Research on Evaluation Methodology of Satellite Positioning System for Enterprise Road Transport Vehicle
Xuan DONG and Chen CAO
Research Institute of Highway Ministry of Transport, Beijing 100088, China

Keywords: Road transport, GNSS, Evaluation methodology.

Abstract. Since the Ministry of Transport organized to carry out the construction of road transport dynamic monitoring system in 2010, road transport dynamic monitoring system has played a more and more important role in road transport safety management. A national networking and joint controlling system of key operating vehicles, covering 31 provinces and four-level structure, has been built. At present, it lacks complete and fair evaluation methodology in terms of results of the system application in transportation enterprises. This paper focuses on researching evaluation methodology of satellite positioning system for enterprise road transport vehicles, and builds evaluation methodology of satellite positioning system for enterprise road transport vehicles in terms of evaluation content, evaluation criteria, criteria weight.

Introduction

With the rapid development of road transport service, people’s demand of “safe transport” is becoming higher and higher [1]. It is required that the use of modern science and information technology should be accelerated, and we should constantly innovate and raise the level of road transport safety management. Satellite positioning system for road transport vehicles takes full advantages of information technology methods[2], makes up for the shortages of traditional road transport safety management methods, solves the problem effectively that trade management departments and enterprise managers “cannot watch, cannot hear, cannot control” in the process of vehicle operation, makes the operation and driving behavior of vehicles effectively controlled and restrained, and combines organically the industry supervision with the enterprise supervision, changes the former situation that accidents can be only investigated and treated afterwards but can’t be prevented in advance[3], realizes the overall-process supervision that accidents are intensively prevented beforehand, process monitored in process, investigated and treated seriously afterwards.

The Ministry of Transport have successively released satellite positioning system terminal (JT/T 794), platform (JT/T 796), communication protocol (JT/T 808) and data exchange (JT/T 809) these four transport industrial standards. However, because of the lack of relevant monitoring method and standard, we can’t give scientific and precise evaluation to the conformity of terminal, platform and four standards of the market. This paper will aim at analyzing and calculating scientifically and detailly the effect on how satellite positioning system for enterprise road transport vehicles prevents and decreases road traffic accidents under the new policy, including evaluation criteria (economy, society, public benefit), evaluation method and evaluation procedure.

Current Situation of Road Transport Dynamic Monitoring System in China

Situation of Application

Since the Ministry of Transport organized to carry out the construction of road transport dynamic monitoring system in 2010, especially since the No. 5 Decree carried out on July 1st, 2014, under the strong push of transport competent department and road transport management organization of all levels, obvious progress has been made in the work of road transport dynamic monitoring [4], and the
effect of preventing and decreasing road transport accidents, as well as strengthening road transport safety supervision, has increasingly emerged. It is reflected in these five aspects below:

**Supporting System has been Built and Strengthened Gradually.** Since the No. 5 Decree issued and carried out, every province (District, City) also has introduced successively the enforcement regulation and relevant rules which thoroughly implement the No. 5 Decree; 19 provinces have carried out filing rule for operator platforms. Beijing drew up “Filing Procedural Provision of Satellite Positioning System Monitoring Platform for Road Transport Vehicles in Beijing”, “Unlawful Act Discretion Standard of Road Transport Vehicles Dynamic Monitoring and Management in Beijing” and “Associated Law Enforcement Working Rules of Road Transport Vehicles Dynamic Monitoring and Management in Beijing”, making each of the rules more detailed and operable. Transportation Bureau of Jilin printed and distributed “Division of Job Duties of Vehicle Satellite Positioning System Management”, clarifying the dynamic supervision responsibility and job division of 9 relevant Offices in the Bureau, implementing the job responsibility. Yunnan Province included constructing and operating fee of dynamic supervision platform in the financial budget, offering the financial guarantee for dynamic supervision.

**Coverage Enhances Obviously.** At present, the four-level Ministry-Province-City-County dynamic supervision system has been initially formed, and the nationwide transport departments of 31 provinces have been all connected to key networking and joint controlling system of operating vehicles. Up to the end of 2014, the work to clear the transportation administration basic data of 786.1 thousand “two types of passenger cars and vehicles for hazardous articles” has been done, among which the number of vehicles connecting to key networking and joint controlling system reached 588.1 thousand, increasing by 79.3 thousand vehicles than the end of November, the rate of connecting to network reached 74.81%, increasing by 0.61 percentage points than 74.20% in the end of November; online rate of “two types of passenger cars and vehicles for hazardous articles” is 80.23%, increasing by 17.86 percentage points than 62.37% in the end of November. The rate of connecting to network in Jiangsu, Hainan, Zhejiang, Shandong, Ningxia, Chongqing, Guizhou, Hunan these 8 provinces is over 90%.

In terms of technic investigation of conformity in vehicle-mounted terminal and system platform, up to now the Ministry of Transport has announced 11 batches 723 types of satellite positioning vehicle-mounted terminals, including 444 vehicle-mounted terminals compatible to Beidou and 279 GPS terminals; 10 batches 423 system platforms, including 31 supervision platforms of provincial government, 15 supervision platforms of prefecture-level government and 377 monitoring platforms of operator and transport enterprise.

**The Supervision Ability of Administrative Department is Improved Further.** After the No. 5 Decree has been carried out, departments throughout the country innovated in working methods, combined the dynamic supervision with the static management of the operating vehicle, made the vehicle operation situation as the vital criterion of annual check, credit assessment, new vehicle admittance, classes and lines examining and approving, strengthened the application of the vehicle dynamic supervision platform, improved the industrial supervision ability. The joint supervision strength was further strengthened by Transport, Public Security and Safety Supervision these 3 departments. From July 1st, 2014 to the end of 2014, Ministry of Public Security and Ministry of Transport notified each other 1741 unlawful clues of transport enterprise, implemented 1709 clues, among which 631 were proved to be true, and they were all corrected and handled on time.

Transportation Commission in Chongqing actively coordinated City Safety Committee and Traffic Police Headquarters, included the dynamic supervision in the city specific project of “two changes and one regulation”, and carried out normalized supervision according to the principle of “divide up the work and assign a part to each, the one who inspects will take the responsibility”. In Spring Festival 2014, the goal, which there was no accident in road transport safety production in Chongqing, was reached again. Up to the end of 2014, there was no single accident for 90 months in a row in Chongqing in which over 10 people died.
Anhui Province and Gansu Province combined with the work of operation control and pushed the application of dynamic supervision information. Anhui Province regarded using the vehicle-mounted terminal which is up to standard as the precondition of annual examination of key operating vehicles, the key operating vehicles without vehicle-mounted terminal will uniformly not be approved and issued road transport certificate in annual examination, changing from supervision in advance to paying attention to all beforehand, in-process and after-event supervision. Gansu Province made constructing and operation situation of enterprise supervision platform, online situation of vehicle as the vital condition of administrative licensing, annual examination, and quality and credit assessment.

Entity Responsibility of Enterprise is Initially Implemented. Road transport enterprises throughout the country in accordance with demand of No. 5 Decree built dynamic monitoring system, equipped full-time monitoring staff, operated and used monitoring platform, monitored the operation situation of vehicles in real time, and implemented initially the entity responsibility of dynamic monitoring. Some enterprises made excellent progress, for example Hefei Anhui Automobile Passenger Transportation Co., Ltd. paid attention to transportation permit management system of operating vehicles, terminal standby application system, routing inspection of two-level monitoring platform from head office and branch office, security examination system of drivers, security information release system and safety performance examination system these 6 institutional improvements. From the monitoring platform coming into use to the end of 2014, the company aimed at 1400 passenger service vehicles and announced more than 140 dynamic monitoring notifications, punished 73346 overspeed vehicles, fired 7 divers, disposed in total 248 superintendents who hasn’t supervised well; since July 2014 the company announced 4 periods of dynamic monitoring notification, punished 408 overspeed vehicles and fired 1 driver. In October 2014, there were less than 100 overspeeds throughout the company, comparing to 33831 overspeeds in October 2008 (beginning of the dynamic monitoring), the percentage decreased by 99.7% on year-on-year basis. Since the No.5 Decree was carried out, there was no single accident, which more than 3 people died (above equal responsible), in the company.

Remaining Problem

With the previous effort of Transport, Public Security and Safety Supervision Departments of all levels, the dynamic monitoring work has made phasic progress, but there are still problems below remaining in the present boosting process:

Firstly, there is still non-standard phenomenon of networking and joint controlling system. Vehicle-mounted terminals in some regions are not installed in place, some vehicle-mounted satellite positioning units can’t be maintained in time, and phenomenon even exist, that satellite positioning units are destroyed on purpose, as well as satellite positioning unit signal is intervened and shielded factiously. At present the quality of dynamic and static data which are uploaded by every province are uneven, the problem of non-standard and unmatched data stands out, quality of networking and joint controlling system needs urgently to be improved.

Secondly, there hasn’t been an evaluation system for enterprise application situation yet. The system should include terminal normative installation system, daily management standard and supervision and investigation system of platforms of all levels and all kinds, examination system of all-level platforms, platform operator filing rule system and inner-enterprise supervision system.

Thirdly, the system and operation control are not mixed effectively. At present, the application of vehicle dynamic supervision in road transport management is still limited, it hasn’t implemented in place yet, that data can be fully used in enterprise supervision and law enforcement, punishment institutional improvement and implementation; in terms of the safety entity responsibility implementation of enterprise passenger and freight transport operation control, vehicle dynamic supervision data isn’t effectively used, and problems reflected by dynamic monitoring haven’t been corrected effectively in the driver management on time.

Fourthly, the reliability of satellite positioning unit needs to be improved, the operation of enterprise monitoring platform is nonstandard yet. In practical work, the phenomenon of regional
protectionism and even benefit protection exist in some regions. Some positioning units are sent to OEM inspection, but their actual qualities are uneven, which influences the data transport and the stability, and system maintaining as well. Some of the platforms are not able to achieve all-weather operation, on-duty personnel, and some even upload the fake data or falsify the data.

Research on System Evaluation Methodology

Evaluation Content

The Installation and Construction Situation of Satellite Positioning Unit and Monitoring Platform. 1. Key operating vehicle of transport enterprise is installed satellite positioning unit which is up to standard or not, sleeper coach is installed satellite positioning unit which is up to standard and has the video function or not, and the unit installation is up to standard or not, the speed signal, brake signal, light signal of vehicle itself are joint up, etc.

2. The transport enterprise installs and uses satellite positioning system monitoring platform or monitoring port or not, examine the monitoring platform that it passes the standard conformity investigation or not, and it is connected to national networking and joint controlling system of key operating vehicles or not, the monitoring data of enterprise platform is uploaded to the superior supervision platform accurately, in real time, and completely or not.

3. Transport enterprise has typed all basic data of vehicles and drivers belonging to it in the platform or not, there is the behavior or not that transport enterprise destroys satellite positioning units on purpose, intervenes and shields satellite positioning unit signal factitiously, and deletes or falsifies the data of satellite positioning unit.

The Establishment and Implementation Situation of the Enterprise Monitoring System. 1. The transport enterprise equips or hires full-time monitoring personnel who are responsible for monitoring vehicle driving dynamic state in real time according to the rules or not, the watch system is implemented during the vehicle operation period or not. Examine that the monitoring personnel grasps the relevant national policies and rules or not, and is familiar with vehicle transportation routes, operating time, go-through situation for roads, vehicle dispatching, basic information of drivers, etc. in the company or not.

2. Transport enterprise establishes and implements the installation, using, and maintaining system of satellite positioning unit, position statement and management system of monitoring personnel or not, there are problems that satellite positioning unit can’t be repaired in time after malfunction, the online rate during vehicle operation is not high or not.

3. Transport enterprise has made rules of vehicle dynamic monitoring operation according to the rules or not, and clarified standard and process of collection, analyzation, treatment of monitoring information, and requirement and process of statistics, submission, treatment of unlawful information, and analyzed dynamic monitoring information at fixed period, and completed safety management and educational training system in time.

The Application Situation of Satellite Positioning Monitoring Platform. 1. Transport enterprise sets up properly the standard of running speed limit of corresponding road section according to maximum road speed limit fitted by law and actual situation of vehicle driving road or not, and sets up corresponding standard of vehicle running speed limit by different period of time according to the requirement of “the running speed of passenger service vehicle in the nighttime shouldn’t be more than 80% of the speed limit in the daytime” in “Opinions of the State Council on strengthening the Work of Road Traffic Safety” (No.30 Document of the State Council〔2012〕) or not.

2. Transport enterprise sets up strictly time limit standard of vehicle continuous operation according to the requirement of No.30 Document of the State Council (2012) or not, in order to make sure that the total driving time of passenger service driver is no more than 8 hours in 24 hours, the continuous driving time in the daytime is no more than 4 hours, the continuous driving time in the
nighttime is no more than 2 hours, and the stop-and-rest time each time is no less than 20 minutes, and implements the system that passenger service vehicle stops operating or uses connection by other equipment from 2 AM to 5 AM or not.

3. Transport enterprise builds up account list of dynamic monitoring, gives warning and correction to the illegal behavior of abnormal parking, speeding driving, fatigue driving, driving out of accordance with ordered route, and deals with it afterwards in time or not. Enterprise responses to and carries out instruct of superior supervision platform, preservation of monitoring information is up to the mustard or not.

4. Transport enterprise takes punitive measures of punishment, job transfer, and dismissal to the driver who shields satellite positioning unit signal and destroys satellite positioning unit on purpose, as well as watchkeeper who doesn’t monitor the vehicle driving dynamic state strictly, and then inspects the online rate of vehicle satellite positioning unit for transport enterprise, punishment rate of unlawful act, etc. or not.

Evaluation Criteria and Weight

Analytical Hierarchy Process. Analytical Hierarchy Process is called HAP for short, and it is a technique for decision-making developed by American operational research expert T. L. Saaty in the middle of 1970s, its basic process is: firstly, the complex problem is decomposed into hierarchical structure, and then its various elements are evaluated by comparing them to each other two at a time, with respect to their impact on an element above them in the hierarchy, and judgment matrix is established. Through the calculation of the judgment matrix, we order in single level and make consistency test, order in whole system finally, then we get the weight coefficients of every level, and can analyze and solve the problem through ranking result. This method has the characteristics that it needs only a few information quantities and takes only a short time for decision-making process.

Establishment of Judgment Matrix. Various elements from hierarchical structure can be evaluated by comparing them to each other two at a time, through which judgment matrix is established. Judgment matrix $A = \left[ a_{ij} \right]_{n \times n}$ has the following characteristics:

$$a_{ij} > 0 \ (i, j = 1, 2, ..., n)$$  \hspace{1cm} (1)

$$a_{ii} = 1 \ (i = 1, 2, ..., n)$$ \hspace{1cm} (2)

$$a_{ij} = \frac{1}{a_{ji}} \ (i, j = 1, 2, ..., n)$$ \hspace{1cm} (3)

In the formula, $a_{ij} (i, j = 1, 2, ..., n)$ stands for proportion criteria referring that how important elements $A_i$ and $A_j$ are to the element above them. The value of judgment matrix reflects directly people’s cognition on relative importance of every element, and normally 1-9 proportion criteria is used to make assignment on importance degree, the criteria and its meaning is as shown in Table1.

<table>
<thead>
<tr>
<th>criteria</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The two elements have the same importance degree comparing with them two</td>
</tr>
<tr>
<td>3</td>
<td>The one element is a little bit more important than the other one comparing with them two</td>
</tr>
<tr>
<td>5</td>
<td>The one element is obviously more important than the other one comparing with them two</td>
</tr>
<tr>
<td>7</td>
<td>The one element is much more important than the other one comparing with them two</td>
</tr>
<tr>
<td>9</td>
<td>The one element is extremely more important than the other one comparing with them two</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>The mid-value between two judgments above</td>
</tr>
<tr>
<td>Reciprocal</td>
<td>Judgment bij is gained by comparing with element i and j, so $b_{ji} = 1/b_{ij}$ is gained by compared with element j and i</td>
</tr>
</tbody>
</table>
Calculation of Criteria Relative Weight. This step will solve the calculation problem of the weight of A1, A2,..., An these n criteria, and make consistency test. Comparing A1, A2,..., An to each other two at a time, we get judgment matrix A, and compute eigenvalue $\lambda_{max}$. The methods to calculate the weight vector and eigenvalue $\lambda_{max}$ are “Asymptotic Normalization Coefficient”, “Square Root Method” and “Power Method”. This paper chooses the easier “Asymptotic Normalization Coefficient”, and the detailed calculation steps are as followed.

Make matrix column normalization to A, which means normalizing every column of judgment matrix A.

\[
\bar{a}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (i, j = 1, 2, ..., n)
\]  

(4)

Then add by line to get sum vector.

\[
W_i = \sum_{j=1}^{n} \bar{a}_{ij} \quad (i = 1, 2, ..., n)
\]  

(5)

Normalize the gotten sum vector, and get weight vector.

\[
\bar{W}_i = \frac{W_i}{\sum_{j=1}^{n} W_j} \quad (i = 1, 2, ..., n)
\]  

(6)

Calculate the biggest eigenvalue $\lambda_{max}$ of matrix.

\[
\lambda_{max} = \sum_{i=1}^{n} \left[ \frac{A\bar{W}_i}{n(\bar{W}_i)} \right]
\]  

(7)

Because of the complexity of objective things and the fuzzification and diversity of people’s cognition to things, the given judgment matrix can’t completely stay the same. So we should make consistency test and calculate Consistency Indexes C.I.:

\[
C.I. = \frac{\lambda_{max} - n}{n-1}
\]  

(8)

In the formula, n is order of judgment matrix.

If Random Conformance Rate $C.R. = C.I / R.I. < 0.10$, then judgment matrix has satisfying consistency, otherwise we need to change the element value of judgment matrix. The value of Random Consistency Index R.I. is shown in Table 2.

Table 2. Value of average random consistency index R.I.

<table>
<thead>
<tr>
<th>n</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>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.I.</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>
<td>1.49</td>
</tr>
</tbody>
</table>

Design of Questionnaire. According to the degree how evaluation criteria influence to safety production of road dangerous cargo transport, the importance degrees are divided into: very important, relatively important, generally important, not too important, very unimportant these five levels. Experts are invited to evaluate the criteria importance according to their understanding and experience of the work of dynamic monitoring of road transport vehicle. At the same time, factors or criteria which haven’t been mentioned in the questionnaire but influence the safety production of road transport enterprise, are also added.
**Questionnaire.** The research group has given out 76 “Inquiry form of safety evaluation criteria weight of road transport vehicle dynamic monitoring system”, and regained 76 inquiry forms, including 7 void forms and 69 valid forms. People who were sent inquiry forms were: road transport administrative personnel, safety supervisor and information supervisor of transport enterprise, including units like transport department, transport enterprise, system manufacturer in Sichuan, Beijing, Anhui, Inner Mongolia and other provinces and cities. Through the data processing of valid samples, the total points are decided to be 100 after discussion. Safety evaluation criteria weight of road transport vehicle dynamic monitoring system and its score distribution is shown in Table 3.

<table>
<thead>
<tr>
<th>Sequence number</th>
<th>evaluation criteria</th>
<th>weight</th>
<th>score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Make and implement vehicle-mounted terminal installation and using rule</td>
<td>0.150</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Vehicle-mounted terminal accord with JT/T 794 is installed and used on “two types of passenger cars and vehicles for hazardous articles”, and it is operated normally as well</td>
<td>0.199</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Vehicle-mounted terminal is connected to monitoring platform accord with JT/T 796</td>
<td>0.148</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Examine the service condition of vehicle-mounted terminal, make sure the online time of the vehicle; vehicle-mounted terminal works normally, and monitoring data is transmitted accurately, in real time and completely</td>
<td>0.052</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Establish satellite positioning system enterprise platform of the road transport vehicle accord with JT/T 796, transmit positioning data to the superior monitoring platform in time, and make sure that data is true and accurate</td>
<td>0.151</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Basic data of vehicle and driver, vehicle technology file, vehicle driving situation recorded in enterprise platform are accurate and complete</td>
<td>0.048</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>Equip full-time personnel to take the charge of monitoring vehicle driving situation and driver’s dynamic situation, analyze and handle dynamic information</td>
<td>0.052</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>Set up monitoring and watch system, dynamically monitor operating vehicles for 24 hours in real time, response to the quality sent by superior monitoring platform and carry out relevant requirements</td>
<td>0.117</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Correct and handle unlawful acts of overspeed, fatigue driving, destroying vehicle-mounted terminal on purpose according to relevant rules in time, record the information of illegal drivers and preserve for at least 3 years</td>
<td>0.050</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Build up account list of dynamic monitoring</td>
<td>0.048</td>
<td>5</td>
</tr>
</tbody>
</table>

**Reference**


