades began to fall, the time relay which is connected with PLC in the moving trolley received the order to begin timing, after barricades down, time relay commanded the elevating motor to stop work, making the barricades accurately placed on white lines in the middle of road. Similarly, when elevating motor reversed, steel cables are elevated, and then through time relay to accurately control rising or falling position, the movement of barricades is eventually finished.

The above design has good enforceability in technology, it can change fixed railings and lifting barricades with existing techniques into moving barricades which do not destroy the original roadbed, by adjusting the vertical and horizontal position of the barricades to achieve maximum use of the road, the tidal traffic jam will be eased in a large degree. It can greatly reduce the reconstruction of city road, increasing the utilization of road and managing tidal traffic, which is consistent with the idea of green city development.

### 3.2. Feasibility Analysis of Mobile Barricades in the Road Resource Allocation

The mobile barricades can solve tidal traffic jam without destroying the original roadbed. It occupies little carriageway space and it is installed on both sides of the road. Consequently, the mobile barricades not only occupy little space, but also could
be installed easily to realize the sustainable development of rural traffic [6].

The span of guide way device can be set according to the width of the road. Its height is set to 6 m and the height of barricades is 0.8 m. When mobile barricades rose to the highest point, the bottom of the mobile barricades from the pavement is 5.2 m, due to the height of the pedestrian bridge is 4.5 m, it does not affect other traffic.

Compare the mobile barricade performance from road traffic, the speed of up and down driveway, investment cost, footprint area, standard deviations of speed and usage ratio of roads. Option One: expansion the access roads on both sides of the road to disperse traffic; option two: build flyovers near the road; option three: establish mobile barricades on the road.

First, in terms of improving road traffic and the average travel speed, after investigation and data analysis of traffic flow of representative roads in ZhouKou we could know that, the speed limit is 50 miles per hour, the traffic volumes increase with the number of the road lanes. At the same speed, eight lanes of traffic flow are greater than six-lane traffic flow whose traffic flow is greater than four-lane traffic flow. That is to say, traffic capacity increases with the road lanes. At the same traffic flow, the average speed of eight-lane is faster than six-lane, and six-lane is faster than four-lane. As ZhouKou road is next to the highway, the traffic flow of highway can divert traffic of ZhouKou road, so the traffic flow of highway by ZhouKou road is similar to traffic flow of flyover. According to these analyses, the average speed of mobile barricades is faster than average speed of flyover.

Second, in terms of investment cost, the establishment of two-side roads investment cost means cost of road and drainage facilities cost. New second - class highway’s cost is about one 4 million RMB per kilometer, and the land is also very expensive, whose cost is around 6 million RMB. Besides, city roads are close to saturation, which make it is impossible to build a new road. The new bridge is approximately 150 million RMB; the mobile barricade includes equipment and control devices. The cost of all devices is 500 million, so the establishment of mobile barricades is most appropriate in terms of investment cost.

Third, in terms of road utilization, analyses of each lane traffic flow shows that the utilization of road conditions, traffic flow of six lanes, compared with four-lane traffic, has been relatively increased by 19.1 %, eight lanes relatively has been increased by 19.1 % compared with four-lane traffic flow, eight lanes relatively has been increased by 3.0 % compared with six-lane. So the utilization of six lanes is the highest one.

Finally, in terms of land area occupied by traffic, the construction of a side road is at least 6 m wide. Although the vertical position of the overpass are effectively utilized, the period of construction is too long, it will cause new congestion; then the construction of the mobile barricades on both sides of the road and traffic land is not occupied, we can minimize the transformation of the city to become the best solution among the three programs, so, mobile barricades could not only be designed with small lands, but also could greatly improve the utilization of land.

Comparative results are shown in Table 1. From the comparison results of the three, the mobile barricades can maximize the decrease of transformation of urban land and improve land utilization among three schemes. Investigation data analyses indicate the fact that using mobile barricades makes road utilization rate higher, travel speed is faster and improves the traffic capacity of roads. Therefore, the mobile barricades create a better traffic environment for distribution vehicles.

### Table 1. Comparative table of the scheme.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Volume of road traffic</th>
<th>Travel speed</th>
<th>Investment cost</th>
<th>Floor area</th>
<th>Standard deviation</th>
<th>Road utilization rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option One, extendable path</td>
<td>-</td>
<td>-</td>
<td>About 4 million</td>
<td>The width is 6 m</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Option Two, bridge building</td>
<td>306 Veh/h</td>
<td>45 km/h</td>
<td>150 million</td>
<td>Largest</td>
<td>35.73 km/h</td>
<td>Lower</td>
</tr>
<tr>
<td>Option Three, barricades</td>
<td>453 Veh/h</td>
<td>40 km/h</td>
<td>5 million</td>
<td>0</td>
<td>31.89 km/h</td>
<td>highest</td>
</tr>
</tbody>
</table>

### 4. Mobile Barricade’s Comprehensive Performance Evaluation Based on Fuzzy-AHP Method

The essence of establishing mobile comprehensive barricades impact assessment index system is to find a group of typical significance indicators, which could fully reflect quantitative evaluation judgments of the target mobile barricades. By moving barricades on the access road to dynamically adjust the operating efficiency of the vehicles, the road resource utilization, environmental efficiency and economic efficiency could be greatly improved. Therefore, the establishment of index system should be based
on the analyses of overall planning design of moving barricade and feasibility analyses. Evaluation objectives and system designing structure and the corresponding relationship among the elements should be established first, then studying the characteristics of indicators, evaluation criteria and its associated evaluation objectives to determine the choices of indicators and settings. In the specific design of indexes system, in accordance with the goal of building mobile barricades with ensured safety, improved efficiency, energy conservation, analyzing from four criteria of economic, utilization, operational efficiency, and environmental benefits to decide the comprehensive evaluation indexes system of mobile barricades.

4.1. Indicators Selection of Mobile Barricades’ Comprehensive Performance Evaluation

Based on the four indexes, we could divide economic benefits, utilization, operational efficiency, environmental benefits into eight specific indicators, which are shown below.

1) Economic indicators selection
As moving barricades could improve the original passage way, and thus traffic access system gained sustainable development to meet the demand of more traffic. Besides, they also reduce the building of transportation facilities and land occupation with improved roads corporate investment revenue rate. In addition, mobile barricades make traffic flow increasing while the standard deviation of the vehicle's speed decreasing, and thereby enable lower total vehicle travel time and fuel consumption savings across the board. Transportation efficiency promotes social production efficiency and makes product distribution volume increase as equipment investment and maintenance cost have great relationship with economic benefits of access road itself. Equipment investment and maintenance cost is the access road in a variety of devices during operation, investment and maintenance cost. Therefore, the equipment investment and maintenance cost is a measure of its own mobile barricades economic indicators.

Therefore, this article adopts five indicators of total travel time savings; fuel savings across the board, traffic system occupies land area, distribution volume increase, equipment investment and maintenance cost as evaluation system of improving economic efficiency.

2) Utilization indicators selection
Most of the driveway in the morning and evening peak period apparently has a tidal transport phenomenon which will result in road utilization dropment significantly. If we can make lane traffic facilities move according to the time, then we can make a part of the vehicle to borrow relatively casual carriageway to improve the utilization of the road, so that 1/2 of the road utilization rate be increased to 2/3. Therefore, utilization of the road is an important indicator of the mobile barricades’ comprehensive evaluation.

3) Operational efficiency indicators selection
Tidal urban road has greatly impact on traffic ability which often controls operational efficiency. As long as there is tide time in traffic on the road, the vehicle will stop when it encounters traffic jam, and then it starts to accelerate traffic, capacity decreased. Even without the tidal encounter traffic jams on the roads, vehicles must be slowed down. Therefore, the vehicle traffic through the tidal section of the travel time is longer than the actual no tidal traffic road travel time; the actual average vehicle speed is low, decreasing operating efficiency and increasing standard deviation. And fuel consumption of the vehicle during braking and starting will also increase.

Based on above analyses, dynamic road mobile barricades regulation benefits could be reflected by the operating efficiency of the vehicle, while vehicle efficiency is mainly revealed through total travel time savings, increased capacity and fuel consumption across the board. Therefore, this paper trades three indicators, namely travel time savings, increased capacity and fuel efficiency as evaluation system to improve operational efficiency.

4) Environmental efficiency indicators selection
Running cars would discharge large amounts of waste which caused great pollution to environment.

Mobile barricades make sure the smooth traffic road network, increasing traffic through rate, capacity increasing, high road utilization, and low speed standard deviation by providing timely carriageway and improving driver's route choice ability. Therefore, it reduced energy consumption, pollution emissions, and thus made the environmental impact of freight transport significantly improved.

In summary, this article uses capacity increase and the standard deviation across the board and fuel consumption savings as three indicators of environmental performance evaluation.

4.2. Research on the Comprehensive Performance Evaluation Indicators System of Mobile Barricades

Based on the analyses of urban delivery vehicles mobile barricades access road dynamic control of four criteria layers, mobile barricades can be drawn in composite indexes architecture, as shown in Fig. 3.

The objective layer is comprehensive estimation for mobile barricades and can be denoted by \( A \), the first-class indexes are economic efficiency, travelling efficiency and environmental benefit, can be denoted by \( B_1, B_2, B_3 \), which contains second – class indexes that can be denoted by \( C_{ij} \).
which refers to the jth second-class indexes of ith level indicators.

Whether establishing mobile barricades can increase the distribution vehicles’ travelling efficiency, reduce logistics cost, increase the amount of distribution of enterprises or not, together with getting more about the access equipment it can apply, is the meaning of establishing this evaluation system.

4.3. Comprehensive Performance Evaluation and Analysis of Mobile Barricades Based on AHP-Fuzzy Methods

Through literature research, we found that in studying of evaluation of transportation facilities, AHP and fuzzy comprehensive combination methods are widely used, and have achieved a good evaluation result of which AHP has simple ideas for nature of the problem, including the factors and analyzing the intrinsic relationship and more clearly the advantages of subjective weighting method is the most commonly used one. In addition, an integrated approach to fuzzy qualitative evaluation of experts effectively transformed into quantitative data which has good results with qualitative issues and for the object of study in this paper has good applicability. This article was based on 3.2 to establish evaluation index system first by AHP method to determine the index position, and in the comparative impor tance of each indicator, using the expert investigation method of information collection and collation. Finally, it used fuzzy comprehensive evaluation method for mobile barricades comprehensive performance evaluation, and analyzed the evaluation results.

4.3.1. Analyze the Decision of Index Weight

Using analytic hierarchy process (AHP) to conform the weighted coefficient, steps are as follows:

1) Establishing the structure of the index system in Table 2.

![Comprehensive performance evaluation indicators system of mobile barricades](image)

**Table 2. Judgment Matrix Table.**

<table>
<thead>
<tr>
<th>Bs</th>
<th>S1</th>
<th>S2</th>
<th>......</th>
<th>......</th>
<th>Sn</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>C11</td>
<td>C12</td>
<td>......</td>
<td>......</td>
<td>C1n</td>
</tr>
<tr>
<td>S2</td>
<td>C21</td>
<td>C22</td>
<td>......</td>
<td>......</td>
<td>C2n</td>
</tr>
<tr>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>Sn</td>
<td>Can</td>
<td>Can</td>
<td>......</td>
<td>......</td>
<td>Can</td>
</tr>
</tbody>
</table>

Note: Cij>0, Cij* Cji=1, and when i=j, Cij=1

2) Constructing judgment matrix and solving it.

The judgment matrix between target layer A and first-class criteria indexes B1, B2, B3, B4, which can be denoted as A-B. The judgment matrix between first-class criteria indexes and second – class indexes which the first-class criteria indexes contain, which can be denoted as B-S. Judgment matrix representation of a level a unit (element), the level is related to its relative importance comparison between units. Generally we could take the following forms.

In the pair wise comparison process, policymakers need to hammer some questions. For standard layer Bk, which one is more important, element A or element B, and to what degree. It needs to give the level of importance to a certain value, using the ratio of 1 to 9 scale, their meanings are shown in Table 3 Proportional scale and significance, relative to the upper layers of indicators on the mutual importance are applied to mobile barricades, and the 12 experts have rich experience in logistics engineering, systems engineering, traffic engineering, industrial engineering and information system analysis and design direction.
Table 3. 1-9 Proportional scale and significance.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Two elements have the same importance for a property</td>
</tr>
<tr>
<td>3</td>
<td>Compare two elements, one element is slightly important than another element</td>
</tr>
<tr>
<td>5</td>
<td>Compare two elements, one element over another element obviously important</td>
</tr>
<tr>
<td>7</td>
<td>Compare two elements, one element is more important than the other elements</td>
</tr>
<tr>
<td>9</td>
<td>Compare two elements, one element over another extremely important element</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Represents the compromise between the above two standard scale</td>
</tr>
</tbody>
</table>

In the process of expert evaluation, in this paper, the weight distribution of each expert is equal, there is access to adequate experience in various fields will be considered, to get more reasonable results. Finally, we conducted a weighted average score according to the score given by the experts, and then constructed judgment matrix, details are as following:

In the case of urban distribution vehicle traffic system, namely targets A, the core requirements of the mobile barricades is that tide traffic phenomena need fast response. Efficient running B1 is slightly more important than road utilization rate B2; road utilization rate B2 is slightly more important than environmental benefits B4; environmental benefit B4 is slightly more important than economic efficiency B1. Consequently, the resulting target layer to the criterion level judgment matrix A-B, are shown below:

\[
B_1 = \begin{bmatrix}
1 & 4 & 1/3 & 3 & 3 \\
1/4 & 1 & 1/5 & 1/3 & 1/3 \\
3 & 5 & 1 & 4 & 4 \\
1/3 & 3 & 1/4 & 1 & 2 \\
1/3 & 3 & 1/4 & 1/2 & 1
\end{bmatrix}
\]

For travelling efficiency B3, the increase of the traffic capacity is the most basic embodiment to travelling efficiency; so, the importance of traffic capacity is the highest. The increase of travelling capacity is to help vehicles to minimize total travel time and reduce fuel consumption. Therefore, the increase of the traffic capacity is more important than total travel time, total travel time is more important than fuel consumption. The resulting judgment matrix B3 to total travel time Y1, traffic capacity Y2, fuel consumption Y4 are shown as follows:

\[
B_3 = \begin{bmatrix}
1 & 3 & 1/3 \\
1/3 & 1 & 1/5 \\
3 & 5 & 1
\end{bmatrix}
\]

For environmental benefits B4, only by increasing the traffic capacity could the standard deviation of vehicle be reduced and fuel consumption be reduced. So, traffic capacity is the highest, speed standard deviation is lower than traffic capacity, all fuel consumption level is lower than the speed standard deviation. The resulting judgment matrix B4 to traffic capacity Y2, speed standard deviation Y3, all fuel consumption Y4, are shown as follows:

\[
B_4 = \begin{bmatrix}
1 & 1/3 & 1/5 \\
3 & 1 & 1/3 \\
5 & 3 & 1
\end{bmatrix}
\]

3) Calculation of mutual importance and consistency check

Although summation method and root method can be used in practice to calculate approximate values of the eigenvalues, in order to calculate the accuracy, this article used matlab to calculate, and weight retention 3 decimal digits.

Firstly, matlab obtained the maximum eigenvalues \( \lambda_{\text{max}} = 4.117 \) and corresponding eigenvectors; the corresponding vector of \( \lambda_{\text{max}} =4.117 \) to the normalization process, got the corresponding weight vector \( W_0=\{0.564, 0.118, 0.055, 0.263\} \).

Second, consistency index CI=0.039 is calculated according to the formula (1).

\[
\text{CI(Consistency index)} = \frac{(\lambda_{\text{max}} - n)}{n-1} \quad (1)
\]

In addition, we need to introduce the average random consistency index RI (Random Index) of judgment matrix. For judgment matrix of order 1-9, RI values are shown in Table 4.
Finally, referring to the formula CR=CI/RI table consistency check, it is clear that CR=0.039/0.9<0.1, and therefore the judgement matrix could pass the consistency test.

Repeat the above steps in order to determine $i = 1, 2, 3, 4$, and then we get the corresponding judgment matrix $B-S$ corresponds to the largest eigenvalue

$\lambda_{max}^{(i)}, \lambda_{max}^{(1)} = 5.259, \lambda_{max}^{(3)} = 3.039, \lambda_{max}^{(4)} = 3.039$

According to the above analyses, we can see that the maximum eigenvalues of judgment matrix $B_1, B_2, B_3$ are respectively equal to $\lambda_{max}^{(1)} = 5.259, \lambda_{max}^{(3)} = 3.039, \lambda_{max}^{(4)} = 3.039$, and

$CR_1=CI/RI=0.065/1.12=0.058<0.1, \quad CR_3=CI/RI=0.012/0.58=0.02<0.1, \quad CR_4=CI/RI=0.012/0.58=0.02<0.1$

so the judgment matrix could pass the consistency test.

For $i = 1, 2, 3, 4$, the corresponding vector of $\lambda_{max}^{(i)}$ to the normalization process, we could get the corresponding weight vector $W_i$ of $B_i$, as follows:

$W_1=(0.25,0.05,0.46,0.13,0.10)^T$;

$W_3=(0.26,0.10,0.64)^T$;

$W_4=(0.10,0.26,0.64)^T$.

Consequently, we could get the evaluation index system of distribution of the weight of each index relative to the upper bound as shown in Fig. 4.

### 4.3.2. Fuzzy Comprehensive Evaluation and Analyses

Based on the above steps, we could determine the evaluation set $V=\{\text{excellent}, \text{good}, \text{fair}, \text{poor}\}$ according to expert reviews of the indicators and get the membership degrees as is shown in Table 5.

---

**Table 4. RI values refer to table.**

<table>
<thead>
<tr>
<th>Judgment matrix order</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI values</td>
<td>0.00</td>
<td>0.00</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
</tr>
</tbody>
</table>

**Fig. 4. Mobile barricades evaluation index relative weight assigned chart.**

**Table 5. Index relative weights at various levels and their membership.**

<table>
<thead>
<tr>
<th>First-class index (weight)</th>
<th>Second – class index (weight)</th>
<th>Membership of evaluation grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic benefits B1 (0.56)</td>
<td>Land area of access system (0.25)</td>
<td>Excellent 0.800 Good 0.200 Fair 0.000 Poor 0.000</td>
</tr>
<tr>
<td></td>
<td>The increased amount of city logistics distribution (0.05)</td>
<td>Excellent 0.450 Good 0.370 Fair 0.150 Poor 0.030</td>
</tr>
<tr>
<td></td>
<td>Equipment investment and maintenance cost (0.46)</td>
<td>Excellent 0.267 Good 0.350 Fair 0.333 Poor 0.050</td>
</tr>
<tr>
<td></td>
<td>The total travel time (0.13)</td>
<td>Excellent 0.333 Good 0.417 Fair 0.167 Poor 0.083</td>
</tr>
<tr>
<td></td>
<td>Fuel consumption (0.10)</td>
<td>Excellent 0.530 Good 0.260 Fair 0.210 Poor 0.000</td>
</tr>
<tr>
<td>Utilization B2 (0.12)</td>
<td>Road utilization (1.0)</td>
<td>Excellent 0.850 Good 0.150 Fair 0.000 Poor 0.000</td>
</tr>
<tr>
<td>Operating efficiency B3 (0.06)</td>
<td>The total travel time (0.26)</td>
<td>Excellent 0.500 Good 0.333 Fair 0.167 Poor 0.000</td>
</tr>
<tr>
<td></td>
<td>Increase of the traffic capacity (0.10)</td>
<td>Excellent 0.700 Good 0.200 Fair 0.100 Poor 0.000</td>
</tr>
<tr>
<td></td>
<td>Fuel consumption (0.64)</td>
<td>Excellent 0.550 Good 0.270 Fair 0.080 Poor 0.100</td>
</tr>
<tr>
<td>Environmental benefit B4 (0.26)</td>
<td>Increase of the traffic capacity (0.10)</td>
<td>Excellent 0.650 Good 0.308 Fair 0.042 Poor 0.000</td>
</tr>
<tr>
<td></td>
<td>Speed standard deviation (0.26)</td>
<td>Excellent 0.370 Good 0.230 Fair 0.225 Poor 0.175</td>
</tr>
<tr>
<td></td>
<td>Fuel consumption (0.64)</td>
<td>Excellent 0.550 Good 0.270 Fair 0.080 Poor 0.100</td>
</tr>
</tbody>
</table>
Based on the Fuzzy comprehensive evaluation of formulas, we could judge the secondary indexes set separately, taking economic benefits for example, 

\[ C_3 = B_4^T \times R_3 = \begin{bmatrix} 0.56 & 0.12 & 0.06 & 0.26 \end{bmatrix} \times \begin{bmatrix} 0.44 & 0.30 & 0.20 & 0.05 \\ 0.85 & 0.00 & 0.00 & 0.00 \\ 0.55 & 0.28 & 0.10 & 0.06 \\ 0.51 & 0.26 & 0.13 & 0.11 \end{bmatrix} = \begin{bmatrix} 0.51 & 0.25 & 0.15 & 0.06 \end{bmatrix} \]

We can work out in the same way:

\[ C_2 = (0.85, 0.00, 0.00, 0.00) \]
\[ C_3 = (0.55, 0.28, 0.10, 0.06) \]
\[ C_4 = (0.51, 0.26, 0.13, 0.11) \]

Above two recorded \( R_o = (C_2, C_3, C_4) \) as a four-level indicators to judge the results of an evaluation of the level indicator levels of membership matrix, according to the level weights and Fuzzy comprehensive evaluation index formula, we can get the membership of mobile barricade A, denoted by \( C_o \):

\[ C_o = B_0^T \times R_o = \begin{bmatrix} 0.56 & 0.12 & 0.06 & 0.26 \end{bmatrix} \times \begin{bmatrix} 0.51 & 0.25 & 0.15 & 0.06 \end{bmatrix} = \begin{bmatrix} 0.51 \end{bmatrix} \]

Set collection and rating \( v = \{ \text{excellent, good, normal, differential} \} \) collection of values that correspond to \( I = \{95, 85, 70, 50\} \), then we can calculate the flexible composite score for the level of distribution centers:

\[ S = C_o^T \times I = (0.51, 0.25, 0.15, 0.06) \times (95, 85, 70, 50)^T = 83.2 \]

4.4. Evaluation Results and Analysis

From the results of fuzzy comprehensive evaluation, comprehensive evaluation of mobile barricades is between benign and middle level with the composite score of 83.2. In this rank level, evaluation of middle and poor class accounts for only 21 %. Access system footprint, utilization of the road utilization, and operational efficiency savings in total travels time and capacity evaluation of these two excellent and good evaluation levels occupy higher membership. Economic benefits of investment in equipment and maintenance costs two indicators evaluation level and the difference in the degree of membership is higher.

As mobile barricades setting is across the road on both sides without taking car lanes, and reducing road transport infrastructure construction on occupied land, it can minimize the transformation of urban land, improving land utilization, and promoting sustainable transportation development. Therefore, the implementation of mobile barricades not only improved the land utilization, making transportation to get sustainable development, but also increased road capacity, reduced total travel time and saved fuel consumption, creating a better traffic environment for distribution vehicles.

During the construction of mobile barricades, we not only need to run the car, barricades, rails these hardware devices, but also need to control the car synchronous operation, lifting and moving barricades controlling and communications software development. Thus, to some extent, the prevalent system equipment investment and maintenance cost would be a little higher.

5. Conclusions

Evaluation studies of mobile barricades comprehensive performance has an important guiding significance on the improvement of traffic flow during tidal road transport. Through the fuzzy AHP and survey data analysis, six-lane’s traffic flow increased by 19.1 % compared with four-lane. Eight-lane’s traffic flow increased by 26.7 % compared with four-lane. In addition, road utilization, total travel time and saving capacity evaluation’s membership to overall significance are higher. Therefore, the allocation of resources in the horizontal road mobile barricades can ease traffic tidal phenomenon. Mobile barricades can also be used as emergency mobile barricades transport. When distribution and delivery vehicles encountered traffic tide, in order to deliver the goods on time, mobile barricades could be set up and down through the tidal carriageway road traffic to improve delivery speed. Engineering method could not only be used to improve the performance of transport, but also could be used to build a new distribution vehicle traffic system, and further enrich the cooperation between the vehicle and the road form through the new road barricades system construction.

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