SCIENCE JOURNAL OF TRANSPORTATION

Especial Issue No. 07
International cooperation Journals
MADI - SWJTU - UTC

Moscow - Chengdu - Hanoi
10 - 2016
Dear researchers, colleagues and readers,

Transportation is the means by which all people are connected, all human activities occur. Nowadays, in strong globalizing process, community activities have not been limited by countries' borders; thus transportation becomes non-confrontiers.

We, transportation makers, in this moment, have had a common forum to together discuss, contribute, share and dedicate.

First Especial Issue of international co-operating transportation science journals of State Technical University (MADI) - Russia, Southwest Jiaotong University (SWJTU) - China and University of Transportation and Communication (UTC) - Vietnam is published in spring – season of blooming and developments.

We wish you and our transportation career were achieved, prosperous and fruitful.

Science is non-limitation,
Transportation is non-border,
Friendship is non-confrontiers,
Aim toward the future, we will do our best to make transportation:
More intelligent and effective,
Faster and safer,
Cleaner and greener,
With that objective, by this forum, we together connect, endeavour, research, create, contribute, share and devote.

Moscow-Chengdu-Hanoi
Board of Editors-in-Chief
Information for Authors

Authors should follow the common rules of the research and publication ethics, avoiding plagiarism, research fraud, and simultaneous submission of manuscript to several journals, duplicate or “sliced” publications. In accordance with the “Science Journal of Transportation” policy, strictly original, unpublished previously manuscripts, resulting from a scientific research, are accepted to publication. Authors are supposed to have made a significant intellectual contribution to the research.

The language of articles is English. The structure of an article should include the following compulsory parts: article title, full authors’ name and surname, authors’ additional personal information (academic degree and title, e-mail, position), affiliation (name and address of working place), summary, keywords, introduction, main text, conclusion, and list of references. Presence of figures, tables, and mathematical dependences is welcomed in scientific articles.

Detailed requirements to publication, including article design and volume, as well as an article example can be found on the “Science Journal of Transportation” official web-page: http://lib.madi.ru/sjt/index.html

MAIL ADDRESSES OF EDITORIAL BOARDS

Prof. Valentin Silyanov (Editor-in-Chief, Coordinator, Russia)
State Technical University - MADI
Leningradskiy prospect 64 (Suite 348A)
125319, Moscow
Russia
E-mail: silyanov@bk.ru

Assoc. Prof. Dr. Nguyen Van Vinh (Editor-in-Chief, Vietnam)
University of Transport and Communications (UTC)
No. 3 Cau Giay str.
Hanoi City
Vietnam
E-mail: nvvinh@utc.edu.vn

Prof. Zhang Jin (Editor-in-Chief, China)
Southwest Jiaotong University (SWJTU)
Chengdu, Sichuan
People’s Republic of China
E-mail: zhjswjtu@swjtu.edu.cn

© MADI
© SWJTU
© UTC

The Journal published and printed by MADI, SWJTU and UTC Publishing House Periodical publication – 1 times per year. Circulation 600 copies
The date of publishing: 26th October 2016
# TABLE OF CONTENT

<table>
<thead>
<tr>
<th>Pages</th>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>VAKULENKO SERGEY PETROVICH</td>
<td>Management of foreign trade transportation in the transport corridors of Europe and Asia</td>
</tr>
<tr>
<td>10</td>
<td>CUI Yi, TANG Hailin, NGUYEN Thi-Yen, SHI Lu</td>
<td>The competitiveness and complementarity of China-ASEAN trade in goods and services</td>
</tr>
<tr>
<td>23</td>
<td>Y.V. Trofimenko, A.G. Nekrasov</td>
<td>Methodological issues of ensuring operational sustainability of transport and logistics systems</td>
</tr>
<tr>
<td>29</td>
<td>Guo-hua ZHOU, Pan ZHENG, Jian-rong WEI, Qiang-jun LENG</td>
<td>Research on land expropriation risk of China high speed rail overseas construction project - a case study of Jakarta-Bandung high-speed rail</td>
</tr>
<tr>
<td>41</td>
<td>A.A. Rementsov</td>
<td>The role of the public and private sector in Russian transport infrastructure</td>
</tr>
<tr>
<td>48</td>
<td>ZHANG Jin, NGUYEN Thi-Yen</td>
<td>Logistics efficiency evaluation for ASEAN based on DEA model</td>
</tr>
<tr>
<td>57</td>
<td>NGO DANG QUANG</td>
<td>Coupled thermal stress analysis for simulation of crack processing in concrete bridge box girders</td>
</tr>
<tr>
<td>64</td>
<td>Mouhamed Bayane, BOURAIMA, Qiu Yanjun</td>
<td>Current engineering practice of pavements maintenance in China</td>
</tr>
<tr>
<td>75</td>
<td>Vladimir V. Tatarinov, Nguyen Van Hieu</td>
<td>Method of dynamic design of rigid airfield pavements</td>
</tr>
<tr>
<td>81</td>
<td>Anh Tu Do, David Verdugo</td>
<td>Effect of heat of hydration of cementitious materials on temperature development of drilled shafts</td>
</tr>
<tr>
<td>88</td>
<td>Haibo Ding, Enhui Yang, Yanjun Qiu</td>
<td>The state of the art of using asphalt concrete as</td>
</tr>
</tbody>
</table>
trackbed of high speed railway

Pages 94
Zorin V.A
Baurova N.I
Kireev V.A

Repair of cracks basic parts of road construction machines with adhesive technology

Pages 97
NGUYEN XUAN HUY
BUI THI THANH MAI
DANG VIET TUAN

Experimental investigation on the seismic behaviour of an l shaped reinforced concrete column

Pages 102
Wu Chaoyang
Yang Enhui
Du Jianhuan
Xu Cheng

The treatment of collapsible loess embankment in lanzhou area

Pages 112
A.A. Burtsev
V.V. Silyanov

Social project «avtotrezvost» (autosobriety) as a model of primary prevention of drinking and driving

Pages 118
GUIHENG HE
YADONG ZHANG
JIN GUO
SHUO WANG

Safety analysis of on - board equipment rbc handover function based on multi - agent and hazop

Pages 129
D.Sc. V.Kapitanov
Dr. O.Monina
Dr. A.Chubukov
D.Sc. V.Silyanov

Simulation of regional mortality rate in road accidents identifies the relationship of the vehicles which have arrived from other regions

Pages 137
SHUO WANG
YADONG ZHANG
JIN GUO
GUIHENG HE

Research on risk analysis method of tcc based on multi-agent and hazop

Pages 148
Korchagin
Victor A
Klyavin
Vladimir E
Baryshev
Nikolai V

Improving the efficiency of road traffic control

Pages 153
Dr. Mikhail Malinovsky

Concept of preventive motion control applied to buses and commercial vehicles
IN INTERNATIONAL COOPERATION ISSUE OF TRANSPORTATION - Especial Issue - No.07

MANAGEMENT OF FOREIGN TRADE TRANSPORTATION IN THE TRANSPORT CORRIDORS OF EUROPE AND ASIA

Vakulenko Sergey Petrovich¹, Kurenkov Petr Vladimirovich²

¹Director of the Institute of Management and Information Technologies
²Deputy director of the Institute of Management and Information Technologies (research and innovations)
Moscow State University of Railway Engineering (MIIT) Emperor Nicholas II

Abstract: The dynamics of global container turnover in the 1990-2015 period is shown, the emphasis being placed on the countries of the Asian-Pacific. Thanks to its favorable geographical position, efficient transportation infrastructure and the busiest sea ports the Russian Federation has considerable potential for providing services in container cargo transportation. Major transportation corridors of various international organizations run through the territory of the Russian Federation. Major links and connections in the technological process of cargo transportation in the system “sea port/river port-connecting station” are introduced. Logistics centers in transportation junctions can be built on the basis of sea and river ports; their functions and services are described.

Key words: Container turnover, sea port, transportation infrastructure, transportation, cargo, transport corridor, logistic center, transportation junction, service, function.

In recent years, the volume of container traffic has been constantly increasing. In the 1970s the growth of container traffic was impressive – 21 percent annually. In the 1980-2000 the average increase of container turnover was up to 10 percent annually.

The only exception was the year 2009 due to the global economic crises when the volume of container turnover dropped by 13 percent compared to the precious year.

These days the global market of container traffic has overcome the financial economic crisis of 2009 and reached the pre-crisis state. After 2000 the annual average growth rates of the container market are 2.5 times higher than those of the global GDP (gross domestic product). In monetary terms the volume of the global container market is almost 1 billion dollars every year.

Taking into account the interstate container turnover we can see that the absolute leader in this process is the Asian region.

Nowadays over 50 percent of the global container turnover is handled by the Asian ports (about 25 percent of the global container turnover is handled by the Chinese ports). Europe, the second largest player in this market, shows the volume of container turnover that is 4 times less. Then follow South America, Middle East, Latin America, Africa and Oceania.

There is the fantastic growth of sea container shipment between the Asian ports – it jumped from 6.7 million TEU in 2005 to 37.6 million TEU in 2015 (over 6 times during ten years!).
Other routes show the increase, too, although it may seem not so impressive:

- The route Asia-Europe: the increase by 59 percent (from 19.2 million TEU in 2005 to 26 million TEU in 2015);
- The route Asia-South America: the increase by 48 percent (from 16.4 million TEU in 2005 to 24.3 million TEU in 2015);
- The route Europe-South America: the increase by 15 percent (from 7.8 million TEU in 2005 to 9.0 million TEU in 2015).

Nowadays it is the route Asia-Europe. In 2015, this route handled 14.3 million TEU of global sea cargo; this volume is expected to double in the nearest 5 years. In monetary terms, the contemporary trade turnover between Europe and Asia is about 600 milliard dollars annually.

Thanks to its favorable geographical position and efficient transportation infrastructure the Russian Federation has considerable potential for providing services in container cargo transportation. A great number of transport corridors belonging to various international organizations can run across Russia.

These days, the share of the Russian transport system in the Asian-European trade turnover is less than 1 percent; the transit potential is 10-15 percent (over 1 million TEU annually). Most of the mutual trade volume between European countries and the Asian-Pacific region is handled by sea transport across the Suez Canal, due to technological aspects which should be taken into account when planning efficient overland transport corridors.

However, nowadays the potential of ports - both Russian and European ones - is not sufficient; some of them are reaching their absolute traffic capacity. We feel concerned about the uncertainty in the sea shipping market. Congestions in the ports cause transport bottlenecks, there are problems in the dockside and coastal waters. In some places port’s waters are not deep enough to make the vessels move free; hence the disbalance between inbound and outbound loaded and empty containers. The running speeds of the vessels are decreased to solve the problem of global tonnage redundancy.

**Under current conditions it is of primary importance to find new alternative overland routes between Europe and Asia**

Two projects are important for the development of the infrastructure of the Eastern logistics ground of the Russian railways to provide perspective traffic volumes. The overland route for container shipment through the Khasan railway border point (RF) – the Tumangang station (North Korea) and the Rajine port (North Korea) is considered the most efficient. Some reconstructions works of railway infrastructure on the section Khasan (RF) - Tumangang (North Korea) and the port Rajine (North Korea) as well as the overhaul of tunnels have been carried out. A new cargo terminal in the Rajine port has been built. This work will provide handling up to 200 000 TEU of container shipment annually.
Another important project is the railway bridge between Isle of Sakhalin and the continent. Joining the Sakhalin railway with the Baikal-Amur Mainline will ensure the growth of export-import and transit potential of the Russian railways.

Implementation of the Khasan-Rajine project and the construction of the railway bridge between Isle of Sakhalin and the continent will give Russia two alternative entries to Asian-Pacific markets).

Of great importance for transit potential of the Russian Federation are the projects in the northern regions – Belkomur project and the project called North Latitudinal Run. The former is to optimize the European section of Transsib as well as the transport junctions of Moscow and St.Petersburg. The latter is to connect the Northern Railway with the Sverdlovsk Railway. It is to ensure the shortest transit of hydrocarbon goods westbound and the goods required for the development of gas and oil deposits eastbound.

Nowadays there are 27 major projects related to the development of the global transport system; seven projects are connected with Russia (picture 1, was publicated early on german in [1] and on russian in [2]).

![Picture 1. The projects of the global transport network development](image)

RZD Holding is to become one of major players in the transport market dealing with container shipment on the route Asia-Europe.
The picture 2 [2] shows the major links and connections of the complicated technological process. As you see, the picture is rather intricate and major processes are not easy to accomplish.

In this slide the solid direct arrows show the links and connections of the technological process of freight movement as the material flow. Resource movement without freight is shown with the curved arrows.

Containers with import cargo running through the Finnish ports arrive at the stations of the Moscow junction two weeks earlier than if they run through the St.Petersburg sea port (both by road and by rail). This is why Helsinki, not St.Petersburg is one of the entry points to the IX Crete transport corridor.

In the Far East coal transported from the Northeast provinces of China to the Russian port is loaded from Chinese to Russian wagons at the border station Grodekovo according to the unified shipping document. What we are dealing with is direct reloading, as it was in Russia in the second half of the 19th century (before 1888). Reloading-free direct traffic has been practiced in Russia only since 1889.

We suggest establishing logistic centers in the traffic junctions on the territory of sea and river ports, such as was published in [3-15] (like coordination councils which provided operation of transport junctions based in sea and river ports according to the system of continuous operation schedule of a transport junction in the 1970-1980s). Have a look at table 1 and 2.
<table>
<thead>
<tr>
<th>Functions</th>
<th>Tasks</th>
<th>Responsible party</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation</td>
<td>Consultancy, analyzing, planning&lt;br&gt;The choice of means of transport&lt;br&gt;Conclusion of the contract of affreightment&lt;br&gt;Drawing up shipping documents&lt;br&gt;Transportation control</td>
<td>Transportation broker</td>
</tr>
<tr>
<td>Transportation</td>
<td>Gathering and distribution of goods in freight short hauls.&lt;br&gt;Organization of freight long hauls in domestic and international traffic.</td>
<td>Carrier, forwarder</td>
</tr>
<tr>
<td>Transshipment</td>
<td>Preparation and handling of transshipment</td>
<td>Stevedore, forwarder, carrier</td>
</tr>
<tr>
<td>Warehousing</td>
<td>Putting freight to/ removing it from storage&lt;br&gt;Transfer goods from one warehouse to another&lt;br&gt;Store management and operations</td>
<td>Warehousing company, forwarder, carrier</td>
</tr>
<tr>
<td>Consolidation</td>
<td>Consolidation of goods into collies&lt;br&gt;Preparation of aggregated shipments</td>
<td>Carrier forwarder,</td>
</tr>
<tr>
<td>Packaging</td>
<td>Consultancy and the choice of package&lt;br&gt;Dispatch of packages</td>
<td>Stevedore, packaging, warehousing or forwarding company</td>
</tr>
<tr>
<td>Preparation</td>
<td>Sorting and labeling goods according to batches&lt;br&gt;Servicing and pre-sale preparation of goods</td>
<td>Forwarder, carrier</td>
</tr>
<tr>
<td>Information dissemination</td>
<td>Shipping notification&lt;br&gt;Monitoring and control of goods distribution</td>
<td>Various companies</td>
</tr>
<tr>
<td>Special</td>
<td>Goods-in-transit insurance&lt;br&gt;Customs formalities&lt;br&gt;Repair services&lt;br&gt;Preservation&lt;br&gt;Restoration&lt;br&gt;Loan and payment services</td>
<td>Various companies</td>
</tr>
</tbody>
</table>
Table 2. The potential volume of services provided by the logistics center based in the sea port

<table>
<thead>
<tr>
<th>Traditional services</th>
<th>Traditional port services and organizational services as well as the whole complex of services in freight distribution are based on modern equipment and electronic information technologies.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial service of ports</td>
<td>Industrial and technological servicing of rolling stock (ship and container repair, etc.) is to increase efficiency and decrease technological and commercial risks when operating port technical facilities. Industrial cargo handling or providing necessary conditions for the industrial development of port areas to attract considerable volumes of freight.</td>
</tr>
<tr>
<td>Administrative and commercial services</td>
<td>Documentation is to be understandable, compatible with marketing and transport documentation and applicable for electronic data exchange. Working out the schedule (cargo handling, its receiving, packing and dispatching is to be carried out twenty-four hours a day seven days a week). Administrative services (under the status of free zone the port may provide all necessary commercial conditions for its direct and indirect customers offering them banking, insurance, legal and communications services).</td>
</tr>
<tr>
<td>Logistics services in cargo distribution</td>
<td>In third generation ports (according to UNCTAD classification) all types of traditional, industrial and commercial activity are carried out according to organizational principles. Usually the ports ensure only basic conditions for cargo distribution; detailed work is assigned to specialized companies. Containerization and distribution of combined traffic make ports provide a new, purely organizational service. In this case the port works like a passage for freight without imposing VAT.</td>
</tr>
<tr>
<td>Warehousing services</td>
<td>Offering areas sufficient for storing goods near the terminals, planning and equipping the warehouse, meeting customers’ requirements (including air-conditioning, stacking, computerized control systems).</td>
</tr>
<tr>
<td>Information service of ports</td>
<td>Information servicing for management organization, management operations, technical and administrative activity, accumulation of information about the cargo and rolling stock for port administration (customs, insurance companies, banks, ship owners, consignors, etc.) meeting requirements concerning precise location of cargo and other information about warehouses, freight and vehicles.</td>
</tr>
</tbody>
</table>
Logistic centers providing efficient work of transport junctions based in sea and river ports and seamless passing of freight trade cargo through the system “port-seaport station” are seen either as a noncommercial partnership or a public corporation or a close corporation. It may have some other commercial or legal status with the strictly proved stock and the charter capital of every transport market subject concerned.

Their establishment is sure to make operation of the whole transport complex more efficient and economically attractive as well as to provide sustainable development of the Russian transport system in the global transport service market.

References
[12]. Logistischen Herausforderung und Chancen für die Binnenschifffahrt. / Lane Uwe. // Internationales Verkehrswesen.- 1993.- 45.- №3.- S. 121-125.
THE COMPETITIVENESS AND COMPLEMENTARITY OF CHINA-ASEAN TRADE IN GOODS AND SERVICES

CUI Yi\(^1\), TANG Hairlin\(^1\), NGUYEN Thi-Yen\(^{1,2}\), SHI Lu\(^{1,3}\)

\(^1\)Southwest Jiaotong University School of Transportation and Logistics Chengdu 610031  
\(^2\)China-ASEAN Collaborative Innovation Center for Regional Development  
\(^3\)China Railway Eryuan Engineering Group CO.LTD

Abstract: China and ASEAN countries have a high similarity of industrial structure, but the export similarity of sub-sectors is moderate, which shows that China and ASEAN countries have certain differences and complementarities in the foreign trade market. According to the Trade Competitiveness Index, the Revealed Comparative Advantage and the Trade Complementarity Index of agricultural products, industrial manufactured goods and services among China and ASEAN countries, we analyze the superior product of each country in goods and services trade and their competitiveness and complementarity in detail. On the basis of this, the main countries of ASEAN are classified, putting forward the countermeasure and suggestion in view of China and each kind of country's competitiveness and the complementarity.

Keywords: China-ASEAN, industrial structure, competitiveness, complementarity

INTRODUCTION

"The Belt and Road" strategy was promoted from the top-level design to gradually implement in 2015. In the "The Belt and Road" strategy, ASEAN is the important part of economic and trade investment in constructing the "Maritime Silk Road". In the same year, China and ASEAN signed the "People's Republic of China and the association of Southeast Asian nations on amendments to ‘Chinese ASEAN comprehensive economic cooperation framework agreement’ and a part of the Agreement Protocol", marking that the China ASEAN Free Trade Area is officially upgraded. In the background of construction of "The Belt and Road" and the upgrade of “China ASEAN Free Trade Area”, the two sides have accelerated economic integration and development, the tariff level has been gradually reduced, the investment environment has been gradually optimized, and has made remarkable achievements in the areas of goods trade, services trade, mutual investment and acquired success in other areas of economic cooperation. Therefore, promoting industry connectivity becomes further fundamental issue in enhancing cooperation depth and keeping collaborative between China and ASEAN.

Surveys on competitiveness and complementarity of China-ASEAN trade are regular. Hoekman (1995) pioneered the idea of RCA index to analyze the characteristics of service trade. In goods trade, Jifeng Jia and Xiaoqing Li (1997) studied the complementarity and competition problem of China-ASEAN trade in goods at the earliest time. Niansong Tu and
Wen Song (2010) studied the complementarity between Yunnan and ASEAN. In services trade, Juan Wang (2008) focused on the China’s service trade in overall level, present structure and international competitiveness compared with ASEAN countries. Chen Xiulian (2011) focused on service trade of China-ASEAN countries complementary features. Jincheng Zhou and Leyi Chen (2012) studied the competitiveness and complementarity of the specific service trade sectors of China - ASEAN through the TCI, TC and ESI indices. But there is no literature deeply analyzing products and services” competitiveness and complementarity of China - ASEAN in the view of three industrial structure. This literature analyzes the competitiveness and complementarity of various products and services between China and ASEAN countries from the three dimensions of agricultural products, industrial products and services, combining with the similarity of industrial structure in different countries. As the main countries of ASEAN are classified, we puts forward the countermeasure and suggestion according to China and each kind of country’s competitiveness and the complementarity, to enhance the bilateral trade volume and bring opportunities of "Diamond ten years” for China and ASEAN.

I. A COMPARATIVE ANALYSIS OF INDUSTRIAL STRUCTURE SIMILARITY AND EXPORT SIMILARITY BETWEEN CHINA AND ASEAN

In 2014, the trade volume of China and ASEAN reached 480.4 billion US dollars, an increase of 8.3%, which is the 2.4 times of China's average increase in foreign trade volume. Despite the huge scale of China and ASEAN foreign trade, while generally it is still in the low-end of global value chain, the added value in per unit exports goods is relatively low which means large potential improvement. The construction of “Maritime Silk Road in 21 Century” brings friendly relations and economic cooperation between China and ASEAN into a new stage. It has become a strong impetus to the development of both sides, bringing further benefit to regional stability and economic growth from now on. The geographical position of China and ASEAN is approaching, which means a natural advantage of trade. Both sides are paying efforts to expanding the developing space, optimizing the traditional industries, introducing characteristic industry, promoting new industries, and continuously improving the industrial structure. The similarity of industrial structure between China and ASEAN countries is shown in table 1.

| Table 1. Industrial Structure Similarity between China and ASEAN Countries in 2011-2014 |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Brunei | Cambodia | Indonesia | Laos | Malaysia | Myanmar | Philippines | Singapore | Thailand | Vietnam |
| 2011 | 0.9097 | 0.8376 | 0.9970 | 0.9257 | 0.9940 | - | 0.9574 | 0.8859 | 0.9974 | 0.9789 |
| 2012 | 0.9070 | 0.8555 | 0.9966 | 0.9367 | 0.9962 | - | 0.9620 | 0.8989 | 0.9988 | 0.9822 |
| 2013 | 0.9149 | 0.8801 | 0.9961 | 0.9462 | 0.9975 | - | 0.9680 | 0.9007 | 0.9990 | 0.9865 |
| 2014 | - | 0.9151 | 0.9953 | 0.9382 | 0.9989 | - | 0.9746 | - | 0.9991 | 0.9872 |

Source: Calculated according to 2015 China-ASEAN Statistics Manual.

Data shows that there are high degree of similarity in industrial structure between China, Indonesia, Malaysia, Philippines, Thailand and Vietnam, indicating serious isomorphism, meanwhile industry competition is very high. Compared with Brunei, Cambodia, Laos, Singapore, industrial structure similarity is relatively low, but still in a higher category, existing industry isomorphism. From the trend of development, the industrial structure similarity of
China and ASEAN countries gradually increased in recent years, which shows the convergence of industrial structure development, also suggests that their direction of development and related industries are similar.

Due to that the industrial structure similarity can only reflect macro conclusions of different countries in the three industrial structure and can not make further accurate analysis of the characteristics in various industries, so this literature makes comprehensive statistics on the 77 sub-items in agricultural products, manufactured goods and services among China and ASEAN countries in 2014. The export similarity is shown in table 2.

<table>
<thead>
<tr>
<th></th>
<th>Brunei</th>
<th>Cambodia</th>
<th>Indonesia</th>
<th>Laos</th>
<th>Malaysia</th>
<th>Myanmar</th>
<th>Philippines</th>
<th>Singapore</th>
<th>Thailand</th>
<th>Vietnam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial products</td>
<td>42.35</td>
<td>27.04</td>
<td>71.89</td>
<td>28.70</td>
<td>70.50</td>
<td>34.15</td>
<td>64.93</td>
<td>59.70</td>
<td>75.01</td>
<td>71.76</td>
</tr>
<tr>
<td>Service</td>
<td>-</td>
<td>57.87</td>
<td>87.61</td>
<td>-</td>
<td>83.08</td>
<td>72.75</td>
<td>66.84</td>
<td>63.56</td>
<td>67.68</td>
<td>55.03</td>
</tr>
</tbody>
</table>

Source: Consolidated data from UN ComTrade and UNCTADstat. "-" indicates data default.

The data in the table 2 can be explained that from the view of Industry segmentation, the similarity degree of industrial exports is not as high as the industrial structure similarity, that is, the superiority products of different countries are in difference. In terms of agricultural products, China has the highest degree of similarity with Thailand and Vietnam, indicating more intense competition in the world market. In terms of industrial products, China has the highest degree of similarity with Thailand, Vietnam, Indonesia and Malaysia. In terms of service, China has the higher degree of similarity with Indonesia and Malaysia. Overall, as the service differentiation is difficult to reflect, so the service competition is more intense.

Next, this literature analyzes the competitiveness and complementarity of China and ASEAN countries on 77 sub-categories of different products and services by using the Trade Competitive Index, the Revealed Comparative Advantage and the Trade Complementarity Index. The data from UN Comtrade and UNCTADstat. Due to the low completeness of statistical data in the database in 2015, the data of goods trade and service trade in China and ASEAN countries in 2014 are used, taking the trade data availability of Brunei, Myanmar and Laos into account, this literature will not include the three industry's competitiveness and complementarity analysis of those countries.

II. ANALYSIS ON THE COMPETITIVENESS AND COMPLEMENTARITY OF AGRICULTURAL PRODUCTS TRADE BETWEEN CHINA AND ASEAN COUNTRIES

2.1. Development of agricultural products trade between China and ASEAN countries

Since China ASEAN Free Trade Zone was officially launched, agricultural trade of China-ASEAN showed a rapid development trend. China-ASEAN agricultural bilateral trade volume was $3.27 million in 2001, then increasing 13.3 times in 2014, rising to $43.26 billion, with an average annual growth rate of 22.7%. After the full completion of China-ASEAN Free Trade Zone in 2010, the amount of trade volume in agricultural products has increased more than 30% year on year. As the growth rate of China’s imports is greater than exports, from 2001 to 2014, China's agricultural trade to ASEAN has been in a deficit position, which is continuous
expanding.

2.2. Competitiveness and complementation analysis

The range of agricultural products mentioned in this article includes agricultural products of chapter 1-24 and parts of goods in chapter 29, 33, 35, 38, 41, 43, 50, 51, 52, 53 of HS1992 (The Harmonized Description and Coding System 1992). Referring to the definition of Regme (2005) and the classification of Liu Linqing (2010), in this paper, the agricultural products are divided into four categories, included bulk commodity, semi-processed goods, horticultural products and processing products. The classification system of agricultural products is shown in table 3.

<table>
<thead>
<tr>
<th>Classification</th>
<th>HS NO.</th>
<th>Product sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk commodity</td>
<td>09011, 0902, 0903, 1001-1008, 1201-1202, 1204-1207, 2401, 5201-5203, 5302 0101-0106, 0209, 0501-0511, 0713, 09019, 1108, 1101-1103, 1109, 1203, 1208-1302, 1401-1404, 1503, 1518, 1505-1516, 1520-1522, 17011, 1802-1805, 2301-2306, 2308-2309, 2905, 3301, 3502-3505, 3501, 38091, 3823-3824, 4101-4103, 4301, 5001, 5003, 5101-5103, 5301</td>
<td>tea, grain, soybean, peanut, Cocoa bean, cotton, tobacco and etc</td>
</tr>
<tr>
<td>Semi-processed goods</td>
<td>1209, 1211, 1213, 1214, 1301-1302, 1401-1404, 1503, 1518, 1505-1516, 1520-1522, 17011, 1802-1805, 2301-2306, 2308-2309, 2905, 3301, 3502-3505, 3501, 38091, 3823-3824, 4101-4103, 4301, 5001, 5003, 5101-5103, 5301</td>
<td>live animals, meat and edible offal, starch, grain dust, shelled wheat, animal fat, cocoa products, proteins, gelatin, leather, fur, wool, linen, soybean meal, animal products, crude glycerin, unsaturated fatty acid, alcohols and etc</td>
</tr>
<tr>
<td>Horticultural products</td>
<td>0601-0604, 0701-0709, 0714, 0801-0810, 0813, 0904-0910, 121291, 121292</td>
<td>live plants, rhizome, edible vegetable, edible fruits and nuts, flavor, oils, industrial medicinal plants, feed and etc</td>
</tr>
<tr>
<td>Processing products</td>
<td>0201-0208, 0210, 0401-0410, 0710-0712, 0811, 0812, 0814, 09012, 09104, 1104-1107, 121299, 12121-12123, 1504, 1517, 1601-1603, 1806, 1701-1704, 1901-1905, 2001-2009, 2101-2106, 2201-2209, 2402-2403, 3502</td>
<td>meat and edible offal, milk product, eggs, honey, specially treated fruits and vegetables, coffee, nuts, specially treated meat, sugar, sweetener, chocolate, beverage, vinegar and etc</td>
</tr>
</tbody>
</table>

According to the agricultural products trade data of China and main ASEAN countries, we analyze and calculate the trade competition index of agricultural products, the revealed comparative advantage and trade complementary index, as shown from figure 1 to figure 3.

**Figure 1.** Trade Competition Index of Agricultural Products (TC/CI) between China and ASEAN data source: According to the data of the United Nations commodity trade statistics database (UN ComTrade)
Compared with the main countries of ASEAN in various category of agricultural products, China, Thailand and Vietnam are more competitive, while others with less competition. There are some differences in the agricultural products type. Singapore, a typical non-agricultural country, with rare crop farming, is inferior in horticultural products and semi processed
products. But Singapore has a strong advantage in agricultural products processing, which is a high complementary with China. Malaysia and the Philippines own excellent natural resources, which are highly complementary to China in semi processed products. But the difference is that semi-products industry in Malaysia has a superior advantage, and outputting more cash crops. While the Philippines's agricultural products processing is stronger, for instance, vegetables and fruit products occupy half of the added value of agricultural products. Cambodia, whose superior products are balanced, has little difference in the advantages of the four types of products. Indonesia, by the ocean and has more than 50% of forest coverage rate, is high complementary with China in bulk commodities and semi-processed goods, as it owns enormous quantity of resource intensive agricultural products. Agriculture in Thailand and Vietnam, a traditional industry, has a long history and diverse characteristics. Rice planting and processing in Thailand is famous in the world. In Vietnam, advantages of products focused on planting and aquaculture. Consequently the semi processed goods and processing category has a strong advantage in Thailand, while the bulk commodities and semi-processed goods in Vietnam. China, with vast size and abundant resources, its categories of goods are superior to more ASEAN countries with monotonous types.

China-ASEAN agricultural trade current characteristics is the comparative advantage of China's agricultural products has continued to decline, the comparative advantage of the ASEAN agricultural products shows a trend of slow growth in volatility. China's trade deficit with ASEAN of agricultural products continues to expand. This is due to the fact that the large number of exports agricultural products from China are mainly processed foods such as vegetables, fruits, nuts, animal products and etc. In the meanwhile, ASEAN imports of these agricultural products accounted for only 1/3 of its total imports. In addition, ASEAN imports vegetable oil, sugar, oilseeds and other products to the world, and Chinese exports these agricultural products round the world accounted for merely 1/6 of its total exports. It's obvious that the state that China's agricultural exports to the world is not a large number of ASEAN imports of agricultural products from the world, contributed to the continuous decline of the trade complementation index of agricultural products. On the other hand, when it comes to the trade complementation index of agricultural products exported from ASEAN to China, it presents a continuous rising trend. For instance, semi-products, importing a large number to China, accounted for a higher proportion of ASEAN total exports to the world.

III. ANALYSIS ON COMPETITIVENESS AND COMPLEMENTATION OF MANUFACTURED GOODS TRADE BETWEEN CHINA AND ASEAN COUNTRIES

3.1. Development of Manufactured Goods Trade Between China and ASEAN Countries

The manufactured goods trade between China and ASEAN has developed rapidly, especially after the 21st century, the bilateral trade relations have made remarkable progress. China-ASEAN trade in manufactured goods amounted to $ 31.906 billion in 2001, and increased by 10.9 times up to $ 379.73 billion in 2014 with an average annual growth rate of 26.7%.
21%. Among the major industrial manufactures that import and export between China and ASEAN, there are three categories of goods are similar, mechanical products, clothes and accessories, and footwear, respectively. Mechanical products are primary trade goods.

3.2. Competitiveness and Complementation Analysis

The range of manufactured goods includes all 38 categories of goods in the International Trade Standard Classification (SITC 5-8), 18 of which are occupied over 85% in the bilateral trade of manufactured goods between China and ASEAN, and the remaining 20 take up small share. The specific product names and corresponding serial numbers are shown in table 4.

<table>
<thead>
<tr>
<th>SITC number</th>
<th>Type of goods</th>
<th>SITC number</th>
<th>Type of goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Chemicals and related products</td>
<td>74</td>
<td>Machinery and parts for other industries</td>
</tr>
<tr>
<td>51</td>
<td>Organic chemicals</td>
<td>75</td>
<td>Office machines and automatic data processing equipment</td>
</tr>
<tr>
<td>57</td>
<td>Primary form plastic</td>
<td>76</td>
<td>Telecommunications and sound recording equipment</td>
</tr>
<tr>
<td>6</td>
<td>Manufactured products classified by material</td>
<td>77</td>
<td>Electrical machinery, apparatus and appliances</td>
</tr>
<tr>
<td>65</td>
<td>Textiles and related products</td>
<td>78</td>
<td>Vehicles</td>
</tr>
<tr>
<td>67</td>
<td>Steel</td>
<td>79</td>
<td>Other transport equipment</td>
</tr>
<tr>
<td>68</td>
<td>Nonferrous metals</td>
<td>8</td>
<td>Miscellaneous products</td>
</tr>
<tr>
<td>69</td>
<td>Metal Products</td>
<td>84</td>
<td>Clothes and accessories</td>
</tr>
<tr>
<td>7</td>
<td>Machinery and transportation equipment</td>
<td>85</td>
<td>Footwear</td>
</tr>
<tr>
<td>71</td>
<td>Mechanical equipment of power generation</td>
<td>87</td>
<td>Professional and scientific instruments</td>
</tr>
<tr>
<td>72</td>
<td>Specialized machinery</td>
<td>89</td>
<td>Other miscellaneous products</td>
</tr>
</tbody>
</table>

According to the trade data of manufactured goods between China and ASEAN major countries in 2014. We analyze and calculate the trade competition index, the revealed comparative advantage and trade complementary index of manufactured goods (Due to the large amount of data, this article is only for broad heading analysis, and each category contains only a small class in table 4) as shown in figure 4 to figure 6.

Figure 4. Trade Competition Index of Manufactured goods (TC/CI) between China and ASEAN
In recent years, ASEAN manufactured goods trade has increased considerably, and products structure has changed towards a higher level. Machinery and transport equipment are the leading products in ASEAN trade in manufactured goods. All kinds of products increased obviously, showing great development potential and business opportunities. Malaysia, the Philippines, Singapore and Thailand are older members of the Association of Southeast Asian Nations (ASEAN), with rapidly developed manufactured goods, especially the SITC7 category of manufactured goods represented by electronic and communication equipment. The data shows that these countries have strong competitiveness in chemical and mechanical products, in which chemicals are highly complementary to China, while mechanical products are highly complementary in bilateral trade, and intra-industry trade trends are developing well. Cambodia, Indonesia and Vietnam are lagging behind in industrialization, the modern industrial system has not been established, still dominated by primary product processing. The data shows that the most advantageous manufacture products are mainly distributed in the SITC6 +8, but in recent years, the rapid economic development in Indonesia and Vietnam has promoted the rapid progress of its domestic industry, but also gave birth to the huge demand for manufacture products import. Indonesia's machinery products in manufacture products exports accounted for 29% with imports for 46%, and Vietnam import and export of machinery products both accounted for about 46%. The trade volume between Cambodia and China is lower than other ASEAN countries.
Comprehensively, China and ASEAN countries have a certain complementarity in the import and export, while there is also a considerable part of the competitive products, and gradually transfer from labor-intensive products such as clothing and footwear to the capital and technology intensive products such as mechanical products. In terms of mechanical products, China’s technology has improved rapidly and the trade level with ASEAN countries has also increased gradually with huge potential in development in the last decade, especially import and export both occupied a large share with rapid growth. The similar industries between China and ASEAN countries derive different products focus, such as the differences in clothing raw materials, grades and styles, and a wide range of electronic products. Compared to agriculture and services, it’s easy for countries to learn from each other and form a horizontal international division of labor.

IV. ANALYSIS ON THE COMPETITIVENESS AND COMPLEMENTATION OF SERVICE TRADE BETWEEN CHINA AND ASEAN COUNTRIES

4.1. Development of service trade between China and ASEAN countries

In recent years, the development of bilateral trade in services between China and ASEAN has made great progress. From $12.6 billion in 2006 to $62.6 billion in 2014, an increase of nearly four times, China has become the fourth largest service trading partner of ASEAN, while ASEAN maintains the status of China's fifth largest trading partner in services. In the aspect of service industry of ASEAN, China has made rapid growth in direct investment, international project contracting, international labor cooperation etc. Meanwhile, ASEAN expands cooperation with China in services such as the field of transportation, tourism, aviation, finance, construction etc. With the development of China and ASEAN Free Trade Area, the rapid growth in goods trade and foreign direct investment activities have become increasingly active, which will further accelerate services demand in transportation, finance, communications, and information, bringing more opportunities for both service providers.

4.2. Competitiveness and complementation Analysis

We classify in accordance with the "international balance of service trade and the international investment position manual" Sixth Edition (BPM6), who puts service trade into 11 departments, since we selected 7 departments related services, transportation, tourism, finance, communications, computer and information services and other business, personal culture and entertainment to analysis, according to the situation of services trade between China and ASEAN. The service sector serial number and name are shown in table 5.

| Table 5. The service sector in BPM6 and the corresponding name |
|------------------------|------------------------|
| number | Service sector | number | Service sector               |
| 1       | services related to Goods | 8       | Communication service, computer and information |
| 2       | transportation       | 9       | Other business                   |
| 3       | Tourism             | 10      | Personal, cultural, entertainment |
| 6       | Finance             | -       | -                                  |


Based on the data of service trade between China and ASEAN in 2014, we analyze and calculate the trade competition index, the revealed comparative advantage and trade complementary index of service trade, as shown in figure 7 to figure 9.

**Figure 7. Trade Competition Index of Service trade (TC/CI) between China and ASEAN**

Data sources: according to the United Nations Conference on Trade and development, statistical data base (UNCTADstat) data calculation.

**Figure 8. The Revealed Comparative Advantage (RCA) between China and ASEAN**

**Figure 9. The Trade Complementary (TCI) of Service Trade between China and ASEAN**

Service trade in ASEAN countries generally shows a steady growth, but the total amount of service trade shows characteristics of regional imbalance. Among them, Singapore is still the leader in service trade, whose dominant industry is mainly concentrated on the higher knowledge and technology content of the emerging services, while other countries are mainly concentrated on the traditional service areas. In recent years, other countries in the ASEAN have
a breakthrough in the emerging services. The development tendency of the Philippines communications services, computer and information field is rapid, significantly enhancing the competitiveness, with slightly lower exports and 1/13 imports compared with Singapore, bringing a large trade surplus to the Philippines, and other business services and personal, cultural and recreational departments also have a considerable competitive power. It has made great progress in financial and other business services in Cambodia, mostly because of the steady development in micro prosperity. Despite the industry volume is still incomparable to Singapore, Cambodia is the second ASEAN country with strong competitiveness in the financial services sector. With blooming tourism, Personal, cultural and entertainment industry of Thailand experience continuous development, becoming the second profit growth point of foreign trade service in Thailand. Except the Philippines's communications and other business services in above countries, these service departments in the revealed comparative advantage and complementarity to China have no significant improvement, indicating that despite the rapid development of industry, related industry is still in the middle position across the world with lack of competitiveness. Service trade volume in China is forefront, taking strong competitiveness in goods related service, communication, computer services and information services, and sick competitiveness in the transport, tourism, culture and entertainment department. But compared to ASEAN, transport and other business services still have certain opposite advantages, so strong complementarity is showed in export to ASEAN. The both sides have a certain complementarity of the import and export in the transport, tourism, and other business services sector, showing the significant differences between the both sides in similar service. In addition, the economic development level, openness degree and service industry importance in Southeast Asian countries are diverse, the trade protection degree in services also have significant differences, so the policy to promote and limit has greater scope.

Overall, Chinese and ASEAN service trade development lagging behind the development of commodity trade, the services demand continues to rise. Improving service trade ability, promoting exchanges and cooperation and exerting all the characteristics of the industry, integrating resources to cope with the international challenges are a common choice for both sides. Although China and ASEAN countries have competition in the service industry base, attracting foreign investment and service outsourcing and other aspects, there is a big difference in the development of infrastructure, industrial structure, development speed and development stage for the both sides which presents a multi-level state, so that the service trade of both sides has formed a strong complementarity. With the development of China-ASEAN Free Trade Area, rapid growth in commodity trade and increasingly active foreign investment, it will further increase demand for services in transportation, finance, communications, computer and information.

V. CONCLUSION

From the perspective of the development of industrial structure, the similarity between China and In terms of industry structure, China and ASEAN has significantly high similarity,
indicating alike emphasis on industry development in both sides. In terms of industry segment, it shows imbalanced development according to lower similarity and diverse advantageous industry. Summarily, there is a big gap in both competitiveness and complementation of products and service with China. To be more advisory, we classify ASEAN countries into 3 level according to its economy development and industrialization level when putting forward some advice respectively.

Singapore is in the first level, which is in the late stage of industrialization, with service industry dominated, and its capital-intensive and technology-intensive industries are competitive industries, meanwhile high-tech and knowledge-intensive industries also have greater competitive advantage. Industrial structure similarity in Singapore and China's is relatively low, and there is basically no planting in Singapore. On the contrary, manufactured goods especially agricultural products processing is in leading position, and chemical and mechanical products highlight the advantages of high capital and technology intensive, meanwhile financial services are obviously ahead of the ASEAN and China. Therefore, based on the comparative advantages of both sides, China and Singapore should develop bilateral trade in service considering local conditions. In the fields of education, science and technology, service facilities, in the aid of finance, management, knowledge and technology from Singapore, China can promote own service sector.

Indonesia, Malaysia, Philippines, Thailand and Vietnam are in the second level. They are all in the late period of industrialization, industry gradually giving way to the service industry. The proportion of the primary industry is between 9% and 19%, and the second industry and the tertiary industry accounted for basically equal proportions. For a long time, China and these countries have their own advantages in natural resources, leading to the structural complementarity of export commodities. Second-level countries tend to export natural resources, while Chinese natural resources are gradually reduced, so there is great potential for cooperation between the two sides. However, the uncertainty impact to trade factors are complex, such as the South China Sea issue, border issues and so on. Trade competition and trade friction continue to emerge, which requires both sides to objectively deal with those problems.

Cambodia is in the third level, who is in the middle of industrialization. Cambodia was an originally typical agricultural country. Since 2010, the third industry developed rapidly, having reached the first place in national economy. The foundation of second industry is weak with slow development speed, accounted for basically equal proportions with the primary industry. The similarity between Cambodia and Chinese industrial structure is relatively low, both based on labor-intensive and resource-intensive products. The sum volume of import and export trade in China and Cambodia is much lower than other countries, showing a certain gap of industry
level with China and strong complementary. Further develop the domestic market will benefit both industry.

For implementation of China-ASEAN industry development and interoperability, we should focus on the following two aspects. Firstly, strengthen ASEAN internal division differences in the same industry, reducing product competition, emphasizing on the development of intra industry trade, promoting exchanges and cooperation, establishing more standardized mechanism, optimizing the structure of bilateral trade, making good use of preferential tariff policy, and promoting the benign competition and regional cooperation. Secondly, according to the industrial development status and policies of different countries, taking the Maritime Silk Road as a breakthrough in industrial interoperability, we should flexibly expand each department service functions, improving service quality and technical level, increate new cooperation ways in service trade, especially through developing talents and communicating aiming at high-tech emerging service industry, to firmly grasp the best time of Chinese ASEAN cooperation.

References


Recently, the concept of "sustainability" has been increasingly mentioned in relation to transport and logistics systems (TLS). Initially, “the sustainability of transport system referred to its ability to provide high level of satisfaction of public needs in transport while minimizing the negative impacts on health, economy and environment,” i.e., on a qualitative level. Currently, however, researchers recognize the need to introduce integrated criteria and quantitative assessments of TLS sustainability levels [1, 2].

Based on the analysis of literature sources, the following criteria (indicators) of sustainable operation of transport and logistics systems can be formulated:

1. ACCESSIBILITY (physical) - to markets and employment; access to basic social services; access to international trade.

2. AFFORDABILITY (economic) - low-cost access to employment and education, to basic transport and logistics services; long-term investment in transport infrastructure;

3. SAFETY – safe transport of cargo, passengers and luggage, safety of people and property throughout the life cycle of transport facilities, transport and logistics technologies; prevention and/or mitigation of transport-related accidents and man-made disasters.

4. SECURITY - protection of individuals, human and cultural capital against the adverse effects of transport; protection of transport facilities, transport and logistics technologies from contingencies (and losses) of social and man-made nature.

5. ENVIRONMENTAL SUSTAINABILITY - TLS is sustainable in relation to energy use, safe environmental pollution levels, land use; transport infrastructure is resistant to natural disasters and calamities.

Risk management methods appear suitable for integrated assessment of TLS sustainability criteria that are so diverse in their nature and physical characteristics. The methods entail
assessment of risks for each of the above criteria, i.e. the likelihood of dangerous (unwanted) events or trends, multiplied by the consequences of their occurrence [3, 4, 5], that are additive and can be aggregated. The resulting estimate of integrated risk is then compared to the acceptable value, and risk control algorithm is employed if necessary to reduce risks to an acceptable/admissible level [6, 7]. To perform such comprehensive evaluation reliably in relation to TLS of a city, region or country does not currently appear feasible.

Therefore, further we will address the methodological issues of sustainability (reliability and safety) of TLS over their life cycle, using the risk management methods for the case of risk assessment in the integrated supply chains. Supply chains are complex multi-structural systems with active elements operating in a fast-growing market environment. Their operation is associated with considerable uncertainty that creates systemic risks. Uncertainty is one of the key issues analysed in the supply chain security management systems. Despite considerable technological and industrial capabilities available, it becomes increasingly difficult to manage supply chain systems due to occurrence of failures that affect the TLS sustainability level.

It appears practical to address supply chain security and sustainability issues from the perspective of system management and system life cycle management theories, through evaluation of the quality of resources and processes utilized at different stages of the life cycle (LC) [8]. Global trends for integration of stakeholders in transport of goods and services on the basis of supply chain management model form new principles and mechanisms of integrated support for efficient operation of transport companies.

Application of the methods of system life cycle management is based on the concept of integrated supply chain security, which is supported by integrated management models, latest information technology and risk management system. [9] Supply chains, designed according to the above requirements, can adapt to ever changing environment and have a significant impact on the TLS sustainability level.

Performance evaluation of the organizations within the supply chain depends on various attributes and on their current strategic and operational objectives. Regular compliance evaluations are carried out to identify vulnerabilities of processes and outcomes in the supply chain, which results in the reduction of overall costs and losses. This enables acceleration of the transport and logistics processes, including vehicle operation.

The process analysis provides detailed description of all current activities related to the delivery of products (goods) in order to collect and analyze relevant information on existing methods and indicators. Reliability indicators for logistics processes are expressed by probabilistic data values in the range $0 \leq p \leq 1$ where "0" indicates a complete cessation of operation (failure), and "1" – a complete interaction (success). Reliability of the processes in the supply chain refers to the probability of reaching the target ("ideal") parameter values in a defined time interval and within specified tolerances. An order for product delivery is considered completed if it is implemented within the admissible deviation domain, or within the positive domain. Areas within the limits of "acceptable" risk level indicate reliable process activity.

TLS development shows trends towards becoming more integrated, holistic systems that operate based on integration of infrastructure, links, resources of the supply chain and
**integrated logistics support** for the processes throughout their life cycle. The operation of TLS should be addressed at the three stages of its life cycle: planning (development), operation (activity), recycling. The life cycle model forms the framework of the new generation TLS, that operates within supply chain and interacts on the principles of self-regulating transport links (elements) with shared resources, providing highly efficient operation through utilization of IT and uniform process management standards. At each stage of the life cycle the three activities are considered: determining what to do (activity W); determining how to do (activity H); delivering (activity D)

Table 1 shows the activities and interrelations between the stages of TLS life cycle.

**Table 1. Relationship between LC stages and activities of TLS**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Activity W</th>
<th>Activity H</th>
<th>Activity D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning and Development</td>
<td>Setting goals</td>
<td>Requirements engineering</td>
<td>Determining parts (components)</td>
</tr>
<tr>
<td></td>
<td>Defining strategy</td>
<td>Concept definition</td>
<td>Provision of services</td>
</tr>
<tr>
<td></td>
<td>Defining needs for TLS processes</td>
<td>Designing TLS services</td>
<td>Testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Process planning</td>
<td>Delivering services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Service provision planning</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>Defining support needs</td>
<td>Determining operational requirements for TLS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Definition of use</td>
<td>Determining requirements for logistic support</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>System operation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Logistic support for processes</td>
<td></td>
</tr>
<tr>
<td>Recycling</td>
<td>Identifying needs for recycling</td>
<td>Determining requirements for recycling</td>
<td>Recycling of services</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Decommissioning</td>
</tr>
</tbody>
</table>

Different life cycle stages may fall under different models, that should be able to interact. Obtaining information at different stages of the life cycle provides a seamless integration of processes, which improves operation quality. Process integration will represent TLS dynamics towards the optimum, i.e. sustainable condition.

The following organizational and technical model consisting of five interconnected modules is proposed as a comprehensive scheme [8]:

- The module of standard processes related to quality management system, structurally supported by ISO 9000 series standards;
- The module of integrated logistical product support, comprising the processes of analysis of logistic support, maintenance and repair, material and technical support, e-manuals for the product;
- The module of the operational logistics cycle management, integrating the resources within the logistic cycle of supply, material and technical support, physical distribution;
- The entire system life cycle process management module, providing adaptation based on the systems engineering methods and product open coding;
- Strategic life cycle management module (planning, sourcing, production, service and reverse flows).

Fig 2 Shows the hierarchy of the supply chain life cycle management:
The bottleneck of the TLS supply chain life cycle is the integration of production and operation (application) material support with transporting based on compatible logistical technologies, electronic document workflow within common information space. At the same time, the issues of operational and technological hazards and related failures (malfunctions) in manufacturing, transport and logistics processes receive little attention. Risk management in the real sector is evolving somewhat independently in several areas: industrial and environmental safety, reliability theory, other disciplines. The logic of management process analysis involves the assessment of the model sustainability and efficiency within the system "design – manufacturing – maintenance – transportation/warehousing – operations – additional services". To understand the technological effects of risk mitigation and ensuring TLS sustainability we will look at the main trends of their development.

The main trends in the development of vehicles and transport infrastructure are expected to be determined primarily by:

- Autonomous (automated) vehicles - driver assistance systems (ADAS);
- Information technologies (broadband 4G, 5G) and connected cars (V2V, V2I, V2P);
- Digital road infrastructure (the BIM technology), web-based services for adaptation of users (transport companies) in the transport and communications environment;
- Electric personal and commercial vehicles.

The above technological trends may bring far-reaching social and economic consequences, including the following:
- Automakers will integrate with IT companies and freight carriers (offering the service of delivering goods or passengers, not the vehicle itself);
- The information and communication services will evolve for citizens, drivers, service and dealer centers, freight consignors and consignees;
- ADAS will develop further, increasing the time in automatic mode up to fully automatic driving. This will allow to slash the number of road accidents resulting in deaths and injuries;
- The use of self-driving trucks and ADAS-equipped vehicles will help to lower the economic risks of carriers by shortening the delivery time, reduction of pilferage and loss, cutting down stock volumes.

With the implementation of the above trends the transport and logistics system is likely to become adapted to info-communications environment to the extent that it will form a new culture of human interaction with the environment (human – vehicle, human – urban environment, human – human, human – natural environment, human – means of production and consumption), which may lead in the near future to the transition from «homo sapiens» stage to «homo in nexu» (man connected) stage. The signs of such transition can already be found in the development of urban transport and logistics systems (implementation of the principle of multimodality, development of info-communication environment, etc.). It is important to understand and adequately respond to them, striving to achieve a seamless fit of the transport and logistics technologies into the natural, social and economic environment.

The implementation of the above trends will require identification and addressing new fundamental and practical problems in the transport and related areas of research, including the following:

1. Setting up new environmental and social standards of human life, economic development, including the mobility of goods, services and people with respect to the use of pervasive global info-communications networks;
2. Development and implementation of intelligent traffic management systems and access of individual vehicles and road users equipped with robotic, mechatronic and bio-adaptive systems to public road network;
3. Elaboration and implementation of supercomputing technology and data storage systems for real time traffic management, assessment and forecasting of integrated TLS development, environmental and social conditions, emergency situations of natural and man-made nature, effects of climate change on transport activity and infrastructure facilities;
4. Stepping up measures to reduce the impact of transport on the environment, decrease the carbon footprint of transport activities [10] by equipping the vehicle fleet with electric vehicles, vehicles with integrated power plants (plug-in hybrids), vehicles running on fuel cells, hydrogen;
5. Development of an integrated approach to management of logistics processes of delivery.
and transportation of goods and passengers based on adaptive risk management systems.

Based on the above, it is clear that we are witnessing explosive growth in information technologies creating the info-communications environment of a new type, where the supply chain safety and reliability are the "golden spike" of the transportation process (of both passengers and cargo), and TLS sustainability. Consequently, the owners of the transport and communications infrastructure may offer their customers not just a vehicle but a transport service of appropriate quality. And this may happen in the foreseeable future.

The practical significance of the suggested methodological approach using the risk management methods lies in setting up requirements for the development of organizational and technical mechanisms and for safety management processes in integrated TLS, which will allow organizations to improve process efficiency in terms of failure prevention and cost reduction, and to achieve sustainable operation of TLS.

References


I. INTRODUCTION

Along with the implementation of the "One Belt One Road" strategy and the "Go globally" strategy, the number of Chinese companies investing abroad is increasing. In 2015, a total of 6,532 overseas enterprises in 155 countries/regions were non-financial directly invested by Chinese investors, with an accumulative investment of $118.02 billion. Among them, the scale of investment of the countries along the "One Belt One Road" is $148.2 billion [1]. Land acquisition is one of the important prerequisites for enterprises to invest in infrastructure construction. The land expropriation will not only affect the success or failure of the project, but also affect the personal and group interests of the host country, and even intensify social contradictions and trigger social conflicts, such as the Saudi project which suffered huge losses as a result of land acquisition [2], the Nicaraguan Canal Project which was endangered by local farmers [3], and the Myanmar Chinese-funded Copper Project which caused land conflicts [4]. Therefore, how to solve the cross-border land acquisition is one of the most important issues for...
Chinese enterprises to enter the international investment market.

Indonesia is the largest economy in Southeast Asia, and is also one of the important cooperative countries of China to implement the strategy of "One Belt One Road". Indonesia has 3.166 million square kilometers of the ocean area, and its transport mode is mainly maritime. The other transport facilities such as railways, highways are long behind and greatly affect the economic development of Indonesia. Therefore, the Indonesian government urgently needs to drive the domestic investment and development through the infrastructure construction. Railway, as one of the important infrastructure of social development, plays a huge supporting role in the economic development of all countries. China's high-speed rail will become an important booster of the implementation of the "One Belt One Road" strategy of the country, with its technology, capital, cost and building capacity highlighting its unique advantages. In the high iron supply demand environment of China and Indonesia, the Chinese consortium led by China Railway Corporation signed the joint venture agreement with Indonesian Consortium, which consists of PT Wijaya Karya, PT Kereta Api, PT Jasa Marga and PT Perkebunan Nasional [5]. And China successfully won the bid for Jakarta-Bandung high-speed rail. Well, the project is a sign of China's high-speed rail into the international high-speed rail market, with a clear lead and exemplary role. And especially the mode of cooperation and output is a major innovation. However, the economic, social, technological and political factors of Indonesia will have a significant impact on whether Jakarta-Bandung high-speed rail will complete the construction within the specified time, meeting the high standards and high quality standards set by the contract.

Different from the general construction projects, high-speed rail is a typical linear project, usually across multiple administrative area, involving a number of land ownership units, with the need to collect large amounts of land. For example, the total length of China's West Ring high-speed rail in the territory of Lin Gao is only 30.86 km. But it covers 2603 mu of Land acquisition area, 1257 mu of temporary land and involves the demolition of housing area of 6353 square meters [6]. As a prerequisite for the smooth operation of high-speed rail, the land acquisition will not only affect the normal implementation of the project, and may even lead to land disputes and conflicts. According to a survey conducted by the Islamic Development Bank in 2009, investors found that one of the most difficult reasons for infrastructure development in Indonesia was land expropriation [7]. For instance, Citra Marga Nusaphala Persada (CMNP) is the first private toll road operator in Indonesia, but the cost of land continues to rise as a result of land expropriation, disrupting the normal operation of the project. Jakarta-Bandung high-speed rail connections to the Indonesian capital Jakarta and Bandung. Cerro Sumarzan [8] describes the process of land reform after Indonesia's independence. It focuses on analyzing “the Basic Land Act” and “the Law on Contracts for the Distribution of Grain”. Wang Zhengli [9] regarded the land acquisition regulations approved by the Indonesian Congress in 2011 as the object, analyzed the legal basis and the expropriation process of land requisition, and provided the legal basis for the real land acquisition project in Indonesia. Shan Yongqi and Zhang Yu [10] analyzed the difficulties of land acquisition for foreign capital enterprises in the process of
investment and construction in Indonesia, sorted out the basic procedures of land acquisition in Indonesia and made some recommendations for Chinese enterprises into Indonesia.

These studies have focused on legal studies of land acquisition in Indonesia, while ignoring the process risk of land acquisition in Indonesia. Especially, The "Indonesian high-speed rail was halted" [11], which was caused by the fact that a construction permit or a concession agreement had not yet been issued on January 29, 2016, was proved to be untrue [12], but have to cause the joint venture company to pay attention to how to effectively manage the land expropriation risk. Therefore, in this paper, the problem of land acquisition in Jakarta-Bandung high-speed rail is taken as the research object. The process of land acquisition in Indonesia is analyzed and compared, and the difficulties and risks in the land expropriation are analyzed emphatically. Suggestions and countermeasures are put forward for the risk control.

II. THE CHARACTERISTICS OF LAND ACQUISITION IN JAKARTA-BANDUNG HIGH-SPEED RAIL

1. A wide range of demolition and complex external environment

Jakarta-Bandung high-speed rail length of 140 km, connecting Jakarta and Bandung, is a linear project with clear characteristics of ribbon, strip and so on. Different from the general project, the akarta-Bandung High Speed Rail Project needs to span a number of areas, not only involving the collection of state-owned land, but also the collection of 240 hectares of agricultural land, and the relocation of 728 rural households [13]. In addition, according to the relevant reports that the land acquisition of Jakarta-Bandung high-speed rail mainly concentrated in West Java province, the province contains a number of volcanoes such as capsizing. At the same time, because Indonesia is in the Pacific Volcanic earthquake zone, it is vulnerable to volcanoes, earthquakes, floods and other natural disasters. And for high-speed rail such as complex projects, it increases the project preparatory work while increasing the difficulty of project construction.

2. Difficult planning and design and more temporary land use

Jakarta-Bandung high-speed rail through the plateau, basin and other types of areas, because of volcanoes, earthquakes and other geological factors, the line planning and design of the project is more difficult. At the same time, according to Indonesia's land expropriation of the relevant laws and regulations, the planning and design of the project needs to adapt to national and regional planning. Besides, joint ventures not only need planning, construction, operation and management of high-speed rail, but also commercial development along the high-speed rail, which requires joint ventures to have high-speed rail resources distribution, population mobility, and other factors to conduct detailed research, rational planning of lines and sites. High-speed rail as a complex large-scale projects, in addition to line land, but also involves a large number of temporary land, such as beam prefabricated field, laying base, mixing field. These temporary land need to be completed after the completion of the project for its reclamation, because of its
great impact on local residents living environment.

3. Involving many agencies and land acquisition procedures are complex

During the process of land acquisition in China, many land acquisition enterprises sometimes adopt the mode of "design, construction, demolition and relocation" when the relevant land acquisition procedures are not completed. However, the land expropriation procedure is expressly stipulated in Indonesian law. The model is clearly not feasible in Indonesia's national conditions. Indonesia's land acquisition process includes planning, preparation, implementation and delivery phases, the work of the various stages shown in figure 1. At various stages, the public can put forward corresponding opinions on the land acquisition of the project, or bring the lawsuit to the law within the stipulated time. In addition, before land acquisition commences, joint ventures are required to obtain multiple permits, which relate to various government agencies, such as the Ministry of Forestry, the Ministry of Transport, the Ministry of Public Works. Therefore the efficiency of various government agencies and the inter - Coordination will directly affect the start time of the Jakarta-Bandung high-speed rail. However, the issue of licenses has always been one of the problems affecting foreign investment in Indonesia. According to the World Bank's ranking of operators' environment, China ranked 84th, while Indonesia ranked 109th[14], so it is hard for the joint venture to obtain relevant documents and procedures as soon as possible.

<table>
<thead>
<tr>
<th>Planning phase</th>
<th>Preparation phase</th>
<th>Implementation phase</th>
<th>Delivery phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. draw up feasibility study report</td>
<td>1. post the development announcements to the residents</td>
<td>1. determine land ownership</td>
<td>1. Land Bureau to deliver the land</td>
</tr>
<tr>
<td>2. submit land acquisition program</td>
<td>2. data collection for expropriated areas</td>
<td>2. assess the amount of compensation</td>
<td>2. registration of acquired land</td>
</tr>
<tr>
<td></td>
<td>3. discuss with residents</td>
<td>3. determine the amount of compensation</td>
<td>litigation and arbitration(within the prescribed time limit)</td>
</tr>
<tr>
<td></td>
<td>4. sign the agreement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Land Acquisition Procedures and Content in Indonesia

4. Relevant subjects too much and it is difficult to harmonize

Different from the general project, high-speed rail project has long construction period, large-scale investment, involving too much subjects and another features. From the preparation stage of the project to the completion of the project phase, the various subjects need to harmonize and communicate with each other to varying degrees. In addition, the behavior and efficiency of the construction unit, design unit, the land acquisition unit and the host institution will affect the progress of the land acquisition process in the land acquisition process of the Jakarta-Bandung High Speed Rail Project, not only affected by the joint venture company. The concrete results are shown in figure 2.
As can be seen in Figure 2, for Chinese enterprises, it is not only necessary to coordinate the cooperation and communication with relevant organizations and enterprises in Indonesia, but also to coordinate with other enterprises involved in the process of land acquisition. At the same time, maximizing the arrangement of the land acquisition process of human, material and financial resources to make Jakarta-Bandung high-speed rail project completed successful and efficiently in the required time, within a reasonable budget. At the same time, they need to maximize the arrangement of the land acquisition process of human, material and financial resources, making Jakarta-Bandung High Speed Rail Project completed successfully and efficiently in the required time and within a reasonable budget. From this, there is no doubt that this will be a great challenge.

5. Affected by the land acquisition greatly

China is the implementation of the land of socialist public ownership, while Indonesia is the implementation of land private ownership system. In other words, in the process of land acquisition in Indonesia, joint ventures can carry out a transaction with the landlord directly. And there is a game relationship between the two. Although the Indonesian government has made it clear that how to deal with these projects for the purpose of achieving the public interest, land expropriation will still be influenced by different degrees of local levy. For example, since some of the private land in Indonesia is not registered with the land administration, there is an unknown boundary and unclear ownership. It is not only difficult to specify the area of land requisitioned and the amount to be compensated, but also increased the difficulty of land acquisition and land acquisition disputes, the possibility of conflict, as well as land acquisition time. In addition, with the increase in land acquisition in Indonesia, Indonesia landlords gradually realized the importance of land acquisition for project construction. In turn, the possibility of bidding up the price and hindering the construction and so on affects the cost and progress of Javango land expropriation.

6. Long time to resolve land dispute with complex procedures

As the land expropriation directly related to the interests of relevant personnel, so often there will be disputes and conflict, due to uneven distribution of benefits, insufficient compensation and other causes. According to the Indonesian Land Reform Association (KPA) data [15], only in 2013, Indonesia caused 22 people to death as a result of violent conflict because of land acquisition, involving 140,000 households. Indonesia PT Bhimasena Electric Power
Company, which is responsible for the construction and operation of the Batang Power Plant project, delayed for many years because of land disputes \[16\]. Identically, Foxconn canceled the plan to invest and build factories in Indonesia because of land acquisition \[17\]. The new land acquisition law provides for the land acquisition process of arbitration, but the litigation process is still more complex and lasts longer. Therefore, in the event of land dispute litigation cases, it is undoubtedly a risk for Jakarta-Bandung high-speed rail to complete within 3 years. At the same time, due to the private ownership of the land, the ownership of some land is unknown and the compensation requirements of interest parties are different. The Government of Indonesia has not formulated a clear solution to such land acquisition problems, which is difficult for arbitration to achieve reconciliation between joint ventures and landowners within a limited time and difficult to guarantee an efficient settlement of conflicts and disputes too.

7. Without the Indonesian government guarantee, the risk increases

The scope of government's guarantee in the construction of infrastructure projects mainly includes such aspects as operation, return on investment and environment \[18\], among which the environment includes land supply and conflict resolution mechanism. Under the environment where the land acquisition is difficult in Indonesia, joint ventures need to bear the risk of land acquisition independently, because the Indonesian government does not guarantee the supply of land. So in the absence of a negotiated inconsistency or land conflict, in the case of an effective conflict resolution mechanism, the Jakarta-Bandung high-speed rail project's progress will inevitably be blocked and risk cost of the project will be increased. In addition, there are partisan factions, party rotations, public opinion and other multiple risks in Indonesia, some people may enlarge the land acquisition conflict (shown in figure 3) and further aggravate the land acquisition risk, by using the land acquisition problem of Jakarta-Bandung high-speed rail.

**Figure 3. The Relationship between Internal and External Causes of Land Acquisition Conflict**

III. SUGGESTIONS ON LAND ACQUISITION RISK MANAGEMENT OF JAKARTA-BANDUNG HIGH-SPEED RAIL

Jakarta-Bandung high-speed rail is China's high-speed rail all-round overall out of the first
single, but also China's "The Belt and Road" initiative demonstration project, which is very important for promoting China's high-speed rail to the international market. So more important is the strategic significance of the Jakarta-Bandung high-speed rail at the national level. Based on the characteristics of Jakarta-Bandung high-speed rail land acquisition, "enterprise as the leading, government support, the project is foothold "three-level land acquisition risk management structure is established, the risk management mechanism of land acquisition at all levels is improved and a holistic and systematic risk management system of land acquisition is formed, so as to ensure the smooth progress of jakarta-Bandung high-speed rail land acquisition work.

1. Risk Management of Land Requisition in State Level

   The issue of land acquisition by Jakarta-Bandung high-speed rail has attracted wide attention. The success of land acquisition will directly affect the cost and progress of the project. Chinese government should start from the following aspects. (1) To build a good cooperation atmosphere for the land acquisition from the national level; to strengthen the bilateral cooperation in trade, security energy and investment; to establish a profound relationship of mutual trust and create a good external environment for the China's high-speed rail. (2) To communicate the problem exist in process of land acquisition with Indonesian government; to urge the Indonesian government to adopt corresponding safeguard policies, and especially try to negotiate with the Indonesian government on the handling procedures of land acquisition formalities if circumstances permit to speed up the formalities for the efficiency, thereby speeding up land acquisition. (3) To carry out targeted diplomatic work to enable the objectives of Indonesia Government in the Jakarta-Bandung High-Speed Rail Project in the consistency, unity of thinking and action on a high degree of cooperation so that both sides can clearly understand the responsibility and obligation in the construction process of the Jakarta-Bandung High-Speed Rail Project, and construct the situation of benefit sharing and risk sharing.

2. Risk Management of Land Expropriation in Enterprise Level

   (1) Strengthen the coordination between the relevant units

   As a result of the Sino-Indonesian joint venture model adopted by Jakarta-Bandung high-speed rail (including several Chinese and Indonesian enterprises), the consortium of the two parties will inevitably have differences in culture and management in the construction of the project. These problems will have an impact on the project construction, business management and other aspects. Strengthening the coordination between the relevant units not only requires the relevant units in the land acquisition goals to maintain a high degree of consistency, but also need to smooth the flow of information so that all relevant enterprises understand their own tasks and responsibilities in all phases of land acquisition, to exert the greatest value of oneself, speed up the efficiency of land acquisition and ensure the effect of land acquisition.

   (2) Control the funds in and out to establish a strict audit mechanism

   The land acquisition process of high-speed rail involves many links and complicated
processes, which are directly linked to economic interests. Especially in the situation of corruption in Indonesia, a rigorous auditing system should be established to prevent the occurrence of violating disciplinary violations. According to the Land appraisal institution’ determination on the land compensation price, establish a special fund and earmark for special purpose. Around the "preparation, planning, implementation, delivery" four land acquisition stage, strengthen the source, process, clearing of land compensation these three core links monitoring.

Through the introduction of comprehensive cost management and meticulous management concept (shown in figure 4), identify the potential risk of land acquisition in advance and formulate the corresponding response measures to ensure the implementation of funds to the land acquisition.

![Figure 4. Investment Management System](image-url)

(3) Establish a variety of reasonable compensation mechanism

Jakarta-Bandung high-speed rail has the dual attributes of commercial and public interest, which is the essence of improving the quality of the living standards of Indonesian residents while realizing the profitability of the enterprise. Land acquisition is partly able to obtain a sum of money from the expropriated. However, in the long run, there are still problems. For farmers with high dependence on land, even if they receive the corresponding compensation, but because of the lack of skills necessary for employment, it is difficult to obtain a long-term source of income. Therefore, the joint venture should establish a variety of reasonable compensation methods for land acquisition (shown in figure 5), with full respect for the wishes of local residents. For instance, for farmers with high dependence on land, should obtain land by way of land replacement. As for the young labor force, should establish employment funds, carry out the appropriate employment training to improving the knowledge and skills, and provide personnel reserve for the commercial development of the Jakarta-Bandung high-speed rail along. In addition, the community transformation, social security funds and venture...
capital funds and other means should be obtained to improve the living standards of field personnel and to achieve regional sustainable development.

Figure 5. Compensation Mechanism

(4) Establish early Warning and Emergency Mechanism of Land Acquisition Risk

The problem of land acquisition in Indonesia is a long-standing problem, which is undoubtedly a great risk for large and complex projects such as Jakarta-Bandung high-speed rail land acquisition.

Therefore, it is necessary to expand and optimize the traditional risk management process (risk identification - analysis - evaluation - response -), change from ex-ante to early-warning and form the risk management system, which combine traditional "risk identification - risk assessment - risk response - risk monitoring" with "early prediction - preliminary judgment - early intervention - advance to resolve ", and use PDCA method to optimize management process continuously too. In addition, it is need to strengthen the participation of relevant units and personnel in land acquisition risk management, establish risk management system of whole process, and form.

A harmonious orderly three-level linkage mechanism of "national-enterprise-project" (shown in figure 6) to ensure orderly land acquisition work.
3. Strengthen the Risk management of Project Land Acquisition in Project Level

(1) Introduce third-party authority actively

Due to the fact that some of the land in Indonesia does not match the landlord information and the land ownership is unclear, and so on, the joint venture will inevitably have problems in the land survey. In particular, when the land levied at the same time belongs to multiple owners, it will not only lead to the cost increase, but also result in disputes arising from the measurement area, the amount of compensation. Therefore, the joint venture company should obtain the relevant information of the land and its owner in advance, entrust the professional organizations to conduct on-site exploration and survey, consult the relevant local governments and landlords on the land in doubt to ensure the compensation to the actual owners. At the same time, it should introduce the notary transaction process to carry out the notarization and clarify that the land transaction conformed to the relevant laws and regulations of Indonesia, and reduce the land dispute as far as possible. In addition, it is necessary to make effective use of local legal institutions and hire professional lawyers to form a special legal department which is responsible for legal advice, legal advisers, disputes and other related work to ensure the legitimacy of land acquisition procedures, procedures, relevant information.

(2) Take "hardness to easiness and on the face of difficulty" land acquisition strategy

In general, the land transaction is not easy, need to go through a certain negotiation process. For the Jakarta-Bandung linear engineering, once the line on a certain land acquisition failure will affect the construction of the entire project. Therefore, the joint venture should be targeted at some "stubborn elements" to take a targeted strategy, and develop different solutions in the full understanding of the interests of landowners demands and their views on land acquisition work. At the same time, the joint venture should seek the understanding and support of landowners actively and overcome difficulties to fully resolve the contradictions and conflicts in land acquisition process through seminars, face-to-face communication and other means. Besides, the joint venture should establish a good relationship of mutual trust with local...
governments, and take the way such as the introduction of incentive mechanism design, sharing of benefits, risk-sharing, so that local governments give full play in coordination and communication role in land acquisition.

(3) Establish transparent land acquisition procedures

One of the main causes of land acquisition conflict is land acquisition procedures and information opacity [22-25]. Due to the differences in the society and culture between Indonesia and China, the landowners in Indonesia are cautious and skeptical about the land acquisition. In addition, some Indonesian officials have raised objections to the environmental impact and urban planning of Jakarta-Bandung high-speed rail, so that the land expropriation of it faced more difficulties. Therefore, in order to avoid the contradiction because of information asymmetry and non-smooth communication, joint ventures should make use of the media such as TV, official network platform, newspapers (Jakarta Post, International Daily, etc.) to publicize the details of land acquisition and make information transparent. What’s more, it is helpful to establish a good corporate image through depth publicity that Jakarta-Bandung high-speed rail is beneficial to Indonesia's national, social and regional development.

IV. CONCLUSION

With the gradual increase of investment and construction of Chinese enterprises in Indonesia, the problem of land requisition always affects the progress of the project. Especially for the large-scale and complex projects with long construction period, large investment scale and many subjects involved, the land acquisition problem is undoubtedly a huge challenge for the Jakarta-Bandung high-speed rail which construction period is 3 years. Based on the analysis of the internal and external characteristics of the land acquisition process of Jakarta-Bandung high-speed rail, this paper analyzes the risk points of Jakarta-Bandung high-speed rail in the process of land expropriation, puts forward the "enterprise as the leading, government support, the project is foothold" three-level land acquisition risk management structure, and build a "national - enterprise - project" three-level land risk management linkage mechanism to strengthen the full participation and the whole process of management philosophy, which provides a certain degree of basis for the Jakarta to Bandung high iron land acquisition risk management. There are many factors involved in the success of the Jakarta-Bandung High-Speed Rail Project. And land acquisition is only one aspect of the project construction. To ensure the success of the project, it is necessary to consider the project from the overall perspective. Therefore, we need to do further research for the project management, operational standards, emergency plans and other aspects in future.

References

[3]. The Sina Net finance and economics. Foreign media: Chinese enterprises in the Nicaraguan Canal

International cooperation issues of transportation - special issue - no.07

INTERNATIONAL COOPERATION ISSUE OF TRANSPORTATION - Especial Issue - No.07

40

40
Today it is becoming more obvious that to ensure a strong and sustainable
development of a country, the achievement of strategic goals is impossible without
the mutually attractive partnership of the state with private sector companies.

PPPs are contractual arrangements between the public sector and a private sector party for
the private delivery of public infrastructure services or other basic services. PPPs are complex
structures, involving different parties, long and demanding negotiations and relatively high
transaction costs and where the effectiveness of the alignment depends on a sufficient transfer of
risk to the private partners.

The private partners usually design, build, finance, operate and manage the capital asset,
and then deliver the service either to government or directly to the end users. The private
partners receiving as reward a stream of payments from government, or user charges levied
directly on the end users, or both (Concessions vs PPPs). Government specifies the quality and
quantity of the service it requires from the private partners.

More than 200 PPP projects are currently being implemented or are in the planning phase
in Russia. Most of these PPPs are aimed at developing transport infrastructure. The Russian
government plans to spend about $1 trillion over the next 10 years on improving infrastructure.

The use of public–private partnerships marks a shift away from traditional ways of
procuring and financing infrastructure projects. A private partner may participate in some
combination of design, construction, financing, operations, and maintenance, including the
collection of toll revenues.

Under traditional public procurement of infrastructure projects, the public agency retains
most of the risks, yet these risks are not usually quantified, nor are their costs always included in
the project cost estimates.

The concept of “transferring risk” requires that the private partner will be responsible for
cost overruns or expenses associated with the occurrence of that risk.

Risk transfer can include, among others, construction risk (i.e., risk that the project will not be completed on time or on budget), usage or traffic demand risk (i.e., risk of lower-than-expected revenues from users of the project), and operation and maintenance risk.

Figure 1. Degrees of risk sharing by project type

Transfer of risk in PPP does not imply the maximum transfer of risk to the private partner. It means that the party best able to carry the risk, should do so.

Internationally there are a number of basic types of agreements recognized which are implemented on the basis of the PPP model. Below is presented a detailed description of most commonly use PPP types in world practice, as well as demonstrating the interdependence of private sector risks and degree of its involvement to a project.

Figure 2. Direct correlation between risk distribution level and the degree of the private sector involvement (based on UN 2008)
The governance structure of a transportation infrastructure project is often a function of the level of risk the private sector is willing to assume. If the private sector is only given the task of designing and building an infrastructure, then there is little risk involved since the public sector assumes the financing and operations of the infrastructure. However, in this case, the private sector would not share any of the potential operational revenue. Inversely, in an entirely private context the private sectors assume all the risks and the revenues. When large and complex infrastructure projects are involved, the private sector is reluctant to assume all the risks, even if the potential revenue could be significant. Pure privatization is therefore not always the most suitable option.

A public-private partnership involves a level of transfer of risk from the public to the private sector, which can take many forms depending upon the degree of private sector involvement. Concessions tend to be the privileged form of PPP for many infrastructure projects, particularly port terminals, since the public sector simply becomes a landlord while the private sector assumes most of the risks, but also the rewards in the likely case that the investment is profitable.

Table 1. Pros and Cons of Different PPP Structures

<table>
<thead>
<tr>
<th>Structure</th>
<th>Service Contract</th>
<th>Management Contract</th>
<th>Lease</th>
<th>Concession</th>
<th>BOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Private sector performs specific service. Public sector remains responsible.</td>
<td>Operation and maintenance of utility transferred to private sector.</td>
<td>Private sector leases assets of utility and operates and maintains them.</td>
<td>Private sector has right to use assets, and responsible for operation, maintenance, and investments. Public sector owns assets.</td>
<td>Private party builds and owns asset, then transfers it to public sector.</td>
</tr>
<tr>
<td>Con</td>
<td>No private sector investment. Limited risk sharing.</td>
<td>No private sector investment. Little incentive to reduce costs and improve services.</td>
<td>No private sector investment. Administratively demanding on public sector.</td>
<td>Limited to stable political and economic contexts.</td>
<td>Lengthy process and high development costs.</td>
</tr>
</tbody>
</table>

The most wide-spread form of public and private partnership in Russia is concession, concession agreement is involvement of the private sector in effective management of state ownership or in rendering of services which are usually rendered by the state, on mutually advantageous conditions. Concession, the concessional agreement-a form of PPP, the involvement of the private sector in the effective management of the state property or in the provision of services, usually provided by the state, with transferring the set of exclusive rights to a certain facility on mutually beneficial conditions.
### Table 2. Types of PPP

<table>
<thead>
<tr>
<th>TYPE OF PARTNERSHIP</th>
<th>DESCRIPTION</th>
<th>WHO BEARS OPERATING RISKS UNDER PROJECT?</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOT: Build – Operate – Transfer or BOOT: Build – Own – Operate – Transfer</td>
<td>A concession holder exercises construction and maintenance (mainly, on the right of ownership) within a set time frame, thereafter the object is transferred to the state.</td>
<td>State/investor</td>
<td>Widely applied in India for road construction.</td>
</tr>
<tr>
<td>BTO: Build – Transfer – Operate</td>
<td>A concession holder constructs the object, to be transferred to state (concessor) ownership immediately after the completion of construction. Thereafter, the object is transferred to operation by a concession holder.</td>
<td>State/investor</td>
<td>In Russia: construction of a section (334-543 km) on the Moscow – St. Petersburg toll road.</td>
</tr>
<tr>
<td>BOO: Build – Own – Operate</td>
<td>A concession holder builds the object and operates it under ownership rights; the time frame is unlimited.</td>
<td>Investor</td>
<td>This type of contract is widely spread in construction of cargo handling terminals at seaports as well as passenger terminals of airports.</td>
</tr>
<tr>
<td>O&amp;M: Operations and Maintenance</td>
<td>Operations and Maintenance: a regulatory body signs a certain service provision and/or maintenance contract with a private company.</td>
<td>State</td>
<td>In Russia: servicing of the federal М-4 Don highway (225-633 km)</td>
</tr>
<tr>
<td>BBO: Buy – Build – Operate</td>
<td>Buy – Build – Operate is a type of sale involving reconstruction or extension of an existing object. The state sells an object to a private sector that performs necessary improvements for efficient operation.</td>
<td>Investor</td>
<td>This type of partnership is widely used in Brazil, where the state arranges largescale privatization of infrastructure objects: namely, motorways, airports and seaports. The Russian example is the privatization of energy assets held in the 2000s.</td>
</tr>
<tr>
<td>LDO or BDO: Lease – Develop – Operate or Build – Develop – Operate</td>
<td>A private company rents or buys from a regulatory body existing property/equipment, invests own funds in renovation and upgrade, and operates it pursuant to the terms of a contract signed with the regulatory body.</td>
<td>State</td>
<td>In Russia: Moscow government is currently in talks regarding the transfer of metro coaches (depots) to be serviced and upgraded by private investors.</td>
</tr>
<tr>
<td>DB: Design – Build</td>
<td>A private company is in charge of design and construction under the project.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The majority of current PPP projects in Russia are in the transport and infrastructure sector. The potential volume of private investment in transport infrastructure has been estimated at €12-15bn per year.

**Table 3. Current PPP projects in Russia**

<table>
<thead>
<tr>
<th>Current PPP projects in Russia</th>
<th>Facts:</th>
</tr>
</thead>
</table>
| **He Western High Speed Diameter motorway (WHSD)** | • Mostly eight-lane with an overall length of 46.6km.  
• Total project contract value estimated at around $9bn.  
• Approximately 50 per cent of construction costs contributed by the Federal government.  
• The WHSD is important for the Russian Federal government, which is keen to use it as a flagship for implementing PPPs, despite concerns over the project’s complexity. |
| **He first section of the Moscow to St Petersburg motorway** | • The first 58km section of the toll motorway linking Moscow and St Petersburg (a total of 650km) aims to relieve congestion on one of the busiest highways in Russia.  
• Estimated value of up to $2.1bn.  
• Includes the construction of five bridges, eight junctions and 21 flyovers.  
• Is estimated to take five years to complete. Half of the funding is expected to come from the state with the remainder to be covered by private sources, including international banks and companies. |
| **He Orlovsky Tunnel** | • This 1km-long tunnel under the River Neva in St Petersburg will open inland shipping to international transport. It will also increase the general capacity of the Volgo Baltic Waterway and is therefore beneficial to the federal transport network. It will also significantly improve the traffic situation in the adjacent areas of the city. |
| **Ulkovo Airport** | • $1.5bn is to be invested, through a special-purpose vehicle, to upgrade the airport, enabling it to accept long haul flights.  
• The concession agreement is likely to last for 30 years. |
| **Adzemny Express** | • Beginning at Baltic Pearl in the Krasnoselskiy district, this 26.5km rail line will pass through five southern city districts, ending at the Obuchovo metro station. The project will also encompass a 22km extension of the system to Pulkovo Airport and a further 22km extension to Petrodvorets (Naukograd).  
• The successful bidder will be required to design, build, part finance and maintain the system, which will have 16 stations and 30km of track.  
• The project has an availability payments structure.  
• The concession will run for 30 years. |

Avtodor has already launched several PPP projects. The first such project – a new exit from the Federal Highway M-1 (Belarus Highway) Moscow-Minsk to the Moscow Ring Road with a length of 18.5 km – was completed in late 2013. Four out of five sections of the Moscow – St.
Petersburg toll-way and one section of the Central Ring Road of Moscow region are currently under construction. Respective operator contracts have been signed with investors for servicing of the M-4 Don road.

Figure 3. Existing and prospective roads managed by Avtodor

The Russian PPP market is potentially enormous. One of the smallest current PPP roads in Russia, the Orlovsky Tunnel in St Petersburg, at around $1bn is still substantially bigger than the largest road PPP in relatively mature markets such as Germany – the A1 at $672m. Further to the first projects being developed mostly in the transport and, to a lesser extent, the utility sector, there is also scope for future use of PPPs to develop social infrastructure.

The recent dramatic devaluing of Russia's stock market has undoubtedly raised general concerns over market volatility. Similarly, currency exchange risk is currently a cause of anxiety. Russia's foreign currency rating is currently BBB+ (Fitch and S&P). In addition, investment in Russia is still affected by concerns over sovereign risk and revenue security, and by the perception that its commercial banks carry political risk. One result of these uncertainties is that export credit agencies are increasingly being approached by bidders to finance or underwrite PPPs.

Despite the recent volatility of its economy, the long term outlook for foreign investment in
Russian infrastructure remains positive. Russian transportation, accounts for 80% of all infrastructure investment in the country.

In Russia, the rate of infrastructure investment averages 3.6-4.2% of GDP, or roughly in line with the global average. By 2020, infrastructure investment will reach $650 bn ($90 bln per year on average). These funds will suffice for moderate expansion of infrastructure and gradual improvement of its quality. It is expected that many of the projects will be completed using PPPs.

The bulk of transport infrastructure investment will be directed to road construction (45%), while rail transport will take 20% (including the Moscow-Kazan High-Speed Railway and subway facilities), pipeline transport should account for 30%, while ports and airports will comprise the remaining 5%.

Whereas most PPPs in the pipeline in Russia focus on transportation, airports and ports, in coming years it is anticipated that this form of project finance can be adapted for use on social infrastructure projects.

References


[2]. PUBLIC-PRIVATE PARTNERSHIP IN DEVELOPING MUNICIPAL INFRASTRUCTURE EBRD 25TH SEPTEMBER 2009 SARAJEVO.


LOGISTICS EFFICIENCY EVALUATION FOR ASEAN BASED ON DEA MODEL

ZHANG Jin1,2, NGUYEN Thi-Yen1,2
1School of Transportation & Logistics, Southwest Jiaotong University, Chengdu 610031, Sichuan, China
2China-Asean Regional Development Collaborative Innovation Center, Nanning 530004, Guangxi, China

Abstract: This paper takes the investment of the logistics industry in fixed assets, logistics network mileage and the number of employees in logistics as input indicator; and quantity of shipments, turnover of freight traffic and logistics production as output indicators to build an efficient evaluation index system of ASEAN regional logistics. 2010-2014 logistics industry to ASEAN economies of scale and technology analysis and evaluation of benefits, the results show 2010 ASEAN logistics efficiency has not reached the best of input-output ratio, logistics inefficiency and waste logistics resources, ASEAN 2011-2014 input and overall effectiveness of the logistics industry, the logistics industry has development potential. According to the analysis of the present situation of logistics industry in ASEAN and the DEA results, recommendations for improvement, and to promote the sustainable development of ASEAN regional logistics industry.

Keywords: Asean; logistics; efficiency evaluation; DEA

INTRODUCTION

Since 2002, the leaders of China and ASEAN countries have signed the Framework Agreement on Comprehensive Economic Cooperation between China and ASEAN. By 2010, the China-ASEAN Free Trade Area will be officially launched. Since the establishment of the China-ASEAN Free Trade Area in 2010, the economic and trade cooperation has entered a new stage of development. The economic cooperation between CAFTA and China-ASEAN Free Trade Area has been continuously strengthened, with rapid trade growth and increasing trade volume (figure 1).

Figure 1. 2002-2015, China-ASEAN trade volume and balance (unit: billion)
Source: China Bureau of Statistics website (www.stats.gov.cn)
At present, as the world's third-largest free trade market, the China-ASEAN free trade area plays an important role in the world economy development. ASEAN has become China's largest trading partner and main source of foreign investment. ASEAN and China have benefited from the deepening of regional economic integration. In order to deepen cooperation between China and ASEAN, the two sides need to strengthen regional trade facilitation, improve logistics efficiency, this is also the basis for bilateral trade development.

China - ASEAN regional economic and trade cooperation, speed up the construction and development of logistics, promote China - ASEAN regional economic and trade cooperation and development. At present, there are few areas of ASEAN regional logistics research, therefore, the ASEAN regional logistics efficiency evaluation research, logistics resources investment, rational allocation, in order to improve the efficiency of logistics operation of the ASEAN regional economic development help.

From the domestic and foreign scholar's documents, there are various methods of logistics system efficiency evaluation. The evaluation methods used by domestic and foreign scholars mainly include comprehensive index analysis method, input-output method, fuzzy comprehensive evaluation method, analytic hierarchy process, frontier efficiency analysis method and data envelopment analysis (DEA). DEA method in the evaluation of the efficiency of logistics services is very effective.

Schinnar used data envelopment analysis to evaluate the efficiency of third-party logistics\(^1\). Weber based on Schinnar, carried out reforms of three inputs to the DEA model: the use of price, return rate, delay arrival rate of the logistics service efficiency evaluation of the analysis\(^2\). Lea Friedman and Zilla Sinuary-Stem through all data in canonical correlation analysis and discriminant analysis to construct a rational evaluation index system\(^3\). Sinuany combines two-stage DEA / AHP complete ordering model with data envelopment analysis and analytic hierarchy process\(^4\). Rabinovic used the DEA model to evaluate the efficiency of US logistics companies and analyzed the impact of logistics service performance and service breadth on production efficiency\(^5\). Domestic scholars in the study of efficiency evaluation using DEA method. The earliest, Zhi Cai use of DEA model for road transport enterprise technical efficiency and scale effectiveness analysis\(^6\). Liu Yuan discussed the feasibility and superiority of the DEA method in the evaluation of the economic benefit of enterprise logistics system, and pointed out that the premise and foundation of using DEA model is to establish scientific evaluation index system\(^7\). Shuai Bin, Du Wen Based on the analysis of DEA and PCA methods, it is proposed that the combination of the two will be more reasonable for the comprehensive analysis and evaluation of the logistics industry\(^8\). Guo Xiao-ping, Zhang Qishan using the fixed assets investment in the logistics industry and the number of employees in the logistics industry as the input targets, the total output of the logistics industry and the total wages of the employees in the logistics industry are taken as the output targets, using improved DEA model analysis of the efficiency of regional logistics in China\(^9\). Lin Tan and Ning Jun fei used the DEA model to evaluate the allocation efficiency of EU carbon emission rights in 2009\(^10\).

The efficiency of the logistics industry has made some progress on the study of the use of data envelopment (DEA) theory of the efficiency of the logistics industry evaluation methods and other efficiency evaluation methods has its unique advantages. For ASEAN regional logistics system
efficiency is less studied in the research documents, applying DEA method to evaluate the efficiency of ASEAN regional logistics system plays an important role in coordinating regional economic development, and for the development of China-ASEAN trade, it also provides strong logistic support.

I. ASEAN REGIONAL LOGISTICS INDUSTRY'S DEVELOPMENT SITUATION

1.1. ASEAN economic development status

ASEAN is a member of the Association of South-East Asian Nations (ASEAN). Since its founding in Bangkok in 1967, it has 10 member states of Indonesia, Malaysia, the Philippines, Singapore, Thailand, Brunei, Vietnam, Myanmar, Laos and Cambodia. ASEAN is located in South-East Asia, North of the Mainland, South Australia, East of the Pacific Ocean, West of India Ocean and Bangladesh, India border, connecting Sanya (Asia, Africa, Pacific), two oceans at a "crossroads" position. The region consists of Indochina and Malay Islands. ASEAN countries have a total area of 4.5 million square kilometers, a population of about 576 million. ASEAN countries, the level of economic development (figure 2).

Data shows that ASEAN regional economic development from an overall perspective of development faster economic development gap between countries, seen from the total GDP, Indonesia and Thailand's GDP is highest, following is Malaysia, the Philippines and Singapore, Viet Nam is at the middle, Laos, Myanmar, Cambodia and Brunei is the lowest, but judging from the per capita GDP, Singapore and Brunei are among the number 1, followed by Malaysia, and Thailand, and Indonesia, and the Philippines, Viet Nam and Laos, the last ones are Cambodia and Myanmar.

1.2. ASEAN logistics infrastructure status

In ASEAN countries, Singapore's infrastructure is the most complete, Malaysia, Thailand's infrastructure is more developed, while other countries' infrastructure is still lagging behind.
Among the ten ASEAN countries, Malaysia, and Thailand, Indonesia, the Philippines and Vietnam are marine State and located in major shipping lanes-the Malacca Straits and its surrounding, and has a long maritime history, in these countries, therefore, shipping plays an extremely important role. Among them, the Singapore Strait of Malacca and Malaysia's Port Klang are the world's most famous goods transfer hub. ASEAN route mode of the various modes of transport as shown in figure 3.

As can be seen from figure 3, in recent years, in the transportation, ASEAN has been vigorously building transport lines, road mileage has continuously increased, from 1569698 km in 2010 to 1405986 km in 2014, an increased by 163712 Km. The railway mileage is also steadily growing, from 197,773.5 km in 2014 to 20,635.5 km in 2014, increased by 862 km. The construction of China – ASEAN Interconnection infrastructure has benefited ASEAN economy and trade development, promotes the fundamental development of ASEAN the logistics industry.

1.3. ASEAN logistics development

At present ASEAN countries attach great importance to logistic development, and invested heavily in logistics infrastructure, can be seen from figure 4, ASEAN logistics industry in GDP increased from 85.145 billion dollars to 109.318 billion dollars, and still growing.
The Economy of China-ASEAN Free Trade Area. The background of trade cooperation brings the efficiency to ASEAN logistics analysis, the comprehensive relativity of ASEAN logistics integrated input-output, technology, and scale, and also important to the efficiency of analysis and evaluation.

II. DEA MODEL OF ASEAN LOGISTICS EFFICIENCY AND EVALUATION METHOD

Data Envelopment Analysis (DEA) is an evaluation method that uses a mathematical programming model to determine the relative efficiency between decision units with multiple inputs and multiple outputs. The DEA model includes: The C²R model is mainly used to evaluate the relative validity of decision-making units. The C²GS² model is mainly used to evaluate the technical effectiveness of decision-making units.

2.1. C²R Model

The DEA method was first established by A.Charnes, W.Rhodes and E.Coopera by CCR model[11]. Zhu J on the CCR model for two element analysis of changes, input oriented efficiency evaluation model can be obtained, that is C²R efficiency evaluation model [12]. The mathematical expression of C²R model is:

\[
\begin{align*}
\min \theta - \varepsilon (eS^- + eS^+) & \\
\sum_{i=1}^{n} X_i \lambda_i + S^- = \theta X_0 & \\
s.t.: \sum_{j=1}^{n} Y_j \lambda_j - S^+ = Y_0 & \\
\lambda_i \geq 0 & \\
S^- \geq 0 & \\
S^+ \geq 0 &
\end{align*}
\]

Form: \( \theta \) is investigating unit efficiency value; \( \varepsilon = (1,1,1...) \in \mathbb{E}^n \), \( e = (1,1,1...) \in \mathbb{E}^n \), \( E \) is the unit matrix; \( X_0 \) is a model of input indicators; \( Y_0 \) is output index; \( X_j = (X_{i1}, X_{i2},...,X_{in})^T \); \( Y_j = (Y_{j1}, Y_{j2},...,Y_{jn})^T \) for \( j \) decision making unit, \( S^- = (S^-_1, S^-_2,...,S^-_m) \) is \( m \) input of slack variables; \( S^+ = (S^+_1, S^+_2,...,S^+_n) \) is output of slack variables; \( \lambda_i \) is a weight; \( \varepsilon \) is a very small (generally \( 10^{-10} \) integer) [3].

The implication of the C²R model is as follows:

1) When \( \theta = 1 \), \( S^- = 0 \), \( \varepsilon = 0 \), the decision-making unit is DEA effective, in the economic system which is composed of \( n \) decision-making units, the combination of production factors of the decision-making unit has reached the optimal state, the optimal allocation of resources is achieved, and the optimal combination and maximum output is achieved;

2) When \( \theta = 1 \), \( S^- \neq 0 \), \( S^+ \neq 0 \), the decision-making unit is effective for weak DEA, and the decision-making unit is not the best technology efficiency at this time;

3) When \( \theta < 1 \), the decision unit for the DEA is invalid, the technology is invalid.

2.2. C²GS² Model

The mathematical expression of C²GS² model is:
\[
\min \theta - \theta (e^T S^- + e^T S^+)
\]
\[
\sum_{j=1}^{n} X_j \lambda_j + S^- = \theta X_0
\]
s.t.
\[
\sum_{j=1}^{n} Y_j \lambda_j - S^+ = Y_0
\]
\[
\sum_{j=1}^{n} \lambda_j = 1, \quad \lambda_j \geq 0 \quad j = 1, 2, \ldots, n
\]
\[
S^- \geq 0, S^+ \geq 0
\]

Form: \(X_i\) is input index, \(Y_i\) is output index, \(\lambda_i\) is a weight, \(S^-\) is a vector consisting of the slack variables corresponding to the output, \(S^+\) is a vector consisting of the remaining variables corresponding to the inputs. When \(\theta = 1\), the decision making unit is effective in technology, otherwise it is not effective.

**Table 1. ASEAN logistics system input-output index system**

<table>
<thead>
<tr>
<th>Index type</th>
<th>Index name</th>
<th>Unit</th>
<th>Index description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>Fixed asset investment in transportation, storage and postal industry ((X_1))</td>
<td>Million dollar</td>
<td>Response logistics industry capital investment</td>
</tr>
<tr>
<td>Input</td>
<td>Logistics network mileage ((X_2))</td>
<td>Kilometre (km)</td>
<td>Response logistics infrastructure investment</td>
</tr>
<tr>
<td>Input</td>
<td>Transportation, warehousing and postal service personnel ((X_3))</td>
<td>Ten thousand people</td>
<td>Response logistics personnel and human resources input</td>
</tr>
<tr>
<td>Output</td>
<td>Freight volume ((Y_1))</td>
<td>Million tons</td>
<td>Response to transport production results, reflecting the number of transport services for the economy</td>
</tr>
<tr>
<td>Output</td>
<td>Freight turnover ((Y_2))</td>
<td>Million ton kilometers</td>
<td>The reaction results of logistics transportation development scale</td>
</tr>
<tr>
<td>Output</td>
<td>Transportation, storage and postal industry output ((Y_3))</td>
<td>Million dollar</td>
<td>Response logistics development scale</td>
</tr>
</tbody>
</table>

In this paper, the ASEAN region 2010-2014 years of data, the 2010-2014 years of logistics input and output data as a decision making unit (DMU), as shown in table 2:

**Table 2. 2010-2014 years of ASEAN logistics industry input and output raw data**

<table>
<thead>
<tr>
<th>Particular year</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed asset investment in transportation, storage and postal industry ((X_1))</td>
<td>201</td>
<td>208</td>
<td>268.8</td>
<td>311.5</td>
<td>418.4</td>
</tr>
<tr>
<td>Logistics network mileage ((X_2))</td>
<td>1457623</td>
<td>1508800</td>
<td>1577861</td>
<td>1615538</td>
<td>1613332</td>
</tr>
<tr>
<td>Transportation, warehousing and postal service personnel ((X_3))</td>
<td>11587</td>
<td>11716</td>
<td>11643</td>
<td>11694</td>
<td>11745</td>
</tr>
<tr>
<td><strong>Output index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freight volume ((Y_1))</td>
<td>237438.3</td>
<td>246925.1</td>
<td>256635.1</td>
<td>243534.8</td>
<td>211992</td>
</tr>
<tr>
<td>Freight turnover ((Y_2))</td>
<td>2785565</td>
<td>3428119</td>
<td>4414050</td>
<td>4811636</td>
<td>4967851</td>
</tr>
<tr>
<td>Transportation, storage and postal industry output ((Y_3))</td>
<td>85145</td>
<td>98627</td>
<td>100865</td>
<td>102715</td>
<td>109318</td>
</tr>
</tbody>
</table>
III. MODEL AND SOLUTION

Application of DEA model in MATLAB software for solving, results are shown in table 3, table 4.

3.1. DEA scale effectiveness analysis of logistics efficiency

| Table 3. C2R model results |
|-----------------------------|------------------|-----------------|-----------------|-----------------|-----------------|
| Variable | 2010 | 2011 | 2012 | 2013 | 2014 |
| θ | 1.0016 | 1 | 1 | 1 | 1 |
| λ_1 | 0.0516 | 0 | 0 | 0 | 0 |
| λ_2 | 0.8927 | 1 | 0 | 0 | 0 |
| λ_3 | 0.0164 | 0 | 1 | 0 | 0 |
| λ_4 | 0.0018 | 0 | 0 | 1 | 0 |
| λ_5 | 0.0007 | 0 | 0 | 0 | 1 |
| S_1^- | 0.0018 | 0 | 0 | 0 | 0 |
| S_2^- | 7956.1301 | 0 | 0 | 0 | 0 |
| S_3^- | 328.8951 | 0 | 0 | 0 | 0 |
| S_1^+ | 40.0297 | 0 | 0 | 0 | 0 |
| S_2^+ | 503122.6920 | 0 | 0 | 0 | 0 |
| S_3^+ | 9210.2827 | 0 | 0 | 0 | 0 |

According to the evaluation results table 3 can be seen in 2011, 2012, 2013, 2014, the four decision - making units in the optimal value of θ=1, $S^-=S^+=0$, which shows that in 2011, 2012, 2013, 2014, the four decision making units for DEA. In 2010, the optimal value of the decision making unit is θ>1, which indicates that the decision making unit is non DEA effective in 2010. Therefore, for the DEA invalid unit can be adjusted by input and output, and ultimately to achieve DEA effective\[13\].

For non DEA effective decision making units to further improve, that is, in the C2R model in 2010 θ>1 projection analysis:

$X_{11} = 201 \times 0.0516 - 0.0018 = 10.36$, Transportation, warehousing and postal industry fixed assets investment decreased 10.36 million dollar;

$X_{12} = 1457.623 \times 1.0016 - 7956.1301 = 145.19$, That is the length of the line is reduced to 145.19km;

$X_{13} = 11587 \times 1.0016 - 328.8951 = 11276$, Transportation, warehousing and postal employees reduced to 112 million 760 thousand people;
Through the adjustment can increase the income for:

\[ X_{14} = 237438.3 + 40.0297 = 237478.32 \], That cargo volume increased to 237478.32 million ton;

\[ X_{15} = 2785565 + 503122.6920 = 3288687.69 \], The freight turnover increased to 3288687.69 million ton kilometers;

\[ X_{16} = 85145 + 9210.2827 = 1047355.28 \], Transportation, warehousing and postal services increased to 1047355.28 million dollar.

### 3.2. Efficiency Analysis of DEA Technology for Logistics Efficiency

**Table 4. C²GS² model results**

<table>
<thead>
<tr>
<th>Year</th>
<th>θ</th>
<th>S₁⁻</th>
<th>S₂⁻</th>
<th>S₃⁻</th>
<th>S₁⁺</th>
<th>S₂⁺</th>
<th>S₃⁺</th>
<th>Technical efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Effective</td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>0</td>
<td>0.0001</td>
<td>0</td>
<td>0</td>
<td>0.0002</td>
<td>0</td>
<td>Effective</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>0</td>
<td>0.0069</td>
<td>0.0001</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Effective</td>
</tr>
<tr>
<td>2013</td>
<td>1</td>
<td>0</td>
<td>0.0001</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Effective</td>
</tr>
<tr>
<td>2014</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Effective</td>
</tr>
</tbody>
</table>

The results from the C²GS² model analysis, in 2010, 2011, 2012, 2013, 2014, the five decision-making units are effective technology.

### IV. CONCLUSION

This paper selects the DEA efficiency evaluation model from 2010-2014 ASEAN logistics input and output data, takes fixed assets investment in transportation, warehousing and postal services, logistics network mileage, transportation and storage postal employees as input variables, The paper analyzes the logistics efficiency of ASEAN, and analyzes the technical efficiency and scale effectiveness of the input and output of ASEAN logistics system, get to the following conclusions:

(1) By C²R model analysis, the ASEAN with the evaluation result of 4 units (2011, 2012, 2013, 2014) out of total 5 from 2010-2014 shows efficiency to DEA, meaning the inputs and outputs of logistic reaches the best achievement, its benefit scale is efficient. Just only the year of 2010 did not achieve economies of scale, and in a State of decreasing income, and did not meet the best of input-output ratio.
(2) Through the C²GS² model analysis, the ASEAN region from 2010-2014 are technically effective. Therefore, from the data dimensions the DEA C²R and the C² GS² models have efficiency to economic development and resources, consequently make it better for improvement direction. In the ASEAN regional logistics industry development, the rational allocation of existing logistics resources has improved the quality of employees, continued developing the logistics industry policy-driven, improved the logistics industry output, play an important role.

References


COUPLED THERMAL STRESS ANALYSIS FOR SIMULATION OF CRACK PROCESSING IN CONCRETE BRIDGE BOX GIRDERS

NGO DANG QUANG
Faculty of Construction Engineering, University of Transport and Communications, Hanoi, Vietnam

Abstract: Temperature is known as one of the major reasons causing cracks in concrete structures. In the members like concrete bridge box girders thermal gradient may exist in many directions of the their sections. However in the current design code thermal gradient is modeled throughout the height of member section only. Moreover in the design practice the thermal gradient is mostly considered in the global analysis to get internal forces for the design purpose. Detail analysis accounting for local temperature distribution is rarely taken into account. Because of that many structure areas subjected to complicated stress condition aren’t investigated properly in design and may crack in the service time.

This paper presents a coupled thermal stress analysis considering the effect of solar radiation and the unequally distribution of temperature in the sections to simulate the cracking process in some local areas of concrete bridge box girders.

Keywords: Concrete bridge box girders, coupled thermal stress analysis, thermal gradient.

I. INTRODUCTION

Beside dead and live loads, shrinkage and creep of concrete, etc. thermal gradient in structure caused by solar radiation and other reasons may have a large effect in the stress distribution and crack development in concrete bridge girders. In current design codes thermal gradient is considered mostly in the vertical direction only. However, in the concrete bridge box girders thermal gradients may be found in horizontal and other directions because of the temperature difference between the inside and the outside of the box. These multi-directional thermal gradients cause a very complicated stress condition in concrete and the crack developing process is hardly to predict by usual analysis.

In some concrete bridge box girders in Vietnam many cracks have been found on the inner surface of the girder webs. They distributed diagonally to the girder longitudinal axis and symmetrically to pier position. Meanwhile there are no cracks found on the outer surface of the girder. In order to find out the reasons of these cracks many analysis have been performed including the global final stage analysis considering dead and live loads, the construction stage analysis taking into account of the effects of concrete creep, shrinkage and heat of hydration as well as the coupled stress and thermal detail analysis considering the unequally distribution of temperature in different parts of girder. The results of the global analysis shown that the effects
of loads alone in the construction and final stages don’t cause such cracks. Whereas the coupled thermal stress analysis presents that some areas in the box section subjected to pretty high stress. The combination of stress from thermal gradient and other actions can exceed the tension strength of concrete and causes cracks in the inside of the web.

This paper present the results of thermal transfer simulation and coupled thermal stress analysis to determine reasons of the cracks in the inside of concrete bridge box girders.

II. THE INVESTIGATED BRIDGE

Bridge NN has been built in 2000 in the Southern of Red Rive Delta (North Vietnam) with 7 spans box girder made of prestressed concrete. It lays in East-West direction. Five years after putting in the operation there are many diagonal cracks found in the inside of the girder webs. Some of them are 1.5 m long and some other are 8 cm deep and they distributed mostly symmetrically to pier positions (Figure 1). A long time observation shows that these cracks are now in still stand. A detailed investigation has been implemented but no cracks were found in the outside of the girders.

III. THERMAL ABSORPTION AND TRANSFER IN THE GIRDER CONCRETE

3.1. Solar radiation

Beside the heat of hydration in the hardening process the thermal effect in concrete bridge in the service time comes mostly from the solar radiation. The sun’s rays which are absorbed directly by the top surface cause it to be heated more rapidly than the interior region thus resulting in a temperature gradient over the bridge cross section.

It can be recognized that surface temperatures increase as the intensity of the solar radiation absorbed by the surface increases. The amount of solar radiation actually received by the
surface depends on its orientation with respect to the sun’s rays. So the intensity becomes maximum when the surface is perpendicular to the rays and is almost zero when the surface is parallel to the ray. Therefore, the solar radiation intensity received by a horizontal surface fluctuates from zero just before sunrise to maximum at about noon and decreases to zero right after sunset. It is found, however, that the maximum surface temperature generally takes place around 2 p.m. [1]. This lag of surface temperature is because of the daily air temperature variation which normally reaches its maximum value at 4 p.m. The coefficient of solar radiation absorption of a concrete surface depends on its colour and has a normal value from 0.5 to 0.8. This value for asphalt surface is about 0.85 to 0.98.

Based on the results of measurement and calibration Thaksin Thepchatri and the co. authors [1] have proposed a model to predict the change of daily solar radiation intensity on horizontal surfaces under sinusoidal with the following equation

\[
I(t) = \frac{1.7S}{T} \left( \frac{\sin^2 \alpha + 2\sin \alpha}{3} \right)
\]

(1)

Where, \( I(t) \) is radiation intensity at time \( t \); \( S \) total radiation in a day (W/m\(^2\)); \( T \) total time of radiation (hour) and \( \alpha = \pi t / T \).

According to Trinh Quang Dung in [2], the summer daily total radiation in the region of the investigated bridge is about 6 kW/m\(^2\) and the total time of radiation is 10 hour, from 7 a.m. to 5 p.m.

3.2. Thermal emission

Bridge girder receives heat from solar radiation and emits heat into the surrounding environment, especially at night, making it cool. This heat emission depends on the property of the surface materials, surface temperature and the temperature of the surrounding environment. The degree of heat emission has a value of 0.85 to 0.95 regardless of the color of the surface [4].

3.3. Thermal convection

Convection is basically the heat transfer from concrete girders into the ambient air or vice versa, depending on the object that has a higher temperature. The heat is transferred by convection depends on the temperature difference between the bridge surface and the air, as well as wind speed. Thermal convection can be described with equation

\[
Q_c = h_c \left( T_s - T_a \right)
\]

(2)

Where, \( Q_c \) is the heat loss of girder by convection, \( T_s \) is the surface temperature, \( T_a \) is the temperature of ambient air environment and \( h_c \) is convection coefficient. Value of \( h_c \) depends on wind speed. Based on [5], convection coefficient \( h_c \) for bridge top surface can be determined by the equation
\[ h_c = 13.5 + 3.88v \left( \frac{W}{m^2 \cdot C} \right) \]  (3)

Where \( v \) is wind speed (m/s). For the bottom exposed surface a value of 0.45 of the top surface heat transfer was used. For inside surfaces of flanges and partially protected lower surfaces, a value of 0.2 of top surface heat transfer was used.

### 3.4. Heat transfer

The heat is transmitted in the concrete by the thermal conductivity and the process is described by the function for thermal conductivity of the material as follows

\[
\frac{\partial T}{\partial t} = \frac{k}{\rho c} \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) \tag{4}
\]

Where, \( T \) is temperature of the material at time \( t \) and at the position of coordinates \( x, y, z \); \( k \) is the coefficient of thermal conductivity; \( \rho \) is the density and \( c \) the specific heat of concrete.

### IV. FINITE ELEMENT MODEL FOR COUPLED THERMAL STRESS ANALYSIS

The coupled thermal stress analysis for the bridge girder is performed by midas FEA - one of the few current software has this feature [3]. The girder is modeled by the solid elements (figure 2) with the material properties of structural concrete and asphalt determined according to the design documents and results of field measurements as listed in table 1.

<table>
<thead>
<tr>
<th></th>
<th>Concrete</th>
<th>Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-weight (kN/m³)</td>
<td>24.5</td>
<td>21</td>
</tr>
<tr>
<td>Coefficient of solar radiation absorption</td>
<td>0.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Compressive strength (MPa)</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Tension strength (MPa)</td>
<td>2.2</td>
<td></td>
</tr>
</tbody>
</table>

Solar radiation on the surface of the bridge is described by equation (1) as shown in figure 3. The daily temperature of the ambient air in June, based on recorded data from a weather station in the region, is shown in figure 4. In the finite element model on midas FEA, solar radiation is described in the form of load “flux” on the upper surface of the asphalt layer. The
heat exchange between the girder concrete and ambient air is modeled as heat convection and emission functions as well as ambient temperature as outlined above.

Figure 3. Daily change of solar radiation on the bridge surface

Figure 4. Daily change of ambient air temperature

V. ANALYSIS RESULTS

5.1. Distribution of temperature

The analytical results provide the distribution of temperature and thermal stress at regions in the structure. Figure 5 displays the change of temperature over day time of the bridge top surface. At around 2 p.m. the bridge surface reaches the highest temperature, nearly 53 °C. Also at that time, the temperature gradient is the largest under both vertical and horizontal directions (figure 6). The difference of temperature on top surface and the bottom surface of the top flange is about 28 °C (figure 7) and between the outer surface and inner one of the web is about 7 °C (figure 8). Thus, on the vertical direction, the thermal gradient calculated fairly agrees with one introduced in Vietnamese bridge design code 22 TCN 272-05.

5.2. Distribution of stress

The coupled thermal stress analytical results show that principal stress 1 has a considerable large value of ca. 1.5 MPa in the inside area near the top edge of the web and that the stress difference between the inner surface and the outer surface is relatively big (figure 9 and figure 10). In the investigated area, the direction of the principal stress 1 skewed ca. 52 degrees compared to the longitudinal axis of the beam. Meanwhile, from global the analysis taking into account of the dead and prestressing loads, principal stress 1 at this area has a value of ca. 1.0 MPa (figure 11) and skewed ca. 58 degrees above longitudinal axis of the beam. Because the directions of principal stresses 1 of the aforementioned causes are quite close together so their values can be added together. Thus the principal stress 1 caused by dead and prestressing load plus thermal gradient at the inner top edge of the web can reach a value of 2.5 MPa, greater than the tensile strength of the concrete. When combined with stresses from other actions such as shrinkage, live load, etc. the total stress can be big enough to cause inclined cracks developed in the inner surface of the girder web.
Figure 5. Daily distribution of temperature on the top surface

Figure 6. Thermal gradient at 2 p.m

Figure 7. Thermal gradient on the height of web (vertical direction)

Figure 8. Thermal gradient on the width of web (horizontal direction)

Figure 9. Distribution of thermal principal stress $\sigma_1$ in the height of web (vertical direction)

Figure 10. Distribution of thermal principal stress $\sigma_1$ in the width of web (horizontal direction)

Figure 11. Distribution of principal stress $\sigma_1$ caused by dead load and prestress on the beam length
VI. CONCLUSION

Due to solar radiation and the temperature difference between the inside and the outside, a multi-directional large thermal gradient can develop in concrete bridge box girders. These can cause a large local tensile stress in some areas of structure. However, in design practice, the thermal gradient is typically considered in the global analysis to get internal forces. Detailed analysis accounting for local temperature distribution is rarely taken into account. In many bridge box girders there are many cracks found, which cannot be predicted by global analysis.

A coupled thermal stress analysis can provide the detail distribution of temperature and stress in different areas of structure. The results of such analysis on a specific bridge shows that the local thermal stress can be one of the main co-causes of cracks in concrete.

For the concrete bridge box girders in regions of intensive solar radiation and large daily temperature change, it is necessary to perform a coupled thermal stress analysis for predicting the stress distribution to develop appropriate structural solutions and reinforcement layout.

References


I. INTRODUCTION

During the last two decades, China’s transportation infrastructure is advancing quickly with rapid economic development and urbanization. According to China’s 2015 highway statistics issued by the Ministry of communications in May, total length of highways in China have reached 4,577,300 kilometers at the end of 2015 against 4,463,900 km in 2014; an increase of 113,400 km have then be noticed in 2015 compared to the previous year. The highway density is 47.68km/100km2; which is 1.18km/100km2 improvements compared to 2014. The total mileage of classified highway was 4,046,300 km by the end of 2015 against 3,900,800 km at the end of 2014; an increase of 145,500 km in 2015 year compare to previous year. Classified highways occupy 88.4% in the total highway mileage of China. The mileage of the secondary highways class and above was 574,900 km in 2015; an addition of 29,200 km compare to 2014. The secondary highways class and above mileage then occupy 12.6% of the total highways mileage of China, an increase of 0.3% has then been noticed compare to 2014. Roads in China are classified as national highways, provincial highways, county roads, township roads and special purpose roads based on the administrative jurisdiction. National highways mileage is 185,300 km, provincial highways mileage is 329,700km, county roads mileage is 554,300km, township roads mileage is 1,113,200km, special purpose roads based on the administrative jurisdiction mileage is 81,700km. In 2015 there is respectively an increase of 6,100km; 6,900km; 2,300km; 8,100km and 1,400km for national highways, provincial highways, county roads, township roads, special purpose roads over 2014. By the end of 2015, the total mileage of China’s expressway was 1,235,000 km against 1,119,000 km in 2014 year. This represents an accretion of 116,000 km compared to the previous year. Among China’s expressways, National
ones account for 79,600km in 2015, an addition of 6,500 km than 2014. National Rural highways (county roads, township roads, and village roads) mileage was 3,980,600 km at the end of 2015 against 3,881,600km at the end of 2014; an increase of 99,000 km has then been noticed. In 2015 there are 779,200 public highway bridges with a total length of 45,927,700 m, an addition of 22,000 numbers of highway bridges and 3,348,800 meters length is noticed compare to previous year [1]. Based on the experience gained by developed countries, a large scale road maintenance era, and road maintenance will be a long term continuous, never ending task when the peak time of road construction is over [2]. Looking at the recent 2015 highway statistics issued by the Ministry of communications and comparing to the year 1988 where the first expressway was constructed, it can be noticed that China is currently undergoing development pattern in its road system development. The Highway maintenance has a total mileage of 4,465,600 km which represents 97.6% of China’s total highway mileage by the end of 2015. According to the average 5-10 year of major and moderate rehabilitation cycle, by the end of 2020 it is expected to have up to 8000 km per year for total major and moderate rehabilitation mileage, and the maintenance will be maintained over this level, reflecting a huge road maintenance market potential. There is no doubt that the first priority of China’s road development is shifting from large scale construction to ever growing maintenance. Many existing highways that were built 10 years ago are wearing out under heavy traffic loads accompanying with China’s rapid economic growth. Rehabilitation or maintenance is an urgent need for these highways. The pavement maintenance strategies through engineering construction and under the guidelines of the concept improve the engineering characteristics of the road surface layer from multiple aspects and thus expand the scope of the whole highway transportation service. Although pavement durability is the main objective of highway project and its materials are continuously updating to adjust, but it is still faced with some common disease problem (crack, rutting, and seepage).

This paper aims to investigate the engineering practice of current new technologies in pavement construction maintenance and their benefits for its life cycle

II. CASE STUDIES

Three typical case studies are outlined in this section with respect to pavement material, construction process and quality control.

Case study 1: Nanchong - Wusheng expressway.

The original pavement test section of Nanchong-wusheng expressway was as follows:

- 4 cm modified asphalt SMA-13
- 6 cm conventional asphalt AC-20 C
- 6 cm conventional asphalt AC-20 C
- 20 cm cement stabilized gravel base
- 30 cm cement stabilized macadam subbase.
After many years of operation, many distress such as cracking (transverse, longitudinal) and rutting occurs in some of the pavement sections: K4+140-+280, K4+040-+140, K3+940-K4+040, K4+280-+420, K4+420-+790, K4+790-+894. In order to give to the road users a comfort and safety while driving, a new structure has been implemented in the deteriorated sections areas. The six concerned pavement sections with different length have almost the same pavement structure used: SBS modifier asphalt in surface layer and in the middle and lower layer, 70 grade petroleum with level A. Pavement sections K4+420-+790 and K4+790-+894 have their subbase layer improve at 2% of cement. High performance asphalt pavement SUP19 is used to improve the performance and elevate the level of original pavement. The subgrade showed good bearing capacity. It is the first time that Emei Basalt has been used in SMA-10. Aggregate-asphalt ratio was respectively 6.3%, 4.5% and 4.1% for SMA-10, high performance asphalt pavement SUP19 and asphalt treated base (ATB-25) and pebble stone has been used as aggregate in both SUP 19 and ATB-25. The new pavement structure performs well to traffic load after many years and no obvious distresses have been shown. The composition and structure of the new pavement structure of Nanchong -Wusheng direction is shown in table 1 of the appendix.

Case study 2: Chengdu-Chongqing expressway

Cement concrete pavement uses cement concrete as surface material. This type of structure has many benefits of high stiffness, good rigidity, durability and a small routine maintenance work load, etc. The Chinese Design Standard prescribes a 30-year life for cement concrete pavement. However, many investigations on the usage have found that few cement concrete pavements can achieve a 15 to 30 year life cycle, and even some serious problems occur after being opened to traffic for 3 to 5 years.

The case study is located in Chengdu-Chongqing expressway and the pavement sections have been opened to traffic flow in 1995. The original pavement comprises of different sections presented below:

A. K7+000-K10+000 section:

The original pavement section is consists of:
- 24cm concrete slab
- 20-30cm lime ash stabilized gravel

B. K10+000-K22+700 section:

The original pavement section is consists of:
- 24cm concrete slab
- 20-30cm lime stabilized gravel

In these two sections above of the expressway, the original pavement condition is evaluated and results are summarized.
1. Original pavement condition evaluation

Prior to any maintenance or rehabilitation, researches have been conducted to evaluate the pavement condition index (PCI), the joint transfer capacity, the percent of voids beneath the concrete slab, pavement ride quality index (RQI) and mechanical performance test in both directions of the concern expressway. All these data have been found every kilometer of road. Results of all these indexes or data evaluated are shown in Appendix respectively through tables 2 to 6.

2. Results and Discussion

From table 2 (in Appendix), it can be concluded that most of sections are in very poor condition; most of sections in passing lane for both directions are either in good condition or sometimes fair condition. For both directions, either main lane or passing lane, the percent of broken slab is high and is either in very poor or poor condition. Table 3 shows the load transfer in the pavement concrete joint. The load transfer along joint in concrete slabs is excellent in both directions for some part and poor or very poor condition in other parts. The voids beneath the concrete slab are higher in main lane for both directions compare to the passing lane. Its results are shown in table 4. Table 5 showed the ride quality index and in table 6, the mechanical performance test results. From table 5, it is shown that the quality of pavement related to riding is range from fair to good. Two different test were performed (splitting tensile strength and compressive tensile strength) to analyze the mechanical performance of the pavement cores. From the table 6, it can show that compressive strength value is higher than splitting tensile strength one.

3. Old pavement structure regulation

Three problems are mainly emphasized to be solved in terms of application of asphalt surface course in old cement concrete structure: (1) prevention of reflection crack, (2) bonding between surface course and cement concrete slabs, (3) water infiltration of pavement surface. Researches results showed that international technical exchange with America and Europe and China’s engineering experience show that the stress absorbing layer technology has obvious advantages technologically and economically. After inspecting original pavement structure condition, and reporting deficiencies, the next step has consisted of treatment. In the Chengdu - Chongqing expressway case, the treatment is done per section of road. The overlay structure for different sections is shown below.

**K7~K9+100 section (Chongqing to Chengdu direction)**

After the treatment of original pavement disease (without grouting), overlay has been applied and consist of

- 2.5cm stress absorption strata layer
- 8cm medium granular modified asphalt concrete AC-20
- 4cm asphalt mastic macadam SMA-13.
The overlay structure has been constructed on July 2006 and after 10 years of operation, only few transverse cracks have been obvious.

**K7-K9+100 section (Chengdu to Chongqing direction)**

After treatment of concrete panels, vertical and horizontal width of 50 cm cracks have been filled with adhesive SBS membrane and 14cm thickness of overlay has been applied and the overlay structure is presented as follows:

- 5cm medium grained modified asphalt concrete leveling layer AC-20C
- 5cm medium grained modified asphalt concrete middle layer AC-20C
- 4cm modified stone mastic asphalt SMA-13.

The overlay structure has been also constructed on July 2006 and after 10 years of operation, only few transverse cracks have been obvious. The above two sections of white and black exhibits better performance, thus the original pavement has better performance after treatment which was the target.

**K9+100-K18+750 section (both directions)**

After crushing the original pavement with hammer, a certain thickness has been implemented as overlay and the pavement structure is shown below:

- 20 cm cement stabilized crushed stone subbase
- 20cm cement stabilized macadam base
- 6cm medium grained conventional asphalt concrete AC-20
- 6cm medium grained modified asphalt concrete AC-20
- 4cm modified stone mastic asphalt SMA-13.

The original pavement condition and construction process are shown respectively in figures 1 and 2.

![Fig 1. Original pavement condition](image-url)

In order to check the effect of different method of treatment on the concrete pavement performance, numerous tests have been done. In December 2013 the general condition of pavement distress has been evaluated by pavement vehicle data acquisition and in April 2014 a walking survey has been done. Tables 7 and 8 (in Appendix) show the evaluation of pavement distresses for both directions. No obvious raveling, settlement, flushing distresses are noticed in the pavement surface. In 2008, 2010, 2013 the pavement deflection has been detected and it is shown in tables 9 and 10 for both directions. There is no deflection and the pavement is in excellent condition. In 2008, 2010, 2012 and 2013, the section K7+000-K18+750 have been checked by laser profiler track for testing rutting. The results of rutting over years are shown in tables 11 and 12 for both directions. It can be concluded that there is not obvious rutting and pavement condition is either good or excellent. From 2007 to 2013 every year, laser instrument has been used to detect the flatness of pavement cross section and results from this investigation for both directions of travel are shown in tables 13 and 14. It can be seen that pavement has good riding quality. Section K7-K18+750 after being treated have good pavement condition, good riding quality and there is no obvious rutting and deflection.

C. K157-161 section: Chongqing to Chengdu direction, Yinshan section

In order to verify the construction operability and practical effect, 4km Thiopave asphalt mixture was paved on the large longitudinal slope uphill section of highway from Chongqing to Chengdu; 4cm AC-13C (Thiopave asphalt mixture) surface layer was overlaid on the original pavement on May 2009. Composite gradation of mineral aggregate is shown in table 15. Asphalt-aggregate ratio determined by target proportion was 5.3%, optimal asphalt content was 5.5%. According to the principle of equal volume conversion, the final asphalt content (asphalt: mineral aggregate) = 4.37%, Thiopave percent (Thiopave: mineral aggregate) = 2.05%. The test results of Thiopave asphalt mixture performance shown in table 16. After many years of operation on the large longitudinal slope uphill section of highway from Chongqing to Chengdu(K157+000~K161+000), the road performance is better, there is no obvious early disease. Table 17 summarize the test results of pavement road test of 2010 and 2013.
**D. K223-K225 section**

Buton rock modified asphalt overlay was constructed on November 2008. It was overlaid over an original modified asphalt mix AC-13 for a given section. Indonesian buton rock asphalt (BRA) is a production from the Indonesian buton Island submarine rock asphalt. It is broken by mining into fine powder particles which have a light brown color. Trichloroethylene as solvent and automatic extraction Infratest 20-1120 instrument detection were used to extract asphalt content from the rock and final mineral aggregates has resulted. Table 18 shows the BRA extraction test results (in Appendix) and its screening results before and after extraction is shown in table 19. In table 18 it is shown that BRA asphalt content is 21.7% and the mineral aggregate percentage accounts for 78.9. Before extraction buton rock asphalt screening are too coarser with maximum particle size of mineral aggregate control below 1.18mm. More than 70% of mineral particles diameter are less than 0.15 mm after extraction. Fine, mineral particles mainly composed of limestone (reacted with hydrochloric acid to bubble), have strong adsorption of asphalt and used as powder. Fine mineral particles of buton rock asphalt mix before and after extraction and its reaction with hydrochloric acid are shown in figure 3.

![Fig 3. Fine mineral particles of buton rock asphalt mix: a) before extraction; b) after extraction; c) reaction with hydrochloric acid](image)

In order to see the effect of buton rock asphalt overlay after few years, the overlaid structure has been evaluated in term of occurrence of distresses: pavement damage condition evaluation, roughness and rutting. Test results are shown through tables 20 to 22. It can be concluded that the buton rock asphalt overlay pavement is in good condition.

**E. K42-K47 section (Chengdu-Chongqing Expressway) overlay**

Hot in place recycling technology is used as overlay in Chengdu - Chongqing Expressway K42-K47 section as pavement test section. On the top of the original pavement surface, 3 to 5cm of hot - in place regeneration is applied followed by 4cm of conventional asphalt mixture. A total of 170 Km of road test has been implemented based on experience and a tracking observation has been investigated as shown in figure 4.
After application of hot-in place recycling overlay in Chongqing Chengdu expressway; deflection, pavement distresses, rutting and pavement roughness were evaluated to see the effect of its application as overlay. Tables 23 to 26 respectively give details of each pavement component measured. From table 23 it can be noticed that in 2005 and 2007, deflection data has been detected in both lanes. In 2006, 2008, and 2010: only the main lane has been put into account for deflection detection. From 2005 to 2010 the deflection of the pavement decreases considerably. In 2009, Comprehensive test vehicles have been used to detect the road surface damage condition. According to the results obtained of the original road in table 24, there are no obvious types of distresses. The track of the test section was detected by laser beam profiler in 2008 and 2009, and the results of the detection of the hot in place recycling rutting test are in table 25. From table 25, it can be concluded that by 2009 most of pavement sections are either in good or fair condition. Only two pavement sections are in poor condition. Table 26 showed that pavement smoothness is also in good condition.

**Case study 3: Zigong to Yibin expressway**

Based on the experience of test section of Chengdu -Chongqing expressway in foamed bitumen cold recycling asphalt, an implementation of 13 kilometers of foamed bitumen cold recycling site has been extended in Zigong to Yibin expressway. The original pavement structure is shown bellows:

- 5cmAK-16B anti-sliding surface layer
- 7cm coarse grained asphalt concrete AC-25I
- 20cm lime fly ash stabilized base
- 39cm lime stabilized mudstone subbase.

After few years of operation the pavement surface was not in good condition and thus the main and overtaking road surface has been improved and the new structure is as follows:

- 4cm fine grained modified asphalt concrete AC-13C
6cm medium grain type conventional asphalt concrete AC-20C

0.6cm slurry seal

14cm foam asphalt cold regeneration,

The pavement test section was treated by slurry before application of the cold regeneration asphalt layer. 14cm of foam asphalt cold regeneration refers to 12-13 cm of original milling asphalt added by 1-2cm top of base layer. According to the original road site grading requirement and amount of new material added, the asphalt foam recycling layer actual thickness is about 17cm. The pavement section has been constructed on May 2010 and after 5 years the road performance tracking is in good condition (table 27).

**Case study 4: Chengdu to Mianyang Expressway**

Chengdu-Mianyang Expressway plays an important role and represents the main squeueleton road network in Sichuan province. According to statistics, Chengdu-Mianyang highway average daily traffic volume data over years before reconstruction is shown in table 28 and table 29 shows Chengdu-Mianyang expressway observation data after Mojia town toll station after reconstruction. From table 29, it can be noticed that after open to traffic, Chengdu-Chongqing expressway traffic flow slightly decreases for some case and still high for others in 2010. The original pavement structure consists of 23cm thick cement concrete slab +25cm thick cement stabilized gravel base (or 23cm thick cement concrete plate+ 20cm thick cement stabilized gravel base). Due to the large traffic volume with high proportion of trucks, the original pavement experienced some early damage in its structure. Therefore in Luojiang County K79-K81 section along Chengdu-Mianyang expressway, 5 sections of rubblization test have been conducted including drop hammer methods or resonant beam rubblizing. Rubblizing is the process of fracturing pavement of Portland Cement Concrete into angular pieces for direct overlay. It is an effective means of rehabilitating deteriorated Portland Cement Concrete (PCC) pavement. The concrete is broken into pieces, and then it is overlaid with Hot Mix Asphalt (HMA). In our case ,after breaking the original concrete pavement structure into pieces, an overlay structure has been applied and it is presented as follow:6cm of conventional asphalt AC-20C+4cm conventional asphalt AC-13C+6cm conventional asphalt AC-20C+4cm modified asphalt SMA-13. The overlay section has been constructed on March 2007 and the mixture design for both SMA-13 and AC-20C are as follows:

- **SMA-13 mixture design bitumen aggregate ratio OAC: 6.2%.

  Corresponding parameters:
  
  - 2.581,=2.475,=4.1,VV(%)=4.1,VMA(%)=17.2,VFA(%)=76.2

- **AC-20C mixture design bitumen aggregate ratio OAC: 4.9%.
Corresponding parameters:

\[ \text{\(=2.581, =2.475, VV(\%)=4.2, VMA(\%)=14, VFA(\%)=76.2,\)} \]
\[\text{\(\%\) =4.44, \(\%\) =10.89, \(\%\) =84.91, FB=1.19, DA () =9.66.}\]

The results of pavement condition survey after application of rubblization method are shown in tables 30 and 31 in appendix. From table 31, it can be see that the pavement condition index (PCI) values are above 90, which means that all pavement sections are in very excellent condition. The same effect is shown in table 31 for roughness index test results.

III. CONCLUSION

In this paper, we evaluate the diseases characteristics and poor condition of existing road for different expressways; use different current technologies for pavement maintenance. Results from these technologies application are summarized as following:

♦ The elevation of the road process of Nanchong-Wusheng expressway is greatly increase by setting a thick layer of high performance asphalt mix SUP 19. It was the first time that SMA10 which aggregate source is Emei basalt was used.

♦ After survey its diseases characteristics in section K7-K9+100 along Chongqing – Chengdu direction, a 2.5 cm thickness of stress absorption strata layer technique is introduced to solve reflection cracks in pavement. After few years of operation only very few transverse cracks were noticed. In the same time for the same section of expressway but in opposite direction, vertical and horizontal cracks on the concrete panels were filled with an adhesive SBS membrane; the section of white (concrete) and black (asphalt) together exhibits good performance.

♦ Pavement performance tracking test has been conducted few years later in the new pavement structure in K9+100-K18+750 after the original one has been crushed by hammer, it is conclude that there is no obvious raveling, settlement and flushing disease in the new built pavement.

♦ In K157-K161 (Chongqing to Chengdu direction, Yinshan section), Thiopave asphalt mixture was used to overlay the existing pavement. After many years of operation the road is still in good condition.

♦ Buton rock asphalt (BRA) mix was used to overlay a given section (K223-K225) in Chengdu-Chongqing expressway. Few years later after evaluation of pavement distresses, roughness and rutting. Buton rock asphalt overlay pavement is in good condition.

♦ Hot-in place recycling asphalt technology has been used to treat the top surface of existing pavement along Chengdu-Chongqing expressway for a K42-K47 section. Few years later the survey has been conducted on the pavement and found that the pavement is in good condition.
Foam asphalt cold recycling has been implemented for use in Zigong-Yibin expressway to replace the existing poor pavement structure after being treated by slurry. After 5 years, road performance tracking test was conducted and pavement condition is in good state.

Rubblization test has been applied in Chengdu-Chongqing expressway (Luojian county K79-K81 section) using both drop hammer methods and resonant beam rubblizing in the cement concrete pavement, the results of pavement condition survey after rubblization test are good. The values of pavement condition index (PCI) are above 90.

References
METHOD OF DYNAMIC DESIGN OF RIGID AIRFIELD PAVEMENTS

Vladimir V. Tatarinov¹, Nguyen Van Hieu²
¹Dr., professor, ²Ph. D student
MADI, 64, Leningradsky prospect, Moscow, 125319, Russia

Abstract: The article presents a method of dynamic calculation of rigid airfield pavement of the airports “Kep” and “Camranh” in Vietnam, taking into account surface roughness. The roughness of airfield pavement was calculated by studying the movement of airplanes on a concrete pavement, which is modeled as an infinite plate on an elastic foundation.

Keywords: Airfield pavement, estimation, spectrum density, dynamic coefficient, plate, elastic foundation.

INTRODUCTION

During airplane movement on the airfield pavement, surface roughness of the pavement is one of the main reasons of the creation of dynamic loads, and must be taken into account in the strength calculation of airfield pavement.

The dynamic loads from the wheels of the airplane are taken into account by the introduction of dynamic factor $k_d$ in the strength calculation of airfield pavements. The values of $k_d$, given in normative documents in Vietnam, were obtained in the 60-ies of XX century, on the basis of multiple tests carried out in the Soviet Union and Vietnam, and almost have not been adjusted. Currently, the fleet and construction equipment, used in the construction of airfields pavements, have significantly changed.

METHOD OF DYNAMIC CALCULATION OF RIGID AIRFIELD PAVEMENTS, TAKING INTO ACCOUNT SURFACE ROUGHNESS

The problem of calculation of rigid airfield pavements for strength is to verify structure design for the limit state [1]:

$$m_d \leq m_u$$

(1)

Where: $m_d$ - the calculated bending moment at the section under the slab, $m_u$ - the ultimate bending moment at the section under the slab. The calculated values of the bending moments $m_d$ per unit width of the cross section of single layer hard coatings determined by the following formula:

$$m_d = m_{c, max} \times k, k_N, k_x(y)$$

(2)

Where: $m_{c, max}$ - maximum bending moment under the central loading of the plate, which is calculated as the maximum total torque produced by the airplane wheel in the calculated cross
sections of the plate:

\[ m_{c, \text{max}} = m_1 + \sum_{i=2}^{n_k} m_{x(y)i} \]  \hspace{1cm} (3)

- transition coefficient of bending moment from the central load case to an edge load case, taken from \([1]\);
- \( k_N \) - coefficient taking into account the accumulation of residual deflections at the base;
- \( k_{x(y)} \) - coefficient that accounts for the redistribution of the internal forces in orthotropic plates coatings, with different stiffness \( B_x \) and \( B_y \) in the longitudinal and transverse directions; for concrete, fibercrete and reinforced concrete pavement with non-stressed reinforcement \( k_{x(y)} = 1 \);

- the bending moment from the action of a wheel, whose print center coincides with the cross-section: \( m_1 = \bar{m}_1 F_d \);

- the bending moment created by the action of the \( i \)-th wheel, which is located outside the calculated cross section plate: \( m_{x(y)i} = \bar{m}_{x(y)i} F_d \);

- \( \bar{m}_1 \) - unit bending moment from the action of a wheel, whose print center coincides with the cross section, defined by a table \([1]\) depending on the given radius.

\( F_d \) - dynamic load from one wheel of the airplane main landing gear;

\[ F_d = \frac{F}{n_k} k_d \gamma_f \]  \hspace{1cm} (4)

\( F \) - load on the main support of design airplane;

\( n_k \) - number of wheels;

\( \gamma_f \) - coefficient of discharge, determined in accordance with a table \([1]\);

\( k_d \) - dynamic coefficient.

In formula (4), the dynamic coefficient is determined according to table \([1]\). It depends on the internal pressure of the air in the tires of the wheels and of groups of sites of airfield coverings.

The article proposes to determine the dynamic coefficient as the ratio of the deflections of the coating under dynamic \( W_d \) and static \( W_0 \) loads from the wheel of the airplane:

\[ k_d = \frac{W_d}{W_0} \]  \hspace{1cm} (5)

To calculate the deflections of the airfield pavement, the model of a thin, infinite in plan, anisotropic and homogeneous plate resting on Winkler elastic foundation should be considered.

The equation of the dynamic equilibrium of such a plate (Fig.1) is a complex biharmonic equation in partial derivatives \([2; 5]\).

\[ \left( \nabla^4 + \frac{\rho}{\ell^2 K_x} \left( \frac{\partial^2}{\partial \xi^2} V_x^2 + 2 \frac{\partial^2}{\partial \xi \partial \eta} V_x V_y + \frac{\partial^2}{\partial \eta^2} V_y^2 \right) \right) W(\xi, \eta) = \frac{q(\xi, \eta)}{K_x} \]  \hspace{1cm} (6)
Where: \( V^4 = \left( \frac{\partial^2}{\partial \xi^2} + \frac{\partial^2}{\partial \eta^2} \right)^2 \) – the differential operator; \( W(\xi, \eta) \) - function of deflection of middle surface of plate under load \( q(\xi, \eta) \); \( K_s \) - foundation reaction modulus; \( V \) - speed of airplane with projections on the axes \( V_x \) и \( V_y \); \( g \) – acceleration due to gravity; \( \ell = \frac{B}{\sqrt{K_s}} \) – elastic characteristic of the plate; \( B = \frac{Et^3}{12(1-\mu^2)} \) – cylindrical plate modulus; \( \rho, E, t, \mu \) – accordingly, mass of plate per unit area, elastic modulus, thickness of plate, and Poisson's ratio;

\( \xi = \frac{(x-V_x.t)}{\ell}; \eta = \frac{(y-V_y)}{\ell} \) - reduced rectangular Cartesian coordinates in plane of plate;

Consider the problem of uniform motion of a load distributed over a rectangle, with sides 2a and 2b along the axis X. In this case we have:

\( \xi = \frac{(x-V_x)}{\ell}; \eta = \frac{y}{\ell}; V = V_x; V_y = 0. \) If we take the parameter of the inertia forces of the plate \( \lambda = \frac{\rho V^2}{2\ell^2 K_s g} \), we get the equation (6) in the following form:

\[
\left( V^4 + 1 + 2\lambda^2 \frac{\partial^2}{\partial \xi^2} \right) W(\xi, \eta) = \frac{q(\xi, \eta)}{K_s} \tag{7}
\]

The use of Fourier transforms allows you to find a solution to the differential equation (7) in the form of double improper integrals for various cases of application of the load.

\[
W(\xi, \eta) = \frac{F_d}{\pi^2 a b K_s} \int_0^\infty \int_0^\infty \sin \left( \frac{\alpha a}{\ell} \right) \sin \left( \frac{\beta b}{\ell} \right) \cos (\alpha \xi) \cos (\beta \eta) \frac{d\alpha d\beta}{\alpha \beta (\alpha^2 + \beta^2)^2 + 1 + 2\lambda^2 \alpha^2} \tag{8}
\]

Consider a special case of this, which corresponds to the application of concentrated load at the origin \( (\xi = \eta = 0); a \to 0, b \to 0 \). In this case, the resulting value of the deflection under a fixed and a movable load:
where \( F_0 \) - static load from a single wheel of main landing gear of the airplane.

The exact value of the deflection in the formula (9) can be calculated analytically and is equal to \( W_0 = \frac{F_0}{8lK_S} \). Thus, the value of dynamic coefficient is defined by the formula (5) can be written in the following form:

\[
k_d = 8 \frac{F_0}{F_0} \int_0^\infty \frac{d\alpha d\beta}{(\alpha^2 + \beta^2)^2 + 1 - 2\lambda^2\alpha^2}
\]  

Value of the dynamic load \( F_d \) is calculated according to the three Sigma rule:

\[
F_d = F_0 + 3C_2 \sqrt{D_{\delta w}}
\]  

Where: \( C_2 \) - stiffness of the pneumatic airplane tires; \( D_{\delta w} \) - dispersion of compression of airplane tires, determined by the method of "Statistical dynamics" [4] by the following formula:

\[
D_{\delta w} = -\frac{CV}{2} \left[ \frac{(M+m)^2C_1^2}{M^2RC_2^2} + \frac{m}{M^2RC_2^2} - \frac{(M+m)^2R}{M^2C_2} + \frac{2m(M+m)C_1}{MRC_2} \right]
\]  

Where: \( M \) - mass of the airplane attributable to main landing gear; \( m \) - mass of main landing gear; \( R \) - coefficient of damping of the strut main support; \( C_1 \) - stiffness of the strut; \( V \) - speed of movement of the airplane; \( C \) - level of the spectral density.

The spectral density of the airfield is represented by the following expressions:

\[
S_\omega (\omega) = \frac{C}{\omega^2} V
\]  

Where: \( \omega \) - spatial frequency.

In the end, we get a formula to determine the dynamic factor:

\[
k_d = \frac{8(F_0 + 3C_2 \sqrt{D_{\delta w}})}{\pi^2 F_0} \int_0^\infty \frac{d\alpha d\beta}{(\alpha^2 + \beta^2)^2 + 1 - 2\lambda^2\alpha^2}
\]  

The application of the proposed method for the design of airfield pavements of airports "Kep" and "Camranh" in Vietnam allowed the following results:

The estimated airplane: IL-96
Inputs to the calculation were the elevation of the longitudinal sections of the runways, obtained by geometric leveling with a step of 0.5 m, and the parameters of the design of the airplane. The calculations used the software package Matlab.

A graph of the dynamic coefficient function of the speed of the airplane is shown in figure 3:

![Graph of \( k_d \) and V for the airport «Kep» and airplane IL-96](image)

Analysis of fig 3 shows that the value of the dynamic coefficient increases in proportion to the speed of the airplane. Some of the data calculated in the airports, "Kep" and "Camranh" is shown in table 1:

<table>
<thead>
<tr>
<th>Speed of airplane (km/h)</th>
<th>Spectral density, C</th>
<th>( k_d )</th>
<th>Spectral density, C</th>
<th>( k_d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.3527e-6</td>
<td>1.000</td>
<td>1.1374e-6</td>
<td>1.000</td>
</tr>
<tr>
<td>10</td>
<td>0.3527e-6</td>
<td>1.010</td>
<td>1.1374e-6</td>
<td>1.019</td>
</tr>
<tr>
<td>30</td>
<td>0.3527e-6</td>
<td>1.018</td>
<td>1.1374e-6</td>
<td>1.033</td>
</tr>
<tr>
<td>50</td>
<td>0.3527e-6</td>
<td>1.023</td>
<td>1.1374e-6</td>
<td>1.042</td>
</tr>
<tr>
<td>100</td>
<td>0.3527e-6</td>
<td>1.033</td>
<td>1.1374e-6</td>
<td>1.059</td>
</tr>
<tr>
<td>200</td>
<td>0.3527e-6</td>
<td>1.047</td>
<td>1.1374e-6</td>
<td>1.083</td>
</tr>
</tbody>
</table>
Dynamic calculation should be done at the speed of taxiing of the airplane, that is up to 100 km/h. At higher speeds, a significant impact will be exerted a lifting force, reducing the load on the coating.

The results of calculations for various airfield pavements are given in table 2.

**Table 2. Characteristics of the layers of airfield pavements designed for airplane IL-96 for different values of k_d**

<table>
<thead>
<tr>
<th>Characteristics of pavement</th>
<th>Unit</th>
<th>Dynamic coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Airport «Kep»</td>
</tr>
<tr>
<td></td>
<td></td>
<td>k_d =1.25</td>
</tr>
<tr>
<td>Thickness of the concrete plate M350/45- t_b</td>
<td>m</td>
<td>0.39</td>
</tr>
<tr>
<td>Thickness of sand reinforced with cement (E_t = 4000 MPa), t_t</td>
<td>m</td>
<td>0.30</td>
</tr>
<tr>
<td>Thickness of the artificial base k_1 = 200 MN/m^3, t_1</td>
<td>m</td>
<td>0.30</td>
</tr>
<tr>
<td>Natural foundation reaction modulus, k_f</td>
<td>MN/m^3</td>
<td>69.0</td>
</tr>
<tr>
<td>Maximum bending moment in the central load case - m_{m, max}</td>
<td>KNm/m</td>
<td>59.314</td>
</tr>
<tr>
<td>Calculated bending moment - m_d</td>
<td>KNm/m</td>
<td>62.522</td>
</tr>
<tr>
<td>Ultimate bending moment - m_u</td>
<td>KNm/m</td>
<td>64.196</td>
</tr>
<tr>
<td>Percentage of under voltage (ε = m_{u} - m_{d} \times 100% )</td>
<td>%</td>
<td>2.61</td>
</tr>
</tbody>
</table>

CONCLUSION

The result of conducted research and calculations shows that the value of dynamic coefficient is to cover airports do not exceed the value of 1.06, which is considerably below the value given in the normative documents (1.25). The technique of dynamic calculation, taking into account the surface roughness, presented in this work allows to reduce the thickness of the layers in airfield pavements.

References

I. INTRODUCTION

Heat is generated during the hydration of cement causing a rise in internal temperature in concrete structures. The larger the concrete structure, the higher the internal temperature generated. Large concrete structures are characterized as mass concrete structures. Mass concrete is defined by the American Concrete Institute (ACI) as “any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change, to minimize cracking” [1].

During the curing of mass concrete structures, the temperature at the exterior surface is dissipated to the surrounding environment while the interior of the concrete remains hot—due to hydration reaction. The difference between the interior temperature and the exterior temperature is referred to as temperature differential.

In mass concrete applications, temperature differential plays an important role. Large temperature differentials can result in thermal cracking of the concrete which can substantially decrease the design life of a structure. The magnitude of the tensile stress is dependent on the thermal differential in the mass concrete, the coefficient of thermal expansion, modulus of elasticity, creep or relaxation of the concrete, and the degree of restraint in the concrete. Since the concrete is still in its early age, its full tensile strength is not developed, and if the tensile stress exceeds the concrete's tensile strength, cracking will occur.

Abstract: A three-dimensional finite element model was developed to simulate the heat generated and transferred with time in a drilled shaft. Thermal analysis was performed to assess the temperature development in a drilled shaft using several concrete mix designs. The obtained results show that the replacement percentage of supplementary cementitious materials significantly affect the heat of hydration and the temperatures in the drilled shaft. High volume fly ash blends should be considered in mass concrete structures as they give low temperatures and temperature differentials, thus low potential of early-age cracking. It was also concluded that all drilled shafts should be considered mass concrete structures regardless of the volume to surface area ratios.

Keywords: Mass concrete, isothermal calorimetry testing, drilled shaft, temperature differential, high volume fly ash.
stresses are larger than the early-age tensile strength, cracking will occur. If cracking does occur, it will ultimately affect the ability of the concrete to withstand its design load, and allow the infiltration of deleterious materials which undermine durability.

To minimize the threat of thermal cracking in mass concrete, The Florida Department of Transportation (FDOT) developed standard specifications to control the temperature differential during design and construction of large concrete structures. Under the mentioned specifications, the maximum allowable temperature measured in a structure is $180^\circ F (82^\circ C)$ and the temperature differential between the concrete core—interior—and the exterior surface cannot exceed $35^\circ F (20^\circ C)$ [2-4].

In recent years, the FDOT has identified concrete structures which show susceptibility to thermal cracking commonly seen in mass concrete applications. These structures are characterized as segmental bridge pier segments, drilled shafts and all other bridge components. FDOT specifications [2] for drilled shafts are: “Drilled shafts: all drilled shafts with diameters greater than 6 feet shall be designated as mass concrete and a technical special provision shall be required.” The TSP in this particular instance generally takes the form of a mass concrete temperature control plan.

Drilled shafts are foundation elements that have been historically constructed without considering mass concrete effects and the possible long-term implications of the concrete integrity—due to water and matter infiltration into induced thermal cracks. For drilled shafts, however, any element with diameter greater than 6 feet (1.83 m) is considered a mass concrete element despite the relative high volume to area ratio. Figure 1 shows that drilled shafts greater than 4 feet (1.20 m) in diameter are candidates to be classified as mass concrete structures—based on the V/A ratio. As a result, understanding the parameters that affect the temperature rise—during the curing stage—in drilled shafts is of great interest to engineers.

![Figure 1. Mass concrete determinations for shaft based on V/A ratio [4]](image)

This study uses finite element (FE) analysis and laboratory isothermal testing of cementitious materials of several concrete mixes to evaluate typical drilled shafts used in
II. ISOTHERMAL CALORIMETRY TESTING OF CEMENTITIOUS MATERIALS

In order to perform thermal analysis of the concrete segments, isothermal calorimetry testing [5, 6] was conducted on several different FDOT typical concrete mix designs to obtain the heat of hydration and calculated adiabatic temperature rises to be used as input parameters for the analysis. Four FDOT approved concrete mix designs were used in the testing program as follows:

- Ternary Blend (TB) – FDOT Mix: 01-1149
- Slag Blend (SB) – FDOT Mix: 07-0852
- High-Volume Fly Ash (HVFA) – FDOT Mix: 05-1526
- Fly Ash Blend (FB) – FDOT Mix: 03-1870

The mixes selected represent actual FDOT mix designs used in concrete structure applications and they represent a suitable range of water-to-cement (w/c) ratios for analysis. These mixes are comprised of pozzolanic materials mixed with Portland cement. Pozzolanic materials are known to lower the heat generated due to cement hydration when used as Portland cement replacements. The details of the concrete mixes (including the control mix) and paste fractions of cementitious materials that were tested are listed in tables 1 and 2.

The outputs from the isothermal calorimetry test consist of heat generation rate (heat flow) and consequent energy rise and cumulative energy (heat of hydration). The energy rise is then approximated to the energy rise of the hydrating concrete that is being represented by the mixture by multiplying by the percent cementitious content. The adiabatic temperature rise is calculated from the energy rise using the relationship described by the first law of thermodynamics and expressed in Equation 1 [7-9]:

\[ \Delta T = \frac{\Delta Q}{mC_p} \]

Where: \( \Delta Q = \) energy rise (J); \( m = \) mass of concrete (g); \( C_p = \) specific heat capacity (J/g°C); \( \Delta T = \) the change in temperature or temperature rise (°C).

The adiabatic temperature rises for concrete mixes were calculated and are shown in figure 2.

### Table 1. Constituents of Mixes Tested

<table>
<thead>
<tr>
<th>Mix Designation</th>
<th>Cement (kg/m³)</th>
<th>Supplementary Cementitious Material (kg/m³)</th>
<th>Fine Aggregate (kg/m³)</th>
<th>Coarse Aggregate (kg/m³)</th>
<th>W/c Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVFA</td>
<td>217</td>
<td>217</td>
<td>-</td>
<td>638</td>
<td>0.30</td>
</tr>
<tr>
<td>TB</td>
<td>235</td>
<td>156</td>
<td>-</td>
<td>667</td>
<td>0.34</td>
</tr>
<tr>
<td>SB</td>
<td>196</td>
<td>196</td>
<td>-</td>
<td>630</td>
<td>0.40</td>
</tr>
<tr>
<td>FB</td>
<td>290</td>
<td>156</td>
<td>-</td>
<td>642</td>
<td>0.36</td>
</tr>
</tbody>
</table>
Table 2. Paste Fractions of Cementitious Materials Tested

<table>
<thead>
<tr>
<th>Mix</th>
<th>W/c Ratio</th>
<th>Cement (g)</th>
<th>Fly Ash (g)</th>
<th>Slag (g)</th>
<th>Metakaolin (g)</th>
<th>Water (g)</th>
<th>Total (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVFA</td>
<td>0.3</td>
<td>2.804</td>
<td>2.804</td>
<td>-</td>
<td>-</td>
<td>1.683</td>
<td>7.291</td>
</tr>
<tr>
<td>TB</td>
<td>0.34</td>
<td>2.686</td>
<td>1.788</td>
<td>-</td>
<td>-</td>
<td>0.633</td>
<td>6.844</td>
</tr>
<tr>
<td>SB</td>
<td>0.40</td>
<td>2.305</td>
<td>-</td>
<td>2.305</td>
<td>-</td>
<td>1.863</td>
<td>6.473</td>
</tr>
<tr>
<td>FB</td>
<td>0.36</td>
<td>3.230</td>
<td>1.739</td>
<td>-</td>
<td>-</td>
<td>1.789</td>
<td>6.759</td>
</tr>
</tbody>
</table>

Figure 2. Adiabatic temperature rises for the concrete mixes tested

III. FINITE ELEMENT MODEL

The finite element model in this study was developed using the TNO DIANA software. The general finite element model consists of a cylindrical mass concrete drilled shaft in a soil layer. The concrete is not insulated. The finite element model is composed of wedge/tetrahedron elements. The finite element mesh of one of the samples is illustrated in figure 3.

The modeled concrete drilled shaft has a segment length of 6 feet (1.83 m). Using this model, a diameter of 4 feet (1.20 m) would achieve a V/A ratio of 0.75 foot (0.23 m).

The boundary conditions imposed for thermal analysis consist of an initial temperature of the model and the external temperature. The initial temperature was set to 23°C (73.4°F) referring to the placement temperature of the concrete. The external and soil temperature was set to 23°C (73.4°F).

The fixed temperatures—external temperature—are applied to the bottom and sides of the drilled shaft. Fixed temperature is also applied to the top surface of the drilled shaft, the only difference being that the top surface is also affected by air convection—as it is exposed to the environment.
The material properties of soil [10,11] and concrete with varying mix designs used in the thermal analysis are listed in Table 3.

**Table 3. Material Properties Used in Thermal Analysis**

<table>
<thead>
<tr>
<th>Mix Designation</th>
<th>Thermal Conductivity (J/h·m·°C)</th>
<th>Specific Heat (J/kg·°C)</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVFA</td>
<td>7920</td>
<td>1009</td>
<td>2236</td>
</tr>
<tr>
<td>TB</td>
<td>7920</td>
<td>1041</td>
<td>2228</td>
</tr>
<tr>
<td>SB</td>
<td>7920</td>
<td>1047</td>
<td>2236</td>
</tr>
<tr>
<td>FB</td>
<td>7920</td>
<td>1047</td>
<td>2259</td>
</tr>
<tr>
<td>Soil</td>
<td>972</td>
<td>800</td>
<td>1515</td>
</tr>
</tbody>
</table>

**Effect of Heat of Hydration on Temperature Development of Drilled Shaft**

The analysis discussed in this section was performed using concrete temperature rise data corresponding to typical FDOT concrete mix designs used for construction in Florida to investigate the effect of different heat of hydrations on temperature development of drilled shafts.

Figure 4 presents the temperature development results of the 4 concrete mix designs tested: TB, FB, SB and HVFA. As shown, the highest temperature is computed in the drilled shaft using the TB mixture. The lowest temperatures are calculated when using the HVFA mix. The HVFA mix is composed of 50 percent replacement of Portland cement with fly ash. This represents a high Portland cement replacement value, as a result the heat of hydration—and subsequent temperature rise—is lower. Additionally, the highest temperatures recorded occur during the first 30 hours after placement.

Figure 5 presents the temperature differential development results of the 4 concrete mix designs tested above. The trend follows that of the before mentioned results. The highest temperature differentials are calculated when using the TB mix whereas the lowest temperature differentials are calculated when using the HVFA mix—a result of the large percentage of...
Portland cement replacement with fly ash. The results show that mix HVFA produced a maximum temperature differential value of 24°C while the TB blend produced a maximum temperature differential value of 26.8°C. All of these values exceed the allowable temperature differential limit set by FDOT (20°C). However, use of high volume fly ash as replacement for cement shows potential of reducing heat of hydration thus lowering the maximum temperature differential in drilled shafts.

**Figure 4.** Temperature development of drilled shafts with varying concrete mix designs

**Figure 5.** Temperature differential development of drilled shafts with varying concrete mix designs

### IV. CONCLUSIONS

Maximum temperatures and maximum temperature differentials of drilled shafts are greatly influenced by heat generated due to hydration and concrete mix used. Use of pozzolanic material replacement—in particular HVFA—greatly reduces the maximum temperature and maximum temperature differential in drilled shafts thus minimizes thermal cracking potential in the concrete.
Trials with V/A ratios of drilled shafts less than 1.0 foot (0.3 m) produced maximum temperature differentials which failed limits set by FDOT. Therefore, in order to ensure the proper implementation of the developed method for thermal analysis, it is recommended that all drilled shafts be treated as mass concrete during design process.

References


Florida Department of Transportation, Standard Specifications for Road and Bridge Construction, Tallahassee, FL, 2010.


THE STATE OF THE ART OF USING ASPHALT CONCRETE AS TRACKBED OF HIGH SPEED RAILWAY

Haibo Ding1,2, Enhui Yang1,2, Yanjun Qiu1,2
1 School of Civil Engineering, Southwest Jiaotong University, Chengdu 610031, China.
2 Highway Engineering Key Laboratory of Sichuan Province, Southwest Jiaotong University, Chengdu 610031, China.

Abstract: The railway industry throughout the world continues to emphasize the importance of developing innovative trackbed design technologies for both heavy tonnage freight lines and high-speed passenger lines. The purposes are to achieve high levels of track geometric standards for safe and efficient train operations while minimizing long-term track maintenance costs and extending track component service lives. During the past several decades designs incorporating a layer of asphalt (or bituminous) paving material, similar to a highway pavement asphalt base layer, as a portion of the railway track support structure have steadily increased until it is becoming a common or standard practice. This technology has demonstrated applications for the construction of numerous new high-speed passenger lines in Europe and Asia. This paper reviewed the development of asphalt used in railway engineering.

Keywords: Asphalt; Trackbed; Railway; Foundation

I. INTRODUCTION

Asphalt concrete (AC) is a material traditionally used in the construction of highway pavement that has several advantages: good bearing capacity, water repellency, shock absorption, noise reduction, and relatively low cost. With the rapid development of high-speed rail in China, the load-bearing infrastructure to support high-speed rail tracks faces challenges in drainage, settlement, and structural fatigue. In recent years AC has been used for constructing the railway infrastructure of China’s high-speed railway system. The primary documented benefits described in relative papers are to: 1) provide additional support to improve load distributing capabilities of the trackbed layered components, 2) decrease load-induced subgrade pressures, 3) increase confinement for the ballast, 4) improve and control drainage, 5) maintain consistently low moisture contents in the subgrade, 6) insure maintenance of specified track geometric properties for heavy tonnage freight lines and high-speed passenger lines, and 7) decrease subsequent expenditures for trackbed maintenance and component replacement costs [1-4]. The load-bearing infrastructure to support high-speed trains at the required safety level must remain stable, offer superior performance, and be maintained in a cost-effective manner. The materials needed to construct the infrastructure for trains operating at 350 km/h should be able to help reduce vibration and noise and maintain needed drainage.
Many studies have been conducted worldwide on the use of new materials to support high-speed rail slab tracks. However, many issues remain, particularly in terms of maintaining low levels of vibration and noise and excellent drainage to reduce water damage. In addition, AC service life as a top layer for highway pavements is typically 15 to 20 years, while the load-bearing infrastructure for high-speed rail is designed to last much longer, even more than 100 years according to the Chinese Code for Design on Railway Subgrades. AC has been used in recent decades on many occasions around the world as a secondary layer to support the top load bearing surface, known as slab track, which directly interfaces with high-speed rails. The current practice of using AC for high-speed rail is for the construction of high-speed rail subgrade beds and for surface waterproofing layers. However, there is lack of documented research about the material composition, durability, and mechanism of AC layers for high-speed rail infrastructure. Since AC materials could emerge as alternatives and entirely or partially replace traditional railway concrete slabs, subgrades, or waterproofing layers on surfaces.

II. INTERNATIONAL APPLICATIONS AND PRACTICES

2.1. Germany

In the past 30 years, Germany’s rail network has undergone constant improvements to allow for high-speed lines with maximum speeds of 300 km/hr. The Germans have selectively implemented the "ballastless" slab into the new high-speed track designs in order to provide the structure with good elasticity independent of the foundation stiffness. The most recent asphalt ballastless track system used in Germany is the GETRAC, which includes an asphalt support layer with concrete ties anchored into the asphalt [5].

![GETRAC in Germany](image)

**Figure 1. GETRAC used in Germany**

2.2. Austria

Since the 1960s, Austrian Railways has developed technical experience with asphalt layers in trackbeds and realized the economic benefits of the material. Austrian Railways uses an 8 to 12 cm asphalt layer beneath the ballast bed which provides a clear separation between substructure and superstructure[6]. Main advantages include preventing rain water from penetrating the substructure, obtaining optimum elasticity, providing consistent support to equalize stresses on the substructure, and prevent pumping of fines upward. Annual deterioration rates for asphalt trackbeds are 50% less than that of granular trackbeds and leveling-lining-tamping frequency has decreased by 67%.
2.3. France

In 2007 the French National Railways (SNCF) opened the TGV-East high-speed line connecting Paris to Strasbourg. It included a 3 km long test section of asphalt subballast trackbed for tests and analyses under high-speed operations[7]. The test zone was fitted with accelerometers on the sleepers, pressure sensors, extension gauges, and thermometers. Figure 2 shows a layout of the test zone instruments.

![Figure 2. Asphalt trackbed tests of TGV in France](image)

The sleepers of the asphalt track experienced roughly the same accelerations as a granular track, but the trackbed subgrade pressure readings for the asphalt track were half as large as the readings on the granular track. Extension readings for the asphalt track were three times below the maximum allowable. Plans for a similar study that will introduce the use of recycled asphalt are being made and an experiment in Lingolsheim is testing the use of asphalt without ballast.

2.4. Italy

The Italian State Railways were one of the initial developers of asphalt trackbeds and they continue to widely utilize the material for their extensive high-speed rail network[8]. The Italian High-Speed Rail network consists of East-West and North-South lines with a total of around 1200 km of track. The line between Rome and Florence, known as the Direttissima, is the original and most frequently trafficked high-speed line. Figure 3 shows a typical cross section for an Italian high-speed rail trackbed.

![Figure 3. Cross section of Italian trackbed](image)

The Italian railways determined that all new lines were to be constructed using an asphalt
subballast layer and this method has been used for the past 20 years.

2.5. Japan

For many years the Japanese have used asphalt trackbeds in ballasted track for both high-speed and regular lines with the purpose of providing substantial support for the ballast and to reduce track irregularities. In 2007, the Design Standard for Railway Structures was revised to consider the fatigue life of the track as it is affected by the number of passing trains. This allows designers to choose various layer compositions and thicknesses to satisfy roadbed performance requirements[9]. Japan has three classifications of trackbeds based on their performance ranks, with asphalt specified for the two highest quality trackbed classifications.

![Figure 4. Railway asphalt concrete structure used in Japan](image)

2.6. Spain

Spanish high speed train reach maximum speeds of 300 km/hr and currently operate on 2600 km of track with that track total expected to increase to 5600 km in the coming years. Spanish Railways has started testing asphalt trackbeds on the Madrid-Valladolid high-speed line and the Barcelona-French border high-speed line which is still under construction. The design for these trackbeds typically follows technology developed by Italian State Railways and includes a 12 to 14 cm layer of asphalt subballast over a form layer with a minimum thickness of 30 cm, and minimum bearing capacity of 80 MPa [10].

The feasibility of implementing an asphalt based high-speed railway network in Spain is heavily dependent on the price of bituminous material compared to granular material. An analysis of the availability and cost of granular and bituminous material in Spain showed that transport distance is the key factor in overall cost. When transportation and material costs are applied to the high-speed lines planned for Spain, the difference in cost between bituminous and granular subballast is only around five percent.

2.7. Korea

Korea Railroad Research Institute has developed Asphalt Concrete Directly Fastened to the Track (ADFT) in order to speed up of high speed rail train. There has been no previous research on asphalt trackbeds in South Korea. Many research were conducted to evaluate an asphalt concrete trackbed system for Korean High-Speed Railway supporting high-speed trains. The asphalt trackbed is expected to utilize the advantages of ballast track (e.g., easy maintenance and low construction cost) and concrete track (e.g., low maintenance) while compensating for the disadvantages of each. Accordingly, asphalt trackbeds are expected to reduce maintenance costs and make maintenance easy and efficient[11].
2.8. China

Researchers also have studied railway AC layers in recent decades in China, such as the asphalt mortar layer, and the asphalt emulsion treated cement mortar layer. Given the fast development of high-speed railways in China, many researches has been taken to study AC railway infrastructure in the past few years. Those involved in the research presented in this paper were directly involved in the design of the first AC applications to high speed railways in Wuguang and Jinghu, China (Figure 6). AC layers were used for all waterproofed surfaces. Researchers also proposed using SAMI (Surface Asphalt Mixture Impermeable) provide a waterproof surface of both sides of the track embankment [12].

III. SUMMARY AND CONCLUSIONS

(1) The primary benefits of the HMA layer are to improve load distribution to the subgrade, waterproof and confine the subgrade, and to confine the ballast providing consistent load-carrying capability-even on subgrades of marginal quality. The waterproofing effects are particularly eliminates subgrade moisture fluctuations, which effectively improves and maintains the underlying support.

(2) The resilient HMA mat provides a positive separation of ballast from the subgrade, thereby eliminating subgrade pumping without substantially increasing the stiffness of trackbed.
The resulting stable trackbed has the potential to provide increased operating efficiency and decreased maintenance costs that should result in long-term economic benefits for the railroad and rail transit industries.

(3) All of the HMA test tracks and specific problem-solving installations are performing extremely well. The increased cost of using HMA is most often minimal, and the indications are that at many sites, the long-term savings may be substantial when compared to conventional construction, maintenance, and rehabilitation techniques. Additional improvement and optimization of field construction procedures represent activities of continuing interest.

(4) Further development of indoor asphalt track test methods will be done using finite element simulation to better simulates the stress state under foundation of railway track.

(5) Ground-penetrating radar and other equipment for rail NDT assessment of damage detection and repair when using asphalt concrete trackbed.

References
REPAIR OF CRACKS BASIC PARTS OF ROAD CONSTRUCTION MACHINES WITH ADHESIVE TECHNOLOGY

Zorin V.A1, Baurova N.I2, Kireev V.A3
1Doctor of Technical Sciences, Professor, 2Doctor of Technical Sciences, 3Undergraduate Moscow State Automobile and Road Technical University (MADI)

Abstract: The properties of adhesive materials used for sealing holes and cracks of body parts of road construction machines are considered. As discussed adhesives epoxy group, acrylate adhesives, hot melt adhesives, their classification depending on the size of the crack and reviewed their technological and mechanical characteristics are considered.

Keywords: Road construction machines, glue, repair, crack, case details.

Housing parts road construction machines, generally have the greatest period of operation, which is associated with high cost and a relatively low damageability (except for emergency situations). Typical damage to the body parts of construction machinery are holes and cracks associated with corrosive whether fatigue damage [1, 2]. The size of these lesions may vary over a considerable range, from a few millimeters to tens of centimeters.

The aim of this work is to conduct a comparative analysis of adhesive materials of different chemical nature that have received the most widespread in the repair of body parts manufacturing road construction machines.

For convenience of comparison, all glue materials are divided into five groups. As a classification sign – the extent of defects of road-building machines which can be eliminated with use of this material is used. Some of brands of domestic glue materials which gained the greatest distribution at seal of cracks in case details [3] are given in table 1 and can be used at repair of road construction machines. Now there is a set of analogs, however, the brands of glues specified in table 1 are the most typical representatives in the groups and on this reason and are chosen for carrying out the comparative analysis. All set of glue materials of other chemical nature (polyurethane, kremniyorganichesky, phenol formaldehyde) in repair production are used is very limited and therefore are not included in table 1.

The comparative analysis of properties of these glue materials was carried out on two types of indicators: technological effectiveness and warm and mechanical characteristics (table 2). As indicators of technological effectiveness the following characteristics are used: quantity of components, a period of storage in a ready state, temperature and time of hardening. Such quality indicator as a possibility of introduction of a filler is also carried to characteristics of technological effectiveness. Such requirement arises in need of essential increase in viscosity of glue to prevent his effluence or running off from the restored surface.

As warm and mechanical characteristics values of adhesive durability at shift at the room temperature were used, the top and lower intervals of working temperatures.

Analysis of data in table 2 shows that no adhesive material, which would in all their characteristics superior to all others.

For example, such parameters processability as component count and viability, acrylate and thermoplastic adhesives have the same properties. But acrylate adhesives cure at room temperature, whereas the elevated temperature required to melt thermoplastic adhesives. At the
same time, the duration of the curing process for acrylate as well as to epoxy adhesives is 24 hours, whereas for the hot melt adhesives it will not exceed ten minutes [4]. Thus, the choice of one of these two types of adhesives must be carried out either by the criterion - the duration of adhesion or temperature. Selection of the most important criteria is up to the designer. Epoxy adhesives (not just those that are listed in Table 1), but all the others, in terms of adaptability significantly inferior to the hot melt adhesives, however, they are superior to them in strength parameters and heat [4-5].

Hot melt adhesives as compared to the epoxy acrylate, and particularly, have high viscosity and thus poor impregnation properties, which prevents their use in conjunction with any reinforcing plates.

It is widely used in small-scale production of the repair of body parts of road construction machinery group received like plaster epoxy adhesives, which are called «cold welding». A distinctive feature of these materials is their very good processability, since they are delivered to the consumer in the form of a single component and its consistency, reminiscent of plasticine. Hardener placed inside the main component (resin). The mixing of components is carried out manually by mashing. This technological feature in many ways, and is the cause of poor quality of the adhesive material. Using this type of adhesives is only suitable for single production, since the cooking (mixing) of adhesive is performed individually for each defect and, even in this small-scale production would require time-consuming[6].

Adhesives marks VK-9, VK-25, K-115 and CMK-5 belong to the group of multicomponent epoxy adhesives which cure occurs at room temperature. The viscosity of these materials (without filler) low, allowing their use in the manufacture of tires and lining sealing of large cracks and holes of body parts of road construction machinery. High adhesion to various surfaces, can be used as a material for tires, metal mesh, carbon cloth, and glass.

Generally, in the preparation of the metal surface to spray glue limited degreasing using acetone. However, this training does not provide quality treatment and to delete only the dust and dirt from metal surfaces. Traces of oil and rust at such purification is not removed [5, 7]. To improve the adhesion strength can use different primers, but in such process technology repair process duration is doubled, since the drying time of soils usually commensurate with the time of curing the adhesive material.

Thus, the choice can not be recommended for the repair of cracks and holes of body parts of road construction machinery of any one type of adhesive materials. Selection of repair material should be made subject to a number of technological and operational indicators.

Table 1. The brands of domestic glue materials used for seal of cracks and holes in case details of road construction machines

<table>
<thead>
<tr>
<th>Sizes of holes, mm</th>
<th>Chemical basis of glue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Epoxy</td>
</tr>
<tr>
<td></td>
<td>Akrilatnye</td>
</tr>
<tr>
<td></td>
<td>Thermoplastic</td>
</tr>
<tr>
<td>to 1 mm</td>
<td>K-115, CMK-5</td>
</tr>
<tr>
<td></td>
<td>AN-1y, AN-8K</td>
</tr>
<tr>
<td></td>
<td>Aren’t used</td>
</tr>
<tr>
<td>to 5 mm</td>
<td>K-115, CMK-5, withfiller</td>
</tr>
<tr>
<td></td>
<td>AN-8K, UG-7, withfiller</td>
</tr>
<tr>
<td></td>
<td>Aren’t used</td>
</tr>
<tr>
<td>to 10 mm</td>
<td>plaster epoxy adhesives, VK-9, K-300</td>
</tr>
<tr>
<td></td>
<td>AN-8K, UG-7, withfiller</td>
</tr>
<tr>
<td></td>
<td>Hot Melt Adhesives</td>
</tr>
<tr>
<td>to 50 mm</td>
<td>VK-9, K-300, withfiller</td>
</tr>
<tr>
<td></td>
<td>Aren’t used</td>
</tr>
<tr>
<td></td>
<td>Hot Melt Adhesives</td>
</tr>
<tr>
<td>more 50 mm</td>
<td>VK-9, VK-25, K-300, withfiller</td>
</tr>
<tr>
<td></td>
<td>Aren’t used</td>
</tr>
<tr>
<td></td>
<td>Aren’t used</td>
</tr>
</tbody>
</table>
Table 2. The properties of glue materials used for seal of cracks and holes in case details of road construction machines

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Chemical basis of glue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Epoxy</td>
</tr>
<tr>
<td>Characteristics of technological effectiveness</td>
<td></td>
</tr>
<tr>
<td>Quantity of components</td>
<td>1…3</td>
</tr>
<tr>
<td>The viability of the adhesive in the finished form, hour</td>
<td>0,5</td>
</tr>
<tr>
<td>Shelf life of glue or its components, year</td>
<td>1</td>
</tr>
<tr>
<td>Curing modes:</td>
<td></td>
</tr>
<tr>
<td>- Temperature °C; - Time, hour</td>
<td>22…24</td>
</tr>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td>The possibility of combining with dispersed fillers</td>
<td>yes</td>
</tr>
<tr>
<td>The possibility of combining with fiberfill</td>
<td>yes</td>
</tr>
<tr>
<td>Thermal and mechanical characteristics</td>
<td></td>
</tr>
<tr>
<td>Tensile shear strength, MPa</td>
<td>15…25</td>
</tr>
<tr>
<td>Tensile strength at the axial shear, MPa</td>
<td>–</td>
</tr>
<tr>
<td>Operating temperature range, °C</td>
<td>-60…+150</td>
</tr>
<tr>
<td>Relative extension, %</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

References
EXPERIMENTAL INVESTIGATION ON THE SEISMIC BEHAVIOUR OF AN L SHAPED REINFORCED CONCRETE COLUMN

NGUYEN XUAN HUY, BUI THI THANH MAI, DANG VIET TUAN
Faculty of Construction Engineering, University of Transport and Communications, Hanoi, Vietnam

Abstract: This paper presents an experimental investigation on the behaviour of an L shaped reinforced concrete column under seismic action. The specimen was one-quarter of typical columns of a prototype medium-rise building tested to failure using shaking table. The loading procedure was successively increasing peak ground acceleration until the test structure collapsed. The seismic response characteristics of specimen such as displacement at the top, failure mechanisms are evaluated and discussed in detail.

Key words: L shaped column, seismic, reinforced concrete, shaking table.

1. INTRODUCTION

L shaped columns can be effectively used at the corner of high-rise building structures. Reinforced concrete (RC) frame structures with L shape column offer advantages of open space and increase the overall flexural stiffness of building structures, reducing lateral displacements due to horizontal loadings such as earthquake or wind. However, the seismic behaviour of such configuration is not well known nowadays and there was rarely investigating available in literature. Ramamurthy and Khan [1] proposed two methods of designs for such columns including the “failure surface” and the “equivalent” rectangular column, while Hsu [2] reported experimental study on L-shaped column under biaxial bending action. Pham and Li [3] tested ten short tied L-shaped reinforced concrete columns under the combination of constant axial and cyclic lateral loads to investigate the seismic performance of such irregularly shaped columns. Aman et al. [4] conducted a quasi-static test on four reinforced concrete shear walls with L-shaped cross sections under the simultaneous action of axial and cyclic loads. An experimental study was investigated the seismic performance of solid steel reinforced concrete frames with special-shaped columns by Liu et al. [5]. In [6], Nguyen et al. presented an experimental program to investigate the effects of cross-sectional shape on the seismic performance of irregularly shaped RC columns. Most of these work carried out by the aforementioned researchers focused on static analysis of such columns. Consequently, in design practice, engineers generally assume that the L-shaped columns respond as two separate, perpendiculars, barbell walls.

With the objective of deepening the understanding of the behaviour of this type structure, an experimental study on the seismic performance of L shaped RC columns has been carried out at University of Transport and Communications of Vietnam. The specimen was dynamically
tested to failure using the shaking table. The seismic response characteristics of specimen such as drift capacity, failure mechanisms are evaluated and discussed in detail.

II. EXPERIMENT PROGRAM

A nine-storey reinforced concrete building is selected as the prototype structure for the experimental investigation. The reinforced concrete frames in residential stories from the second to the top floor are infilled with masonry walls, while in the ground storey façade is made by glass (figure 1). During a seismic event, the ground columns, without strengthening effects of infilled masonry walls that are present in the stories above, are the most vulnerable and will be governed by shear-sliding mechanisms.

2.1. Test setup

Test setup is designed based on two assumptions. First, under seismic action reinforced concrete frame from the second to the top floor is strengthened by infilled masonry walls so that the seismic performance of the prototype building structure will solely be governed by the shear-sliding mechanism of the ground columns. Second, with the presence of the upper building structure strengthened by infilled masonry walls and the pile caps at the foundation level, the column is rotationally restrained at both top and bottom.

The typical test setup is represented in figure 2. The specimen was anchored to the shaking table by eight high-strength 14mm bolts. Four steel bars (diameter of 22 mm) are used to create the shear-sliding mechanism in the test specimens. A concrete block (0.84mx0.7mx2.4m) was mounted on top of specimens using four high strength 18mm bolts.
2.2. Specimens detail

Due to the limited capacity of the shaking table, dimensions of test specimen were scaled down from the actual ones by ¼. The column body of 1000 mm length was cast monolithically with two concrete bases of 300 mm thickness at both ends that were used to connect to a concrete block (at the top) and the shaking table (at the bottom). At the testing time that was 40 days after the specimens were cast, the average cylinder strength of the concrete was 18 MPa and the secant modulus of elasticity of concrete is 24500 MPa. Average yield and ultimate strengths of the reinforcement were 390 MPa and 420 MPa. Figure 3 showed the section design of the test specimen.

2.3. Testing procedure

In this experimental program, the specimen was tested to failure using the shaking table to investigate the seismic performance of the columns. Specimens were subject to a combination of gravity and seismic lateral loadings. Gravity axial load of 20 tons was applied at the top of specimen while seismic loading was simulated by the shaking table with the time history of the
input base motion (accelerogram). The acceleration time history was applied uni-directionally to the specimen with the duration of 15 seconds with increasing scale of the peak acceleration from 1 m/s² until the test structure collapsed.

III. EXPERIMENTAL RESULTS & DISCUSSIONS

3.1. Test observations

Two types of cracks were observed in this experimental study, including: flexural horizontal cracks located at height of specimen and vertical cracks located at the base of specimen (see figure 4).

The first cracks ever appeared were flexural ones in specimen at the peak acceleration of 4 m/s². The vertical cracks appeared much latter in at acceleration levels of 8 m/s². It is worth noting the shear diagonal crack that is reported in previous tests [6] has not been observed in the present specimen.

Figure 4. Tested specimen
3.1. Displacement at the top

The figure 5 shows the maximum horizontal displacement at the top of the specimen in all the tests. As can be seen, the displacement changes gradually following the increase of ground acceleration. However, this value increases rapidly from the turning point after the peak acceleration of 4 m/s² where the first cracks appeared.

![Figure 5. Horizontal displacement at the top](image)

VI. CONCLUSIONS

In the experimental program presented herein, one L-shaped RC column has been tested to failure to examine the performance of this type of column. The test specimen that was 1/4 scaled from columns of the soft storey of a prototype building. The loading procedure was successively increasing peak ground acceleration. As can be observed, two types of cracks were observed: flexural horizontal cracks located at height of specimen and vertical cracks located at the base of specimen but the shear diagonal crack has not been appeared. Future study is suggested to investigate on different parameters such as the axial load, aspect ratio, horizontal loading direction and arrangements reinforcement. Theses parameters probably influences to the failure mechanism of L-shaped RC column under seismic action.

References

I. INTRODUCTION

The improved soil is popularized in highway and railway engineering projects in recent years [8, 18]. During the construction of roadworks in Lanzhou, high embankment is usually encountered in these projects. Loess has the characteristics of high porosity ratio, poor water stability and easily collapse. It cannot directly be used as construction material on site and must be improved to be a high stranded road construction material.

There are some ways to treat loess, such as cement, fly ash and lime etc. [1, 4, 6, 7, 14, 16, 19, 21]. Researcher discussed about the cement treatment methods [9, 11]. Some scholars even add some fiber to enhance the property of loess and discuss its structural properties [10, 22]. Several studies focused on the slope stability of lime [12, 13]. Sungjin Lim compared the Engineering properties of water/wastewater-treatment sludge modified by hydrated lime, fly ash and loess in laboratory [1]. In 1991, Ali tried to find a way of using rice husk ash to enhance lime treatment of soil, and evaluated the effectiveness of using RHA as a pozzolan to enhance the lime treatment of the soil [4]. Ian Jefferson test the engineer property of collapsible loess soils using cement materials [6]. GUO Nai-zhen did some research of test and simulation on dynamic compaction in high roadbed (2007) [26]. Li ping made some contribution Experiment of CBR value of loess subgrade improved with quick lime and its application [5]. All the researches...
which has been down just discussed the mechanism of measures, all what they have done haven’t compared the treatment methods using gravel and lime with different height of embankments and some investigators did not commit a relatively long field observation. This project chooses three different experimental section in three different roads in the new district of Lanzhou, and the period of observation is every 14 days. The parameters are tested in the laboratory precisely, and those parameters is helpful in the procession of numerical simulation. The factor of safety (FOS) and settlement of embankments works as important assessments methods. After comparison has been accomplished, the suitable suggestion of treatment is proposed and promoted to the whole area of Lanzhou.

II. INDOOR TESTING

The characteristics of collapsible loess soil is very complex, and testing in laboratory is essential to acquire the parameters needed in the numerical simulation [15]. By the oven drying method, the moisture content of soil specimen is tested. the absolute error is less than 0.01% and it satisfies the road specification in china. The relative density is about 2.68 g/cm³. The liquid limit and plastic limit of loess is 12.5 and 29.8 respectively. The plasticity index is about 17.3 [25].

Fitting the dots of geo-technical compaction data with multi-nominal interpolation method, the multi-nominal of water content was obtained. The maximum dry density and optimum water content were obtained by calculation and comparison of each dot. The compaction test get a chart as follows, optimum water rate is about 13.1%, and the maximum dry density is 1.802g/cm³[5].

The Engineers on site did a series test, and the result of best rate of lime weighs to soil is 5% [2]. The compaction curves show that after adding lime, the optimum moisture content has increased, while the maximum dry density shows reduction. After treatment, the optimum moisture content was 13.9%, increased 5.79% than treated before. After treatment, the maximum dry density of loess is 1.754g / cm³, decreased 2.77% than before treatment. From the compaction curve, it shows that the range of optimum moisture content becomes larger than untreated loess. This will be beneficial to site construction [23, 24].

Figure 1: Compaction Curve of Loses
As Fig 1 shown, after the measured compaction factor of 96% has achieved, the cohesion of disturbed soil is about 40.67 kPa and the internal friction angle is 17.9 ° by direct shearing tests.

Experimental results also show that after adding lime the effect of age has a greater impact on shear strength and the friction angle [20]. Both cohesion and friction angle show nonlinear growth, and the growth rate tends to slowing. The initial test is about 7 days curing. After 14 days curing, cohesion has improved 8.28% than that of 7 days. Similarly, the cohesion after 28 days curing raised 15.07% comparing to 7 days. After 14 days curing friction angle was raised 7.52% than 7 days. After 28 days curing friction angle of the treated loess improved 17.25% than 7 days curing.

For loess, self-weight collapsible coefficient is a very important parameter to discriminate its properties. Self-weigh collapsible tests showed that adding lime is helpful to reduce the self-weight collapsible coefficient, to a certain extent, weakened its collapsibility. Normally, applying 200kpa pressure by steps is a good approach to assess loess collapsibility. If the result of collapsibility coefficient greater than 0.015, it could be distinguished as collapsible loess in projects. As can be seen from figure 3, after adding lime the collapsibility coefficient of loess has been greatly reduced by 67.5%.
Table 1. The collapsible coefficient of disturbed loess

<table>
<thead>
<tr>
<th>Load/kpa</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5</td>
<td>0.0012</td>
<td>0.0007</td>
<td>0.0009</td>
<td>0.0009</td>
</tr>
<tr>
<td>25</td>
<td>0.0052</td>
<td>0.0062</td>
<td>0.0075</td>
<td>0.0063</td>
</tr>
<tr>
<td>50</td>
<td>0.0083</td>
<td>0.0094</td>
<td>0.0085</td>
<td>0.0087</td>
</tr>
<tr>
<td>100</td>
<td>0.011</td>
<td>0.012</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td>200</td>
<td>0.015</td>
<td>0.016</td>
<td>0.018</td>
<td>0.0163</td>
</tr>
</tbody>
</table>

Table 2. The collapsible coefficient of treated loess

<table>
<thead>
<tr>
<th>Load/kpa</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.004</td>
<td>0.002</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td>200</td>
<td>0.005</td>
<td>0.007</td>
<td>0.005</td>
<td>0.006</td>
</tr>
</tbody>
</table>

California Bearing Ratio (CBR) has been commonly accepted and used as an indication of resistance and stability of subgrade all over the world. The chemical reaction occurred between lime and loess after the addition of lime [7]. CBR value shows a rapid growth, reaching 3 times than the original. Adding lime improves the bearing capacity and deformation resistance of the embankment effectively, and may be helpful to increase the safety and long-term service behavior.

III. NUMERICAL SIMULATION

Based on the results of indoor test, comparison has been made between before treatment and after treatment. Due to many conditions, an optimized solution could be found to guide construction by comparison different treatment ways [3].

3.1. Slope stability analysis and elasto-plastic analysis

In the model, four working conditions are considered. The first one is that full section is untreated, and the second one is that full section is treated by 5% lime. The third one is that only roadbed section is treated, and the fourth one is that upper roadbed is treated with gravel while the lower part is treated with lime.

A model for the typical working conditions was established. Suppose an embankment have different heights under different situations, and compares those treatment methods. The section
of K18+770 was chosen to analysis the stability of embankment. Then a recommendation could be made to help the Engineers on site.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>E/MPa</th>
<th>Density/kg.m³</th>
<th>poisson’s ratio</th>
<th>c/kPa</th>
<th>φ/°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Treatment</td>
<td>35.2</td>
<td>1985</td>
<td>0.3</td>
<td>40.67</td>
<td>17.9</td>
</tr>
<tr>
<td>After Treatment</td>
<td>45.4</td>
<td>1900</td>
<td>0.3</td>
<td>57.56</td>
<td>22.6</td>
</tr>
</tbody>
</table>

After initial calculation finished, reset displacement to be zero and construction of embankment by stages. Displacement contour of embankment under its own weight can be acquired from the calculations.

The section of embankments are filled by different construction materials and method. It might influence the performance of subgrade. Comparing with the untreated loess embankment, the deformation of huozhanbeilu road,weiyi road and zhongshui road is reduced respectively by 16.35%, 12.64% and 8.18%. With respect to factor of safety (FOS), the FOS of huozhanbeilu road,weiyi road and zhongshui road is decreased respectively by 7.65% and 5.04% ,while the FOS of zhongshui road is similar to that of untreated one. Calculation result demonstrates that adding lime to the loess is very helpful to improve and enhance the plastic deformation and FOS of embankment. The full section treatment method, which huozhanbeilu road was applied, shows this method is the best among those methods.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Before treatment</th>
<th>Huozhanbeilu Way of treatment</th>
<th>Weiyi Road Way of treatment</th>
<th>Zhongshui Way of treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settlement/m</td>
<td>0.0269</td>
<td>0.0225</td>
<td>0.02350</td>
<td>0.02494</td>
</tr>
<tr>
<td>FOS</td>
<td>2.125</td>
<td>2.925</td>
<td>2.232</td>
<td>2.176</td>
</tr>
</tbody>
</table>

3.2 Influence of filling height

Considering that many roads are going to build and the height of those roads might be different, under embankment heights of 5m, 10m, 15m respectively.
Similarly, embankment of different heights need to be compared regarding the FOS and maximum displacement contour. Choosing the height of 5m, 10m, 15m embankment as examples. As mentioned before, the treatment conditions were in four ways: NO.1-without any Treatment; NO.2 lime improved loess of the whole section; NO.3- only top 80cm (road bed portion) treating with lime; NO.4- only treating road bed, top 30mm with gravel and lower 50 cm with lime.

According to calculation results, the following conclusion could be acquired: for embankment height more than 10m, the NO.1 method is recommended; in terms of embankment less than 10m but more than 5m, if the FOS is satisfied, NO.2 method is recommended. For embankment less than 5m, more attention should be paid to the quality of filling materials and compaction than other factors.

IV. FIELD OBSERVATIONS

The loess is widely distributed in Lanzhou area. It forms collapse deformation easily, resulting in the occurrence of uneven settlement of foundation and affecting the stability of the roadbed and bridge foundation. By monitoring the settlement of embankment, several targets could be made.

4.1. Site information

For huozhanbeilu road, the selected monitoring stations is K16 + 680 ~ K16 + 750 segments and K19 + 440 ~ K19 + 490 segments. Monitoring observation period is every 14 days.

Monitoring points are arranged at Stake for K16 + 688, K16 + 740, K19 + 440, K19 + 480
four sections. Set up five deformation observation post on each cross-section.

For Weiyi road, K4 + 080 ~ K4 + 150 section and K5 + 410 ~ K5 + 470 segments are selected Monitoring points are arranged at Stake for K4 + 100, K4 + 140, K5 + 420, K5 + 460 four sections, set up five deformation observation post on each cross-section. Referring to the drawings. Monitoring observation period is also every 14 days.

For zhongshui road, K9 + 710 ~ K9 + 770 segments and K10 + 330 ~ K10 + 390 segments are selected Monitoring points. Monitoring observation period is also every 14 days.

4.2 Field test results

4.2.1 Huozhanbeilu Road

The observation starts at 30th March 2015. Both K16+690 and K160+740 segments have four monitoring piles. The figure below shows that the differences among those piles are minor, and the maximum settlement is about 14mm. At K16+690 section the differential settlement is also not very large. This result shows that after 8 months, the huozhanbeilu road becomes stable, and the treatment approach shows its priority.
4.2.2. Weiyi Road

The observation starts at 14\textsuperscript{th} March 2015. The treatment only applies at the roadbed part. Compares with huozhanbelu road, the deformation is much larger than that of huozhanbeilu road. The maximum displacement is 36mm, 2 times than that of huozhanbeilu road.

4.2.3. Zhongshui Road

The observation starts at 12\textsuperscript{th} April 2015. The treatment only applies at the roadbed part. Compares with huozhanbelu road, the deformation is much larger than that of huozhanbeilu road. The maximum displacement is more than 60mm, but most of the figures is 40mm, and it is a little larger than that of weiyi road.
V. CONCLUSION

Based on this project, the following conclusion could be acquired.

1. The compaction curves show that after adding lime, the optimum moisture content has increased, while the maximum dry density shows a little reduction. After treatment, the optimum moisture content was 13.9%, increased 5.79% than treated before. Before treatment, the maximum dry density of loess 1.754g/cm³, and it decreased 2.77% after treatment. From the compaction curve, it shows that the range of optimum moisture content becomes larger than untreated loess. This will be beneficial to site construction. The compaction properties of loess didn’t show much difference between before treatment and after treatment.

2. Both cohesion and friction angle show nonlinear growth, and the growth rate tends to slowing. The initial test is about 7 days curing. After 14 days curing, cohesion has improved 8.28% than that of 7 days. Similarly, the cohesion after 28 days curing raised 15.07% comparing to 7 days. After 14 days curing friction angle was raised 7.52% than 7 days. After 28 days curing friction angle of the treated loess improved 17.25% than 7 days curing.

3. After adding lime, CBR value shows a rapid growth, reaching 3 times than the original. Adding lime improves the bearing capacity and deformation resistance of the embankment effectively, and may be helpful to increase the safety and long-term service behavior.

4. For embankment height more than 10m, the NO.1 method is recommended; in terms of embankment less than 10m but more than 5m, if the FOS is satisfied, NO.2 method is recommended. For embankment less than 5m, more attention should be paid to the quality of filling materials and compaction than other factors.

5. Field test also prove that the NO.2 method is better than NO.3 method and NO.4 method. Adding lime is helpful to the performance of road.

Acknowledgement. The authors would like to thank the reviewers for the careful reading of the manuscript and the insightful and constructive comments. Thanks to the supporting of national natural funds in china (NO.51378440).

References


A number of factors determined the beginning of a new educational project aimed to prevent drinking and driving in Russia in 2013. In 2013, the federal government started reforming the Russian driver schools education curriculum. Also in that year, the “Improvement of Road Safety 2013-2020” federal target program was launched, providing a perfect opportunity to put forward a drink driving module that could be included in novice driver courses. The Federal Program continued a multifaceted approach to road safety envisaging among other improvements the education and training system for drivers [1]. In 2011-2013 official statistics revealed negative trends in road crash data associated with drinking and driving (table 1).

SOCIAL PROJECT «AVTOTREZVOST» (AUTOSOBRIETY) AS A MODEL OF PRIMARY PREVENTION OF DRINKING AND DRIVING

A.A. Burtsev¹, V.V. Silyanov²
¹Narcology Scientific and Research Institute – affiliate to the «Federal Medical Research Center on Psychiatry and Narcology named after V.P. Serbsky”, Ministry of Health, Russian Federation
119002 Russia, Moscow, Maly Mogiltsevsky pereulok, 3

²Moscow Technical University (MADI) 125319 Russia, Moscow, Leningradskiy Prospect, 64

Abstract: The article gives analysis of the key road crash death and injuries data associated with drinking and driving in 2010-2015 in the Russian Federation. It proves necessity of preventive work aimed at reducing the number of cases of driving while intoxicated among students in driving schools. The article presents information about the social project “Avtotrezvost” (“Autosobriety”) and suggests a methodology of primary prevention of driving while intoxicated with alcohol, drugs or other substances among driver schools students within the framework of the Order N 343n of 15.06.2015 of the Russian Ministry of Health.

Keywords: Road crash death and injury prevention; road crash; road crash trauma; drinking and driving; blood alcohol concentration (BAC); drinking and driving prevention.

A number of factors determined the beginning of a new educational project aimed to prevent drinking and driving in Russia in 2013. In 2013, the federal government started reforming the Russian driver schools education curriculum. Also in that year, the “Improvement of Road Safety 2013-2020” federal target program was launched, providing a perfect opportunity to put forward a drink driving module that could be included in novice driver courses. The Federal Program continued a multifaceted approach to road safety envisaging among other improvements the education and training system for drivers [1]. In 2011-2013 official statistics revealed negative trends in road crash data associated with drinking and driving (table 1).

About authors:

Burtsev Alexander Alexandrovich, Researcher, Doctor of medicine, Doctor of philosophy, senior researcher at the Legal Issues in Narcology Unit, Prevention Department, Federal Medical Research Center on Psychiatry and Narcology named after V.P. Serbsky, Ministry of Health of the Russian Federation, Moscow, Russia. E-mail: burtsev@mail.ru, phone: + 7 (499) 241 06 03;

Silyanov Valentin Vasilyevich, Doctor of Technical Science, professor, State Technical University (MADI), Moscow, Russia. E-mail: silyanov@bk.ru, phone: +7 (499) 155 01 81.
Table 1. The dynamics of absolute and relative number of road crash data related to drinking and driving in 2010-2015 in Russia [2]

<table>
<thead>
<tr>
<th>Year</th>
<th>Absolute numbers of road crashes, deaths and injuries in road crashes associated with DD</th>
<th>Proportion in relation to the overall numbers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Road crashes</td>
<td>Killed</td>
</tr>
<tr>
<td></td>
<td>abs.</td>
<td>rel. (% to the previous year)*</td>
</tr>
<tr>
<td>2010</td>
<td>11845</td>
<td>-</td>
</tr>
<tr>
<td>2011</td>
<td>12252</td>
<td>3.4</td>
</tr>
<tr>
<td>2012</td>
<td>12843</td>
<td>4.8</td>
</tr>
<tr>
<td>2013</td>
<td>13581</td>
<td>5.7</td>
</tr>
<tr>
<td>2014</td>
<td>16517</td>
<td>21.6</td>
</tr>
<tr>
<td>2015</td>
<td>16360</td>
<td>-1</td>
</tr>
</tbody>
</table>

Note: * - «--» marks negative growth in percent as compared to the previous year.

The figures in table 1 show that in Russia for the period 2011-2013 both the absolute and relative number of road crashes associated with drinking and driving (in the overall structure of road crashes) were growing. In 2014 the growth of relative number continued with a slight decrease of the absolute numbers of “drunk” road crashes and the number of injuries in them by 1 and 3 percent respectively.

We would like to highlight three significant factors from our analysis of the data.

Firstly, in 2015 the total growth of fatal “drunk” road crashes continued for drivers of private cars as well as for professional drivers, which, in turn, indicates the need to introduce a system of additional “quality controls” such as pre-trip capacity examinations aimed, among other things, to identify intoxication of professional drivers [3; 4; 5]. In the period of 2010-2015 in Russia the annual number of fatalities in road crashes related to driving in a state of intoxication, almost doubled (from 1 954 to 3 997 persons).

Secondly, despite a slight decrease of absolute number of drunk driving related road crashes and injuries, the proportion of drink driving in the overall structure of road crashes continued growing. Thus, the proportion of road crashes associated with drinking and driving and the number of fatalities and injuries in 2010-2015 in Russia increased from 9 % to 8.9 %, from 7.4 % to 17.3 % and from 6.9 % to 9.8 % respectively.

Thirdly, the increasing number of road crashes connected with intoxication have occurred while at the same time there has been an overall decreasing number of road death and injuries during the past three years in Russia (table 2).

Table 2. The dynamics of absolute and relative number of road crash data in 2010-2015 in Russia [2]

<table>
<thead>
<tr>
<th>Year</th>
<th>Total N of road crashes</th>
<th>Total N of killed</th>
<th>Total N of injured</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>abs.</td>
<td>rel. (growth in % in relation to previous year)*</td>
<td>abs.</td>
</tr>
<tr>
<td>2010</td>
<td>199 431</td>
<td>-</td>
<td>26 567</td>
</tr>
<tr>
<td>2011</td>
<td>199 868</td>
<td>0.2</td>
<td>27 953</td>
</tr>
<tr>
<td>2012</td>
<td>203 597</td>
<td>1.9</td>
<td>27 991</td>
</tr>
<tr>
<td>2013</td>
<td>204 068</td>
<td>0.2</td>
<td>27 025</td>
</tr>
<tr>
<td>2014</td>
<td>199 720</td>
<td>-2.1</td>
<td>26 963</td>
</tr>
<tr>
<td>2015</td>
<td>184 400</td>
<td>-7.7</td>
<td>23 114</td>
</tr>
</tbody>
</table>

Note: * «--» marks negative growth in percent as compared to the previous year.
As follows from the data presented above in 2013-2015 in Russia there was an overall annual decrease of the number of killed in road crashes: from 28 thousand in 2012 to 23 thousand in 2015, and injured from 258,6 thousand in 2012 to 231,2 thousand in 2015.

Thus, the analysis in the field of road safety trends conclusively demonstrates the need for the introduction of additional measures aimed primarily at reducing the frequency of cases of driving in the state of intoxication, which, in turn, will reduce the number of "drunk" crashes and their consequences [6]. In these circumstances, primary prevention activities appear as the most appropriate, since the policy of strengthening the administrative sanctions proved only to be moderately effective for a short term [7, c. 69-94]. The international experience shows that measures increasing the term of driving license suspension lead to an increase in the number of cases of driving without a license [8]. In 2015 in Russia, among novice drivers (less than 2 years of driving experience) in road crashes with injuries and/or fatalities, the number of people driving under intoxication and those who refused a medical test was more than 10 % (table 3).

Table 3. Absolute and relative number of road crash death and injuries, including cases of drinking and driving, among novice drivers in Russia in 2015 [2]

<table>
<thead>
<tr>
<th>Категории водителей</th>
<th>Road crashes</th>
<th>Killed</th>
<th>Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>abs.</td>
<td>rel. (%)</td>
<td>abs.</td>
</tr>
<tr>
<td>Drivers with less than 2 year experience of driving</td>
<td>14 473</td>
<td>100</td>
<td>1 540</td>
</tr>
<tr>
<td>- incl drinking and driving</td>
<td>1 163</td>
<td>8</td>
<td>231</td>
</tr>
<tr>
<td>- incl those who refused to take a medical tests</td>
<td>325</td>
<td>2,3</td>
<td>9</td>
</tr>
<tr>
<td>Drivers with less than 2 year experience of driving intoxicated or refused to take a medical tests</td>
<td>1 488</td>
<td>10,3</td>
<td>240</td>
</tr>
</tbody>
</table>

The data shows a rather small number (2 percent) of refusals to take a medical test among novice drivers as compared to all drivers [7, c. 69-94]. This proves the conclusion that novice drivers are more responsive to the strengthened measures of administrative sanctions responsibility [7, c. 111, 126]. This finding predicts a higher effectiveness of preventive work among novice drivers as compared to older and more experienced drivers who might have had “positive” experience of driving while intoxicated. Thus, a group of young and inexperienced drivers is of greatest interest for primary prevention efforts to reduce drinking and driving. The most simple and efficient way to carry out this work is to ensure a preventive effect at the stage of training of this category of drivers in driving schools by supplementing the model programs of vocational training of drivers [9].

In 2013 a draft training module targeting drinking and driving was developed in Russia for driver candidates at driver schools. The development of the module was made possible with support of the International Alliance for Responsible Drinking (IARD). A partnership within the framework of a social project between IARD, Moscow Automobile and Road State Technical University (MADI) and other participants was a natural outcome from the Commitments made by global producers of beer, wine and spirits. These Commitments to reduce harmful drinking include a provision that "the decision of each person about drinking or not drinking must
comply with the law, safety and personal responsibility… this decision can only be taken with availability, knowledge and understanding of the facts” [10]. In 2013 considering the law that prohibits drinking and driving [11] and to ensure “availability, knowledge and understanding of facts” the authors of the project developed the following: a training module aimed to reduce drinking and driving; a methodology of promoting the module to driver schools; a trainer’s book with a lesson plan; thematic slides and video clips; a guidebook on how to work with special glasses simulating a state of a drunkenness called “Fatal Vision”; tests and instructions on measuring the effectiveness of the training; hand-out materials and a set of messages like “alcohol and driving do not mix”.

Launched in several driver schools in Smolensk region with support of Smolensk Humanitarian University and the Public Council at the Smolensk Department of the Russian Internal Ministry the project was named “Avtotrezvost” (“Autosobriety”). At the beginning of 2014, the results of the first workshops for driver school teachers, the public polls and surveys on drinking and driving issues in Smolensk region, student tests before and after the lesson, interviews with focus groups of students, teachers and experts, allowed further development of the project methodology.

With regard to the implementation of the training module, we would like to highlight several important points.

Firstly, the low cost. The project structure can be divided into three levels: the project coordinator, a work group of like-minded people (the authors of the manual and materials, staff and representatives of driving schools, researchers), and a support group comprised of journalists, volunteers, and corporate representatives (transport and insurance companies, trade centers, restaurants, etc.), as well as representatives of the authorities. In this case, material remuneration for participation in the project is provided for a project coordinator, who is also responsible to teach the training module (6-8 academic hours during one day) and for the project experts who help to upgrade the module according to the latest changes. Expenses for public information campaigns and other events to support the module in driving schools can be agreed upon and divided with regional partners.

Secondly, introduction of the training module in a driving school curriculum does not require any additional approvals from the parent organizations. A driving school director’s order is enough to make changes in the basic curriculum cycle under the subject "Psychophysiological aspects of a driver’s activity.”

Thirdly, all training materials include positive information without photos or images of road crashes and their consequences.

The training module “Avtotrezvost” is a 2 to 4-hour interactive course that includes a lecture, practical exercise, group work and discussions. It includes four parts: statistics (official data on road crash death and injuries, including those related to drinking and driving in the world, in Russia, and in the respective region); alcohol and driving (alcohol influence on a human body); drinking and driving and the law (legal consequences of drinking and driving); drinking and driving and society (personal position and responsibility).

The practical part (exercises) is based on the use of special devices – “Fatal Vision” glasses which simulate behavior of a person under the influence of alcohol. While wearing the glasses a
driver candidate gets personal experiences of the dangers of drinking and driving as he/she observes distortion of object shapes, misperceives distance, and loses reaction rate.

As a result, three simple steps are required to introduce the project into a driving school: make changed to the curriculum, get one or two teachers trained, and obtain the so called “Fatal Vision” glasses provided by the project sponsors.

Wide public support for the project in Smolensk region lead to a quick project development that allowed to begin the project promotion to other Russian regions. In 2015 the new module was actively used in 31 driving schools in four regions (Smolensk and Ulyanovsk regions, in the cities of Sterlitamak and Kursk) where more than 7000 students received additional knowledge on drinking and driving risks.

In October 2016, the project was launched in Moscow at a conference held in one of the oldest Russian Universities – MADI, where prominent Russian scientists, lawmakers, experts, directors of driving schools, business representatives and journalists witnessed the presentation of the second edition of the “Avtotrezvost”. Trainer’s book which emphasizes prevention of drinking and driving as well as highlights the risks of use of some medical drugs that can influence a driver’s behavior. The participants agreed to conduct a research project in Moscow aimed to assess the effectiveness of the new module. Two workshops for 30 driving schools teachers who had followed the conference began delivering the “Avtotrezvost” lessons for candidates to drivers in Moscow in November 2016.

In addition to the training module in driving school, “Avtotrezvost” project includes information campaigns for drivers and wider population aimed to prevent drinking and driving and to reduce tolerance of this phenomenon in the society. These campaigns included: "I am for Avtotrezvost" on the Day of the City of Smolensk; distribution of information leaflets in the traffic police checks on the roads in Smolensk and Ulyanovsk; flash mob and handing out flyers in shopping centers of Ulyanovsk; special events on the Day of Remembrance for Road Traffic Victims in Sterlitamak; a campaign "The Sober Drive!" in a city park in Smolensk; a three-week campaign "PitNelzyaRulit" together with a popular bar and a taxi company on New Year’s Eve holidays in Smolensk. Many other supportive activities reinforce the “Avtotrezvost” message of raising awareness of the risks associated with drinking and driving.

As mentioned above, the project is rather economical. However, with the funding provided by the sponsors alone it is not possible to spread the project throughout the entire territory of the Russian Federation. Considering that the Russian Ministry of Health Order N 343n of 15.06.2015 "On organizing and conducting health education on the prevention of driving under alcohol, drugs or other toxic substances" [12] envisages engagement of medical workers (medical doctors-psychiatrists-narcologists) in drivers professional training, it seems appropriate to use the training module "Avtotrezvost" and its materials (posters, video clips, handouts, etc.) at the state and municipal narcological institutions.

To carry out such an approach is possible as follows: Firstly, the project coordinator conducts a remote training for a group of psychiatrists, narcologists (1-2 physicians from one institution) in a subject territory (region). Secondly, the materials of "Avtotrezvost" project are transferred in an electronic form to the relevant institutions based on a Memorandum of Understanding (MoU) that, among other, includes the rights for the non-commercial use of
these materials.

In conclusion, the results of trends in road safety discussed in this article indicate the need to introduce and intensify new methods of preventive work. The most promising is the realization of this work among the students of driving schools and the use of the existing training materials from the “Avtotrezvost” program.

References
[8]. Dr Sjoerd Houwing. European experience in fighting Drink Driving Research and practical approaches. SWOV, The Netherlands. Presentation at a conference at MADI (Moscow, Russia). 03.02.2015.
[9]. Order of the Ministry of Education and Science of the Russian Federation N 1408 of 26.12.2013 “On approval of the sample programmes of professional education for drivers of respective categories and subcategories”. URL: http://xn--80abucjiibhv9a.xn--plai/%D0%B4%D0%BE%D0%BA%D1%83%D0%BC%D0%B5%D0%BD%D1%82%D1%8B/6201/%D1%84%D0%B0%D0%B9%D0%BB/5179/Prikaz_%E2%84%96_12.05.2015.pdf. (consulted 18 December 2016).
[12]. Order of the Ministry of Health of the Russian Federation N 343n of 15.06.2015 "On approval of the organization and conducting health education on the prevention of driving under alcohol, drugs or other toxic substances” URL: file:///C:/Users/unnamed/Downloads/%D0%9F%D1%80%D0%B8%D0%BA%D0%B0%D0%B7_%D0%9F%D0%BE%D1%80%D1%8F%D0%B4%D0%BE%D0%BA_343%D0%BD_%D0%BE%D1%82_15_%D0%83%D1%8E%D0%BD%D1%8F_2015_%D0%9B3..pdf. (consulted 18 December 2016)
SAFETY ANALYSIS OF ON-BOARD EQUIPMENT RBC HANDOVER FUNCTION BASED ON MULTI-AGENT AND HAZOP

GUIHENG HE, YADONG ZHANG, JIN GUO, SHUO WANG
The School of Information Science and Technology
Southwest Jiaotong University, Chengdu 610031, China

Abstract: In CTCS-3 train control system, the RBC handover function of the on-board equipment seriously affects the operation efficiency and the safety of the train. In this paper, the on-board equipment RBC handover function is modeled by Multi-Agent, and then the formal analysis of the model is established. Finally, the HAZOP method is used to analyze the formal analysis and the hazard log table, which could provide a basis for risk management in full life cycle, is obtained.

Keywords: RBC handover, Safety analysis, Multi-Agent, HAZOP.

I. INTRODUCTION

CTCS-3 (China Train Control System) uses GSM-R wireless communication to transfer information between on-board and wayside, and RBC (Radio Block Center) generates a MA to control the safe operation of the train according to the track circuit occupancy, route status, temporary speed limit and other information. In CTCS-3, lines are divided into several RBC sections. Therefore, the train should be able to achieve RBC handover function efficiently, safely and reliably when it running to the RBC boundary. The train in CTCS-3 should be controlled by RBC all the time. The RBC handover process will affect the efficiency and even the safety of the train, if the train does not be controlled by RBC or be controlled by multiple RBC. And the handover process of adjacent RBC control right is the weak link of RBC to train control. The RBC handover function of the on-board equipment in the RBC boundary is very important to the safety of the train.

In the process of RBC handover function, the information may be delayed, lost, errors, etc which will affect will affect the efficiency of RBC handover function and even affect traffic safety. Therefore, it is necessary to find out the security risk of the RBC handover through establishing a model of the on-board equipment RBC handover function and analyzing the security of the model.

II. MULTI-AGENT MODEL AND HAZOP

2.1. Multi-Agent Model

CTCS-3 is a complex system, it has complex structure and the internal subsystems in
CTCS-3 interact frequently, and the interaction process is complicated. Traditional modeling and simulation method are influenced by the theory of reduction and determinism obviously, whether the process simulation method based on the deterministic model or the statistical simulation method based on the probability model, the modeling and Simulation of the dynamic characteristics of the CTCS-3 level train control system can not be solved well. The modeling method based on Agent can combine the whole attribute of complex system with the individual behavior in complex system. This modeling method is an effective way to solve complex system and complexity.

Multi-Agent Model is based on signal Agent, this method abstracts the complex system into several Agent combinations, defines and describes the behaviors, relationships and interactions of these Agent, so that it can accurately complete the function and behavior of complex systems. This method provides an effective way for modeling and Simulation of complex systems. The method has a stronger ability of modeling and simulation of complex systems, a more abstract, which reducing the complexity of modeling structure and logic modeling compared with the traditional simulation technique[3].

Agent is a kind of subject which can continuously perceive the environment and act on the environment. The Agent can be in an environment and as a part of the environment. In order to achieve the design goal, the Agent can carry out the flexible behavior. The model structure of Agent is shown in the following figure.

![Agent model](diagram.png)

Fig 1. The model structure of Agent

In the model structure, the perception perceives the input information from the environment, and then transfers it to the controller. According to the information and the Agent internal state, the controller can select the appropriate rules and send the operation that Agent need to perform to the effector. According to the command given by the controller, the effector modifies the state of the Agent and outputs information to the environment. State is responsible for storing the state of Agent at this time. Time is the logical clock of Agent.
The structure of a single Agent can be divided into the careful thinking type, the reactivity type and the mixed type. The reactivity type Agent work through the reaction behavior of the external stimuli, it does not need to express and reason about the environment. The reactivity type Agent has good robustness and fault tolerance and simple interaction behavior of the reactivity type Agent can be combined into complex behavior. In addition, the reactivity type Agent does not have complex logical reasoning and the speed of execution is fast. According to the characteristics of reactivity type Agent, modeling the on-board equipment RBC handover function through reactivity type Agent is discussed in this paper.

2.2. HAZOP

HAZOP (Hazard and Operability Analysis) is a structured approach to identify design defects, process hazards and operational problems. Because it is able to analyze the system completely, HAZOP has become one of the most popular analysis methods in the field of risk analysis and is widely used in railway industry. In this paper, we mainly use HAZOP to identify the hazard identification of the RBC handover function model of the on-board equipment[4].

III. THE ON-BOARD EQUIPMENT RBC HANOVER FUNCTION MULTI-AGENT MODELING AND IMPLEMENTATION

3.1. Multi-Agent model of the on-board equipment

The CTCS-3 level system is mainly composed of wayside equipment and on-board equipment. The on-board equipment adopts distributed structure, mainly including: C3-Kernel, C2-Kernel, DMI, TIU, BTM, RTM, GSM-R, SDU, TCR, JRU. The reference model of the on-board equipment is shown below.

![Fig 2. The reference model of the on-board equipment](image-url)
According to the reference model, as well as the function and interaction behavior of the subsystem of the on-board equipment executing the RBC handover function. The on-board equipment can be abstracted into a Multi-Agent model, as shown in the following figure.

![Multi-Agent model of the on-board equipment](image)

**Fig 3. Multi-Agent model of the on-board equipment**

The main functions of the main modules in the on-board equipment RBC handover function are as follows.

- **C3K_Agent**: The core function module in the on-board equipment RBC handover function. C3K_Agent is mainly responsible for processing the information receiving from other Agent and controlling the on-board equipment to perform different actions.

- **C2K_Agent**: In the on-board equipment RBC handover function, C2K_Agent is mainly responsible for receiving the track circuit code from the TCR_Agent, and then sending the track circuit code to the C3K_Agent.

- **RTM_Agent**: In the on-board equipment RBC handover function, RTM_Agent is mainly responsible for the transmission of information from RBC to C3K_Agent and the transmission of information from C3K_Agent to RBC.

- **SDU_Agent**: In the on-board equipment RBC handover function, SDU_Agent calculates the real-time speed and the distance of the train based on the pulse information generated by the speed sensor, and then reports to the C3K_Agent.

- **BTM_Agent**: In the on-board equipment RBC handover function, BTM_Agent is mainly responsible for receiving information from balise and then sending the information to the C3K_Agent.

- **DMI_Agent**: In the on-board equipment RBC handover function, DMI_Agent is mainly responsible for receiving train control information from C3K_Agent and then showing the information to the driver.

- **JUR_Agent**: In the on-board equipment RBC handover function, JUR_Agent is mainly responsible for receiving the information from C3K_Agent and recording the information.

- **TIU_Agent**: In the on-board equipment RBC handover function, TIU_Agent is mainly responsible for receiving the information from C3K_Agent and controlling the speed of the train.
From the above functional analysis, C2K.Agent, RTM.Agent, SDU.Agent, BTM.Agent, DMI.Agent, JUR.Agent and TIU.Agent play the same role in the on-board equipment RBC handover function. Their main function is to receive and send the information. As for the Multi-Agent model of the on-board equipment RBC handover function, we do not need to pay attention to the forms of information interaction and the process of encoding and decoding of information in the process of interaction. Therefore, we only need to analyze the content of information interaction among the Agents. Therefore, due to space limitations, in this paper, taking C3K.Agent and Agent RTM_ as an example, we can make formal analysis on the multi-Agent model of the on-board equipment RBC handover function.

3.2. Formal analysis on the RTM.Agent

The function of RTM.Agent in the multi-Agent model of the on-board equipment RBC handover function is transferring information between RBC and RTM.Agent, therefore, the RTM.Agent can be regarded as an information transceiver. The rule of RTM.Agent can be set to send what it has received to the corresponding target. The formal description of RTM.Agent can be defined as the following eight elements:

RTM.Agent=< RTM_time, RTM_input, RTM_output, RTM_state, RTM_Rule, RTM_GetENV, RTM_Control, RTM_action>

RTM_input represents the collection of RTM.Agent input messages, and the formal description of the RTM_input is shown below:

RTM_input=={MA, acknowledgement, position report, general message, initiation of communication session, system configuration, communication established, train data, train data confirmed, end of communication session, end of communication session confirmed}

RTM_output represents the collection of RTM.Agent output messages, and the formal description of the RTM_output is shown below:

RTM_output=={MA, acknowledgement, position report, general message, initiation of communication session, system configuration, communication established, train data, train data confirmed, end of communication session, end of communication session confirmed}

RTM_state represents the RTM.Agent state collection, and the formal description of the RTM_state is shown below:

RTM_state=={work, error}

Using RTM_GetENV to indicate the RTM.Agent perception, which is used to receive and process input messages from the environment, and then send the message to the RTM.Agent controller. The formal description of the RTM_GetENV is shown below:

RTM_GetENV==[env?: Environment
Perceiver: Environment→RTM_input
result!: RTM_input|
∀ per: Perceiver ∙ ran(per)=dom(per)
result!=ran(per)]

Using RTM_Control to indicate the RTM.Agent controller, it is a rule processing system. According to the input message and the internal state of the RTM.Agent, RTM_Control can select the appropriate rule and determine the effect of the effector. In the Multi-Agent model of...
the on-board equipment RBC handover function, we only need to pay attention to the content of information interaction among the Agents, therefore, the RTM_Control can be set to send the information same with the information it has received. The formal description of the RTM_Control is shown below:

\[
\text{RTM-Control} = \langle \text{in}?: \text{RTM-input} \quad \text{out}!: \text{RTM-output} \quad S: \text{RTM-State} \quad \text{RTM-Rule}: (\text{in} \times S) \rightarrow (\text{out} \times S) | \forall \text{rule}: \text{RTM-Rule} \cdot \text{ran}(\text{ran Rule}) = \text{ran}(\text{dom Rule}) \land \text{dom}(\text{dom Rule}) = \text{dom}(\text{ran Rule}) \quad \text{out}! = \text{dom}(\text{rule}(\text{in} \alpha S)) \rangle
\]

Using RTM_action to indicate the RTM_Agent effector, it can determine the output of the RTM_Agent and the changes of the RTM_Agent state according to the rule given by the controller of the RTM_Agent. The formal description of the RTM_action is shown below:

\[
\text{RTM-action} = \langle \Delta \text{RTM-Agent} \quad \text{env}? : \text{Environment} \quad \text{in}: \text{RTM-input} \quad \text{out}!: \text{RTM-output} \quad \text{in} = \text{GetENV}(\text{env}? \rangle \quad \text{in} \in \text{RTM-input} \quad \text{out}! = \text{Control}(\text{in}) \quad \text{RTM-state}' = \text{ran}(\text{ran RTM-Rule} (\text{in} \alpha \text{RTM-state})) \rangle
\]

RTM_action can also be regarded as the action function of RTM_Agent, which can represent the whole execution process of RTM_Agent from receiving information to sending information.

3.3. Formal analysis on the C3K_Agent

C3K_Agent is the most important and most complex part of the Multi-Agent model of the on-board equipment RBC handover function. It needs to send the information selectively according to the different information received, so it has a relatively complex rule definition. C3K_Agent can also be formalized as the following eight elements:

\[
\text{C3K-Agent} = \langle \text{C3K-time}, \text{C3K-input}, \text{C3K-output}, \text{C3K-state}, \text{C3K-Rule}, \text{C3K-GetENV}, \text{C3K-Control}, \text{C3K-action} \rangle
\]

C3K_input represents the collection of C3K_Agent input messages, and the formal description of the C3K_input is shown below:

\[
\text{C3K-input} = \{ \text{Preview information}, \text{MA}, \text{BTM report}, \text{position report}, \text{general message}, \text{call RBC}, \text{system configuration}, \text{train data confirmed}, \text{end of communication session}, \text{end of communication session confirmed} \}
\]

C3K_output represents the collection of C3K_Agent output messages, and the formal description of the C3K_output is shown below:

\[
\text{C3K-output} = \{ \text{MA}, \text{acknowledgement}, \text{position report}, \text{general message}, \text{initiation a communication session}, \text{communication established}, \text{train data}, \text{end of communication session}, \text{end of communication session confirmed} \}
\]
C3K_state represents the C3K_Agent state collection, and the formal description of the C3K_state is shown below:

C3K_state=\{work, error\}

C3K_Rule represents the C3K_Agent rule collection. Depending on the input message, the output message is different. The formal description of the C3K_Rule is shown below:

C3K_Rule=\{( MA α work)→(work α acknowledgement) \\
(BTM report α work)→ (work α position report) \\
(call RBC α work)→ (work α initiation a communication session) \\
(system configuration α work)→ (work α communication established) \\
(position report α work)→ (work α position report) \\
(general message α work)→ (work α acknowledgement) \\
(train data α work)→ (work α train data confirmed) \\
(session management α work)→(work α end of communication session)\}

Using C3K_GetENV to indicate the C3K_Agent perception, which is used to receive and process input messages from the environment, and then send the message to the C3K_Agent controller. The formal description of the C3K_GetENV is shown below:

C3K_GetENV=[input?: Environment  \\
Perceiver: Environment→C3K_input \\
result!: C3K_input|  \\
∀per: Perceiver ∙ ran(per)=dom(per)  \\
result!=ran(per)]

Using C3K_Control to indicate the C3K_Agent controller, it is a rule processing system. According to the input message and the internal state of the C3K_Agent, C3K_Control can select the appropriate rule and determine the effect of the effector. The formal description of the C3K_Control is shown below:

C3K_Control=[in?: C3K_input  \\
out!: C3K_output \\
S:C3K_State \\
C3K_Rule:(in?×S) →(S×out!)|  \\
∀rule: C3K_Rule ∙ ran(ran Rule)=ran(dom Rule)  \\
out!=dom(rule(in? α S)]

Using C3K_action to indicate the C3K_Agent effector, it can determine the output of the C3K_Agent and the changes of the C3K_Agent state according to the rule given by the controller of the C3K_Agent. The formal description of the C3K_action is shown below:

C3K_action==[ΔC3K_Agent  \\
en?: Environment \\
in: C3K_input  \\
out!: C3K_output|  \\
in = GetENV_C3K (env?)  \\
in∈C3K_input
C3K_action can also be regarded as the action function of C3K_Agent, which can represent the whole execution process of C3K_Agent from receiving information to sending information.

The following is a brief description of the previous use of the symbol. ? represents the input variable; ! represents the output variable; \( \rightarrow \) represents the corresponding relationship; \( \Delta \) represents the change of state; ran is said to get the range; dom is said to get domain of definition\(^5\).

3.4. Formal analysis on the implementation process of the on-board equipment RBC handover function

According to the process of the on-board equipment RBC handover function, the whole process can be divided into 3 steps to carry out the formal description. First, we can have a formal analysis on the process of the train passing through LAT. After the train passes through LAT, BTM_Agent and SDU_Agent collect the position information of the train and then report to the C3K_Agent. After receiving the position information, C3K_Agent sends the position information to RBC1 through RTM_Agent. Then, RBC1 sends a position reference point adjusted MA to C3K_Agent through RTM_Agent. After receiving the MA, C3K_Agent sends an acknowledgement to RBC1 through the RTM_Agent. The formal description is shown below. Among them, BTM_action represents the action function of BTM_Agent, SDU_action represents the action function of SDU_Agent and so on.

\[
\langle \text{Agent}_\text{process} \rangle ::= (\text{Do}(\text{position report}))
\]

\[
\| \text{INFORM}
\]

\[
\text{def position report}(
\exists \text{env1, env2}: \text{Environment}· (\text{env1}=\text{BTM report})&& (\text{env2}=\text{position report}) \rightarrow
(\text{BTM.BTM_action(env1)&& SDU.SDU_action(env2)} \rightarrow (\text{C3K.C3K_action(BTM report)&& C3K.C3K_action(position report)}) \rightarrow \text{RTM.RTM_action(position)})
\]

\[
\exists \text{env3}: \text{Environment}· (\text{env3 in RTM.RTM_input})
\]

\[
\text{input: RTM_input}· \text{input}=\text{RTM.RTM_action(env3)}
\]

\[
\text{if (input=MA)} \rightarrow \text{C3K.C3K_action(input)} \rightarrow \text{RTM.RTM_action (acknowledgement)}
\]

Second, according to the telephone number provided by RBC1, C3K_Agent sends initiation a communication session to RBC2 through RTM_Agent. Then, RTM_Agent receives system configuration from RBC2 and sends it to C3K_Agent. Then, C3K_Agent sends communication established to RBC2 through RTM_Agent. At the same time, RTM_Agent receives the train data confirmed sent by the RBC2, and sends to the C3K_Agent. The formal description is shown below:

\[
\langle \text{Agent}_\text{process} \rangle ::= (\text{Do}(\text{call RBC}))
\]

\[
\| \text{INFORM}
\]

\[
\text{def call RBC}(
\]
if (∃env4: Environment∙ (env4=call RBC)) → input: BTM_input∙
input=BTM.BTM_action(env4)

if (input=call RBC) → C3K.C3K_action(input) → RTM.RTM_action(communication established) → C3K.C3K_action(System configure)

→ RTM.RTM_action(communication established) → RTM.RTM_action(general message) → C3K.C3K_action(general message) → RTM.RTM_action(acknowledgement) → C3K.C3K_action(train data confirmed) → RTM.RTM_action(general message)

Finally, after the max safe front end passes RN, BTM_Agent and SDU_Agent receives position report from the environment and then sends it to C3K_Agent. C3K_Agent sends position report to RBC1 and RBC2 through RTM_Agent. Then, RBC2 sends MA to C3K_Agent through RTM_Agent. After the min safe rear end goes through RN, C3K_Agent sends position report to RBC1 and RBC2 through RTM_Agent. And then, C3K_Agent receives session management from RBC1 through RTM_Agent. Then, C3K_Agent sends end of communication session to RBC1 through RTM_Agent and receives end of communication session confirmed from RBC1 through RTM_Agent. The formal description is shown below:

<Agent_process>::=(Do(RBC handover))

def RBC handover{

∃ env7, env8: Environment∙ (env7=balise switching report)&&(env8 =position report)
→ (BTM.BTM_action(env7)&&SDU.SDU_action(env8)) → (C3K.C3K_action(train head over balise switching report) → RTM.RTM_action(position report) → RTM.RTM_action(MA) → C3K.C3K_action(MA) → RTM.RTM_action(acknowledgement)

∃ env9, env10: Environment∙ (env9=balise switching report)&&(env10 =position report) → (BTM.BTM_action(env9)&&SDU.SDU_action(env10)) → (C3K.C3K_action(train tail over balise switching report) → RTM.RTM_action(position report) → RTM.RTM_action(session management) → C3K.C3K_action(session management) → RTM.RTM_action(end of communication session) → RTM.RTM_action(end of communication session confirmed))

IV. RISK ANALYSIS OF THE MULTI-AGENT MODEL FOR THE ON-BARD EQUIPMENT RBC HANDOVER FUNCTION

The safety of the system is closely related to the hazard identification, the more comprehensive the hazard identification, the more it can ensure the safety of the system. Therefore, the analysis of the on-board equipment handover function model in different views can fully identify hazards of the system. In this paper, the system is analyzed from 3 aspects of hardware structure, function and implementation process. Taking RTM_Agent as an example, we choose RTM communication board as the element and combine the guide word with the element. The results are shown in table 1.
We choose RTM_GetENV as the element and combine the guide word with the element. The results are shown in table 2.

Table 1. Hazard log table of RTM-Agent structure

<table>
<thead>
<tr>
<th>Number</th>
<th>Node</th>
<th>Guide Word</th>
<th>Element</th>
<th>Deviation</th>
<th>Cause</th>
<th>Result</th>
<th>Recommended Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RTM_Agent</td>
<td>In error</td>
<td>RTM communication board</td>
<td>RTM communication board error</td>
<td>Poor reliability of RTM communication board</td>
<td>Unable to receive MA and other information, affecting traffic safety</td>
<td>Select the higher reliability communication board</td>
</tr>
</tbody>
</table>

Table 2. Hazard log table of RTM_GetENV

<table>
<thead>
<tr>
<th>Number</th>
<th>Node</th>
<th>Guide Word</th>
<th>Element</th>
<th>Deviation</th>
<th>Cause</th>
<th>Result</th>
<th>Recommended Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RTM_GetENV</td>
<td>No</td>
<td>RTM_GetENV</td>
<td>Unable to get input information</td>
<td>Program vulnerability</td>
<td>RTM_Agent could not get information, affecting traffic safety</td>
<td>Standardized program design</td>
</tr>
<tr>
<td>2</td>
<td>RTM_GetENV</td>
<td>In error</td>
<td>RTM_GetENV</td>
<td>Input information error</td>
<td>Program vulnerability</td>
<td>RTM_Agent receives wrong input information, affecting traffic safety</td>
<td>Standardized program design</td>
</tr>
<tr>
<td>3</td>
<td>RTM_GetENV</td>
<td>Part of</td>
<td>RTM_GetENV</td>
<td>Input information incomplete</td>
<td>Program vulnerability</td>
<td>The input information is not complete affecting the traffic safety</td>
<td>Standardized program design</td>
</tr>
<tr>
<td>4</td>
<td>RTM_GetENV</td>
<td>Later</td>
<td>RTM_GetENV</td>
<td>Input information delay</td>
<td>Program vulnerability</td>
<td>Input information delay, the train may be speeding</td>
<td>Standardized program design</td>
</tr>
</tbody>
</table>

We choose RTM.RTM_action(position report) in implementation process as the element combine the guide word with the element. The results are shown in table 3.
Table 3. Hazard log table of RTM.RTMuros(action(position report)

<table>
<thead>
<tr>
<th>Number</th>
<th>Node</th>
<th>Guide Word</th>
<th>Element</th>
<th>Deviation</th>
<th>Cause</th>
<th>Result</th>
<th>Recommended Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RTM.RTM_action(position report)</td>
<td>No</td>
<td>RTM.RTM_action(position report)</td>
<td>RTM_Agent is unable to report position to the RBC</td>
<td>RTM transmission channel error</td>
<td>Can not perform RBC handover function, affecting traffic safety</td>
<td>regular maintenance</td>
</tr>
<tr>
<td>2</td>
<td>RTM.RTM_action(position report)</td>
<td>In error</td>
<td>RTM.RTM_action(position report)</td>
<td>The position report is error</td>
<td>Program vulnerability</td>
<td>Can not perform RBC handover function affecting normally, causing emergency stop</td>
<td>Standardized program design</td>
</tr>
<tr>
<td>3</td>
<td>RTM.RTM_action(position report)</td>
<td>Part of</td>
<td>RTM.RTM_action(position report)</td>
<td>The position report is not complete</td>
<td>Program vulnerability</td>
<td>RBC could not determine the location of the train, causing emergency stop</td>
<td>Standardized program design</td>
</tr>
<tr>
<td>4</td>
<td>RTM.RTM_action(position report)</td>
<td>Later</td>
<td>RTM.RTM_action(position report)</td>
<td>RTM.Agent reports position to RBC too late</td>
<td>Program vulnerability</td>
<td>Can not perform RBC handover function in RN, affecting traffic safety</td>
<td>Standardized program design</td>
</tr>
</tbody>
</table>

V. CONCLUSION

In conclusion, this paper presents the formal description of the on-board equipment RBC handover function Multi-Agent model, performs risk analysis of the model by HAZOP method, and finally carries out a comprehensive and reliable hazard identification of on-board equipment RBC handover function model.

References

Practically in any field of activity mathematical representation of an object of management is the cornerstone of decision making process. The mathematical models, methods and algorithms intended for the description of road and transport accident rate at the regional and federal levels are developed taking into account the factors characterizing the "Voditel (driver)-Avtomobil (vehicle)-Doroga (road)-Sreda (human environment)" complex. At the same time one of the determining factors is the number of the vehicles (V) registered in the territory of the subject of the Russian Federation [1]. At the same time, participation in traffic of the vehicles, arrived from other regions, can bring a certain error in calculations.

Until recently rather precisely territorial accessory of the vehicles could be determined by a code of the state registration sign of the vehicles. Now according to point 24 of Rules of registration of automotive-vehicles and trail cars to them in State Inspection for Road Traffic Safety of the Ministry of Internal Affairs of the Russian Federation (The order of the Ministry of Internal Affairs of Russia of November 24, 2008 No. 1001 "About an order of registration of vehicles") "Vehicles are registered behind physical persons to the address specified in the passport of the citizen of the Russian Federation or in the articles of incorporation at the place of residence of owners granted by bodies of registration accounting. Registration of vehicles behind the physical persons which don't have registration at the place of residence is made to the address specified in the articles of incorporation in the place of stay of owners granted by bodies of registration accounting". Also, according to the item 25 "According to Statements of Owners the Unregistered Vehicles Belonging on the Property Right to the Physical Persons Having Registration at the Place of Residence Can Be Registered in the Place of Stay of Specified Persons for Stay".
That is, there is no accurate differentiation of accessory of the vehicles moving on roads on "local" and "third-party" now. Therefore accounting of the vehicles, arrived from other regions, can be only estimative.

Two approaches for receipt of this assessment were considered:

On the basis of the statistical data on the vehicles registered as in the territorial subject of the federation (according to the State traffic inspectorate) [9, 3], and in other subject, taking part in road accident with death (tab. 1). It is necessary that a share "third-party" the vehicles from regional to equally corresponding relation of participants of the specified road accidents;

On the basis of the assumption that the attitude of number of vehicles from another town towards the number of the vehicles registered in the region to equally corresponding relation of quantity of administrative offenses in the field of traffic (tab. 2).

The carried-out calculations showed that the second approach doesn't lead to improvement of results of modeling (the possible reason – concentration of photovideo fixing devices on certain highways that doesn't allow to assess a situation in a road net in general).

**Table 1. Death toll in the road accidents with participation of the vehicles, registered in other regions, and also other countries (given 2015)**

<table>
<thead>
<tr>
<th>Region</th>
<th>Has died</th>
<th>Third-party</th>
<th>All</th>
<th>The relation of the dead with participation third-party to the &quot;local&quot; vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altai Krai</td>
<td>80</td>
<td>313</td>
<td></td>
<td>0,34348</td>
</tr>
<tr>
<td>Amur region</td>
<td>39</td>
<td>152</td>
<td></td>
<td>0,345133</td>
</tr>
<tr>
<td>Arkhangelsk region</td>
<td>36</td>
<td>136</td>
<td></td>
<td>0,36</td>
</tr>
<tr>
<td>Astrakhan region</td>
<td>44</td>
<td>137</td>
<td></td>
<td>0,473118</td>
</tr>
<tr>
<td>Belgorod region</td>
<td>54</td>
<td>207</td>
<td></td>
<td>0,352941</td>
</tr>
<tr>
<td>Bryansk region</td>
<td>112</td>
<td>244</td>
<td></td>
<td>0,848485</td>
</tr>
<tr>
<td>Vladimir region</td>
<td>213</td>
<td>389</td>
<td></td>
<td>1,210227</td>
</tr>
<tr>
<td>Volgograd region</td>
<td>132</td>
<td>345</td>
<td></td>
<td>0,619718</td>
</tr>
<tr>
<td>Vologda region</td>
<td>48</td>
<td>138</td>
<td></td>
<td>0,533333</td>
</tr>
<tr>
<td>Voronezh region</td>
<td>198</td>
<td>543</td>
<td></td>
<td>0,373914</td>
</tr>
<tr>
<td>Jewish Autonomous Region</td>
<td>22</td>
<td>42</td>
<td></td>
<td>1,1</td>
</tr>
<tr>
<td>Zabaykalsky Krai</td>
<td>61</td>
<td>213</td>
<td></td>
<td>0,401306</td>
</tr>
<tr>
<td>Ivanovo region</td>
<td>44</td>
<td>127</td>
<td></td>
<td>0,531012</td>
</tr>
<tr>
<td>Irkutsk region</td>
<td>115</td>
<td>479</td>
<td></td>
<td>0,315934</td>
</tr>
<tr>
<td>Kabardino-Balkar Republic</td>
<td>54</td>
<td>168</td>
<td></td>
<td>0,473684</td>
</tr>
<tr>
<td>Kaliningrad region</td>
<td>8</td>
<td>168</td>
<td></td>
<td>0,05</td>
</tr>
<tr>
<td>Kaluga region</td>
<td>148</td>
<td>268</td>
<td></td>
<td>1,233333</td>
</tr>
<tr>
<td>Karelchanka Krai</td>
<td>10</td>
<td>56</td>
<td></td>
<td>0,217391</td>
</tr>
<tr>
<td>Karachay-Cherkess Republic</td>
<td>36</td>
<td>129</td>
<td></td>
<td>0,387097</td>
</tr>
<tr>
<td>Kemerovo region</td>
<td>106</td>
<td>435</td>
<td></td>
<td>0,322188</td>
</tr>
<tr>
<td>Kirov region</td>
<td>65</td>
<td>192</td>
<td></td>
<td>0,311811</td>
</tr>
<tr>
<td>Kostroma region</td>
<td>28</td>
<td>86</td>
<td></td>
<td>0,482759</td>
</tr>
<tr>
<td>Krasnodar Krai</td>
<td>430</td>
<td>1132</td>
<td></td>
<td>0,612536</td>
</tr>
<tr>
<td>Krasnoyarsk Krai</td>
<td>148</td>
<td>567</td>
<td></td>
<td>0,353222</td>
</tr>
<tr>
<td>Kurgan region</td>
<td>92</td>
<td>198</td>
<td></td>
<td>0,867925</td>
</tr>
<tr>
<td>Kursk region</td>
<td>98</td>
<td>244</td>
<td></td>
<td>0,671233</td>
</tr>
<tr>
<td>Leningrad region</td>
<td>193</td>
<td>611</td>
<td></td>
<td>0,461722</td>
</tr>
<tr>
<td>Lipetsk region</td>
<td>60</td>
<td>212</td>
<td></td>
<td>0,394737</td>
</tr>
<tr>
<td>Magadan region</td>
<td>2</td>
<td>30</td>
<td></td>
<td>0,071429</td>
</tr>
<tr>
<td>Moscow</td>
<td>142</td>
<td>673</td>
<td></td>
<td>0,26742</td>
</tr>
<tr>
<td>Moscow region</td>
<td>432</td>
<td>1389</td>
<td></td>
<td>0,451411</td>
</tr>
<tr>
<td>Murmansk region</td>
<td>11</td>
<td>56</td>
<td></td>
<td>0,244444</td>
</tr>
<tr>
<td>Nenets Autonomous Okrug</td>
<td>5</td>
<td>5</td>
<td></td>
<td>0,05</td>
</tr>
<tr>
<td>Nizhny Novgorod region</td>
<td>174</td>
<td>522</td>
<td></td>
<td>0,54</td>
</tr>
<tr>
<td>Novgorod region</td>
<td>84</td>
<td>169</td>
<td></td>
<td>0,988235</td>
</tr>
<tr>
<td>Novosibirsk region</td>
<td>137</td>
<td>360</td>
<td></td>
<td>0,61435</td>
</tr>
<tr>
<td>Omsk region</td>
<td>68</td>
<td>259</td>
<td></td>
<td>0,356021</td>
</tr>
<tr>
<td>Region</td>
<td>In total</td>
<td>With photovideo fixing application</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>----------</td>
<td>------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arkhangel'sk region</td>
<td>0.152894</td>
<td>0.134247</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krasnodar Krai</td>
<td>0.3272</td>
<td>0.4268</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leningrad region</td>
<td>2.810225</td>
<td>4.390677</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moscow</td>
<td>0.385191</td>
<td>0.382078</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moscow region</td>
<td>1.333935</td>
<td>1.585219</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nizhny Novgorod region</td>
<td>0.3883</td>
<td>0.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novosibirsk region</td>
<td>0.2165</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Komi Republic</td>
<td>0.13973</td>
<td>0.148748</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rostov region</td>
<td>0.2622</td>
<td>0.239</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sverdlovsk region</td>
<td>0.185</td>
<td>0.141</td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Petersburg</td>
<td>0.183735</td>
<td>0.155982</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tver region</td>
<td>2.349561</td>
<td>2.943396</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Share of administrative offenses of drivers third-party the vehicles from regional.
Lower for the characteristic of a social and economic, climatic condition of regions, and also the taken corrective actions on participants of traffic, the indicators applied at the previous stages of work [1] (tab. 3) are used.

At the same time, it should be noted that results of a research have shown that orientation only to official statistical data doesn't provide the results allowing to find an explanation of a number of the facts, in particular, connected with a role of alcoholic intoxication in road and transport accident rate.

The new indicator - the rating of sobriety of regions which is result of the research executed within the Federal project "Sober Russia" and CEC "Rating" [6], and characterizing both extent of alcoholization of regions, and effectiveness of the antialcoholic legislation is included in the list of indicators (tab. 2). In rating are considered: volumes of sale of beer and vodka, the number of the dead from an alcoholic poisoning, number of the people having alcoholism and alcoholic psychoses the crimes committed by drunk faces, operability of the antialcoholic legislation in regions of the country.

Selection of indicators from the list (tab. 3) for modeling is made on the basis of values of coefficients of rank correlation of a death toll in road accident and the indicators presented in table 3. Critical value of coefficient of correlation of Spirmen is equal 0,217 for significance value 0,95 at selection of data on 82 regions.

Table 3. Values of coefficients of rank correlation of a death toll in road accident and various indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Values of coefficients of rank correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment ((x_0))</td>
<td>0,461005</td>
</tr>
<tr>
<td>Average annual temperature ((x_{10}))</td>
<td>0,284819</td>
</tr>
<tr>
<td>Density of highways ((x_{11}))</td>
<td>0,410618</td>
</tr>
<tr>
<td>Investment potential ((x_1))</td>
<td>0,839408</td>
</tr>
<tr>
<td>Level of economic development ((x_2))</td>
<td>0,541247</td>
</tr>
<tr>
<td>Investment risk ((x_3))</td>
<td>-0,66002</td>
</tr>
<tr>
<td>Population ((H))</td>
<td>0,92962</td>
</tr>
<tr>
<td>Number of vehicles ((T))</td>
<td>0,919595</td>
</tr>
<tr>
<td>Total assessment of quality of life (rating point) ((x_4))</td>
<td>0,609813</td>
</tr>
<tr>
<td>Demographic situation ((x_5))</td>
<td>0,006449</td>
</tr>
<tr>
<td>Level of the income ((x_6))</td>
<td>0,220676</td>
</tr>
<tr>
<td>Amount of precipitation (rainfall amount)</td>
<td>0,064556</td>
</tr>
<tr>
<td>Number of the registered administrative offenses (in the sphere of road-safety) ((x_7))</td>
<td>0,854019</td>
</tr>
<tr>
<td>Number of the registered administrative offenses with use of means of automatic photovideo fixing ((x_9))</td>
<td>0,755385</td>
</tr>
<tr>
<td>Beer sale (liters per capita) ((x_{12}))</td>
<td>0,2113</td>
</tr>
<tr>
<td>Rating of sobriety of regions ((x_{13}))</td>
<td>-0,52144</td>
</tr>
</tbody>
</table>
At a large number of indicators and their correlation interrelation the statistical analysis becomes complicated therefore there is a need of the description of the studied phenomenon (object) more integrated indicators, so-called main components [7].

For the list of economic indicators (investment potential, level of economic development, investment risk, total assessment of quality of life, a demographic situation, level of the income) the main components have an appearance [8]:

\[
\begin{align*}
  y_1 &= 0.42 \cdot x_1 + 0.47 \cdot x_2 - 0.41 \cdot x_3 + 0.487 \cdot x_4 + 0.147 \cdot x_5 + 0.42 \cdot x_6 \\
  y_2 &= -0.188 \cdot x_1 + 0.023 \cdot x_2 - 0.462 \cdot x_3 + 0.12 \cdot x_4 - 0.847 \cdot x_5 - 0.135 \cdot x_6 \\
  y_3 &= -0.6 \cdot x_1 + 0.315 \cdot x_2 + 0.19 \cdot x_3 - 0.183 \cdot x_4 - 0.1 \cdot x_5 + 0.676 \cdot x_6 \\
  y_4 &= -0.54 \cdot x_1 + 0.01 \cdot x_2 - 0.59 \cdot x_3 - 0.022 \cdot x_4 + 0.57 \cdot x_5 - 0.168 \cdot x_6 \\
  y_5 &= 0.097 \cdot x_1 + 0.47 \cdot x_2 - 0.377 \cdot x_3 - 0.368 \cdot x_4 + 0.248 \cdot x_5 + 0.654 \cdot x_6 \\
  y_6 &= -0.128 \cdot x_1 + 0.427 \cdot x_2 - 0.267 \cdot x_3 - 0.578 \cdot x_4 + 0.5 \cdot x_5 + 0.376 \cdot x_6 .
\end{align*}
\]

Relative shares of the total dispersion caused by one, two... the main components, 0.6, 0.78, 0.9, 0.955, 0.98, 1.0 are respectively equal. Below the 4th components as the exception two a component doesn't affect the accuracy of calculations are used.

For the indicators characterizing law-enforcement practice of the State traffic inspectorate, the main components following:

\[
\begin{align*}
  y_7 &= x_7 \\
  y_8 &= 0.97 \cdot x_7 + 0.24 \cdot x_8
\end{align*}
\]

The regression equation with the main components has an appearance (without the vehicles, arrived from other regions).

\[
y' = 0.766928y_0 + 1.744578y_1 + 2.210101y_2 - 2.765713y_3 + 2.243566y_4 + 1.054771y_7 + 0.937212y_8 + 4.074471x_9 + 9.524224x_{10} - 0.267582x_{11} + 22.937101, \tag{1}
\]

\[
y_0 = 0.389305 \cdot H^{0.642368} \cdot T^{0.321184} .
\]

The coefficient of determination is equal 0.9037, coefficient of rank correlation - 0.908642.

The accounting of the vehicles, arrived from other regions (according to these tab. 1) leads to the specified model assessment of number of the dead in road accident with use main a component, given above:
\[ y' = 0.987437 y_0' + 1.254723 y_1 + 4.947724 y_2 - 1.066012 y_3 + 7.560156 y_4 - 0.942654 y_7 \\
+ 0.838684 y_8 - 19.046045 x_9 + 12.376387 x_{10} - 0.224517 x_{11} + 0.378907 x_{13} - 6.284509, \tag{2} \]

\[ y_0' = 0.282832 \cdot H^{0.648705} \cdot T^{0.324352}. \]

The coefficient of rank correlation is equal 0.916773, determination coefficient - 0.916338.

It should be noted rather small value of the free member in the equation that can testify to completeness of set of indicators for the description of process.

The average deviation of calculated and actual values decreases by 12.4% (in comparison with the results corresponding to a formula 1).

The relevant actual and settlement data are submitted in the drawing.

*Fig. Calculated and actual values of a death toll in road accidents (2014)*

The analysis has shown that the major factors connected with a death toll in road accident are (percent from a total settlement death toll):
Population and the number of vehicles (in total provide about 95%);
Social and economic condition of the region (in total about 15%);
Environment (-22%);
Average annual temperature (about 11%);
Density of highways (-16%);

Punishments for administrative offenses in the field of traffic (nearly -6%, at the same time the insignificant role of automatic photovideo fixing of violations of traffic regulations is noted);

Rating of sobriety of regions (23%).

Lists of regions with rather high weight contribution of rating of sobriety to accident rate, and also with a high share of the dead because of drivers in state of intoxication are presented in table 4 (from total of the dead). Comparison of these two lists to some extent can serve as check of the received results.

Table 4. Regions with rather high weight contribution of rating sobriety (I) in a formula (2), and also with a high share of the dead because of drivers in state of intoxication (II)

<table>
<thead>
<tr>
<th>(I)</th>
<th>(II)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amur region</td>
<td>Altai Republic</td>
</tr>
<tr>
<td>Bryansk region</td>
<td>Sakhalin region</td>
</tr>
<tr>
<td>Jewish Autonomous Region</td>
<td>Zabaykalsky Krai</td>
</tr>
<tr>
<td>Zabaykalsky Krai</td>
<td>Udmurt Republic</td>
</tr>
<tr>
<td>Ivanovo region</td>
<td>Magadan region</td>
</tr>
<tr>
<td>Kaliningrad region</td>
<td>Republic of Adygea</td>
</tr>
<tr>
<td>Kamchatka Krai</td>
<td>Altai Krai</td>
</tr>
<tr>
<td>Karachay-Cherkess Republic</td>
<td>Kaluga region</td>
</tr>
<tr>
<td>Kurgan region</td>
<td>Komi Republic</td>
</tr>
<tr>
<td>Lipetsk region</td>
<td>Republic of Mordovia</td>
</tr>
<tr>
<td>Magadan region</td>
<td>Chuvash Republic</td>
</tr>
<tr>
<td>Murmansk region</td>
<td>Tambov region</td>
</tr>
<tr>
<td>Novgorod region</td>
<td>Jewish Autonomous Region</td>
</tr>
<tr>
<td>Oryol region</td>
<td>Vladimir region</td>
</tr>
<tr>
<td>Pskov region</td>
<td>Republic of Tyva</td>
</tr>
<tr>
<td>Republic of Adygea</td>
<td>Republic of Mari El</td>
</tr>
<tr>
<td>Altai Republic</td>
<td>Arkhangelsk region</td>
</tr>
<tr>
<td>Republic of Karelia</td>
<td>Kurgan region</td>
</tr>
<tr>
<td>Komi Republic</td>
<td>Penza region</td>
</tr>
<tr>
<td>Republic of Mari El</td>
<td>Yamalo-Nenets Autonomous Area</td>
</tr>
<tr>
<td>Republic of Sakha (Yakutia)</td>
<td>Kamchatka Krai</td>
</tr>
<tr>
<td>Republic of North Ossetia</td>
<td>Vologda region</td>
</tr>
<tr>
<td>Republic of Tyva</td>
<td>Republic of Karelia</td>
</tr>
<tr>
<td>Republic of Khakassia</td>
<td>Krasnoyarsk Krai</td>
</tr>
<tr>
<td>Chuvash Republic</td>
<td>Ivanovo region</td>
</tr>
<tr>
<td>Yamalo-Nenets Autonomous Area</td>
<td>Amur region</td>
</tr>
</tbody>
</table>
Follows from results of comparison that from 26 regions, the worst on each indicator, 14 enter both lists (tab. 4) that rather not bad characterizes results of modeling. Incomplete coincidence can be partly explained with feature of work of the State traffic inspectorate in different regions on identification of drivers in state of intoxication.

It should be noted that the rating of sobriety of regions offered in work [6] and which is well correlating with the number of the dead in road accident has allowed for the first time it is model to estimate influence of alcoholic intoxication on accident rate.

Results of calculations have shown that the offered approach to assessment of number of the CU, participating in traffic, allows to increase the accuracy of modeling of number of the dead in road accident. The average deviation of calculated and actual values decreases by 12.4%. The presented results find a logical explanation and can be used for assessment of a condition of road and transport accident rate.

**References**


[4]. Level of the income, total rating point of regions on quality of life, the level of economic development, a demographic situation. 1prime.ru/ratings/20131217/773219432.html. (consulted 18 December 2016).

[5]. Investment potential, investment risk. Raexpert.ru

[6]. The most drinking regions of Russia. Rating of sobriety. Basetop.ru


I. INTRODUCTION

The train operation control system is a real-time control system, which controls the high-speed train operation in conditions of high speed and high density. TCC (train control center) is the key system of the ground signal control of the train operation control system. According to the track section occupation, the line speed limit, the interlocking route, the communication between station and so on information, it produces the train traveling license command, and transmits to the vehicle equipment through the track circuit and the active balise. Cui[1] et al.

In order to manage TCC securely and effectively, it is a necessary and effective method to identify the risk in TCC as far as possible. Effective management and analysis of the identified risks can avoid major accidents caused by risk source.

Therefore, the research on risk analysis method of TCC is of great significance to ensure the safe and efficient operation of high-speed railway.

II. MULTI-AGENT AND HAZOP

Multi-agent theory

Agents are generally considered to be hardware system or computer systems based software, which has autonomy, reactivity, pro-activeness and social ability. Multi agent modeling theory and technology is an important branch of distributed artificial intelligence,
which can construct complex systems into a system that is small, mutual communication, coordination and easy to manage. It is one of the important modeling techniques to describe complex systems.

Multi agent modeling has the ability of natural description of complex systems and the ability to capture the emergence of complex systems. Therefore it is able to carry out a very good description for TCC. TCC is composed of a number of modules, each module needs interaction and cooperation to complete the function of TCC. Every unit module of TCC uses agent to describe and the interaction between agent and agent, between agent and environment is modeled. Thus it is able to combine the microscopic behavior of the individual with the whole attribute of TCC.

The agent model is the basis of multi agent modeling technology, which is divided into RA (reactive agent), DA (deliberative agent) and HA (hybrid agent). RA is characterized by the rapid response to external information, but the intelligence and flexibility is low. Huang et al. DA has a high intelligence, but the environmental response is relatively slow. Huang et al. HA has the advantages of RA and DA, But the internal structure is complex. Huang et al. Because TCC is a real-time information processing control system and needs to make a quick response to the external information, so this paper all use RA. The multi-agent model of TCC all adopts RA.

Agent-agent and agent-environment need the interaction of various information in order to complete the function of TCC. So their communication is defined and adopts KQML (knowledge query and manipulation language). KQML is divided into three layers: the content layer, the message layer and the communication layer. Liao et al. The content layer mainly contains the information to be transmitted by KQML, whose presentation language is the language used by the message content. Liao et al. The message layer contains information about the attitude of the sender to the information in the content layer and the description of the content layer properties. And it usually includes the language used by the content, provenance of the term in the content and so on. The communication layer contains the parameters of the underlying communication, usually including the message sender, message receiver and so on. The form of KQML used by the multi-agent model of TCC as follows:

```
(tell
  :sender agent/environment
  :receiver agent/environment
  :language word
  :ontology TCC
  :content (expression))
```

The agent model structure used in this paper is showed in fig 1. In fig 1, perceiver is responsible for the perception of external information, receiving KQML communication information. Controller is responsible for the operation of the Rule, and combined with the internal state generates control commands. According to the control command, effector uses perceptual information to generate result information, sends result information to the agent external, and updates the internal state according to the result information and the transmission situation. Rule is a mapping of the received information to the corresponding function action. State is the internal working state of agent. Time is a discrete time series which is changed according to a certain interval.
HAZOP analysis method

HAZOP (Hazard and Operability Study) was first developed by the Imperial Chemical Industries Ltd in 1974. Because it is simple, easy to operate, and has characteristics of comprehensive analysis and strong adaptability. At present, it is widely used in the field of railway industry risk identification. HAZOP methods need to convene professionals of security aspects to analyze the object. These professionals will combine guide words with elements to determine the deviation through the form of a meeting. Then according to the deviation, the reasons for the deviation, the possible consequences and the measures taken are determined. Finally, the hazard log is formed. European railway transport management system in its security research report, adopts 9 guide words, which can be a very good description of deviation in the railway transport. Cui et al. These 9 guide words are No, More, Less, In error, As well as, Part of, Reverse, Earlier, Later. The same guide word combines with different elements, which has different meaning. Some combination between guide word and element has no meaning. And these combination need to be discarded. Cui et al.

III. MULTI-AGENT MODELING OF TCC

According to the structure of TCC in the 《TCC technical specification》, the reference model of TCC is obtained by simplifying its structure. The reference model of TCC is showed in fig 2.
In the reference model, SHU is mainly used for the logic operation and software and hardware management. DU is used to drive the suction and the fall of the corresponding relay. AU is used to collect the status of the relay. TCCIU is used for the information transmission between TCC and the track circuit. LEUCIU is used for the information transmission between TCC and LEU (Lineside Electronic Unit). AMU is used for the information transmission between TCC and centralized monitoring. CTCCIU is used for the information transmission between TCC and CTC (Centralized Traffic Control). SDNCIU is used for communication between the TCC and the adjacent TCC, interlock devices, and temporary speed limiting servers.

According to the reference model and the function of each unit, the multi-agent model of TCC can be obtained. The multi-agent model of TCC is showed in fig 3.

![Fig 3. The multi-agent model of TCC](image)

According to the structure and characteristics of TCC, the multi-agent model of TCC is abstracted into 8 agents, whose types and main functions are shown in table 1.

<table>
<thead>
<tr>
<th>Name</th>
<th>abbreviation</th>
<th>type</th>
<th>main function</th>
<th>classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHU agent</td>
<td>SHUA</td>
<td>RA</td>
<td>Data transceiver and logic operation</td>
<td>first kind</td>
</tr>
<tr>
<td>TCCIU agent</td>
<td>TCCIUA</td>
<td>RA</td>
<td>Data transceiver and time injection for information</td>
<td>Second kind</td>
</tr>
<tr>
<td>LEUCIU agent</td>
<td>LEUCIUA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AU agent</td>
<td>AUA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DU agent</td>
<td>DUA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SDNCIU agent</td>
<td>SDNCIUA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTCCIU agent</td>
<td>CTCCIUA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AMU agent</td>
<td>AMUA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The agents of multi-agent of TCC can be divided into two classes according to their main functions. The first class includes SHUA, which has complex logic operations and data transceiver functions. The second class is the other 7 agents, whose main function is to transfer...
the data between the environment and SHUA, and inject time to the transmitted information.

**Design and description of SHUA**

The SHUA is defined as the 6 tuple model. SHUA:=[<Name, Time, Input, State, Rule, Action, Output>]. In addition, SHUA also includes 5 actions, which are SHUA_GetEnv, SHUA_Control, SHUA_Act, SHUA_Send, SHUA_Updata. SHUA's tuple and actions are defined as follows.

SHUA_Name={SHUA};

SHUA_Time={t0, t1, t2…};

ISHUA_input={<balise status information and LEU device status information from LEUCIUUA>, <Track segment status information and Track circuit device status information from TCCIUA>, <Computer interlocking information, Temporary speed limit command information and Safety information between adjacent TCC stations from SDNCCIUA>, <Relay status information from AUA >};

SHUA_Rule={Rule-R1: if{[Route information, Temporary speed limit information, open state of inbound signal machine, Adjacent station line boundary information, Interval direction information, Directional relay status information, Interval track relay status information, The status information of Interval foreign invasion relay, Interval track segment status information]} Then (Interval track circuit code)

Rule-R2: if{[Route information, Temporary speed limit information, The status information of station foreign invasion relay, Station track relay status information, Station track segment status information]} Then (Station track circuit code)

Rule-R3: if{[Adjacent station line boundary information, The status of interval signal filament, The status of station entrance light filament]} Then (Interval signal lighting)

Rule-R4: if{[Route information, Temporary speed limit information]} Then (balise code)

SHUA_State={<stop>, <Start self checking>, <Set up communication>, <Communication failure>, <Initialization>, <Initialization exception>, <normal operation>, <Abnormal operation>, <off-line}> ;

SHUA_Action={<Interval track circuit code>, <Station track circuit code>, <Interval signal lighting>, <balise code>,…} ;

SHUA_Output={<balise message data to LEUCIUUA>, <The track circuit frequency and low frequency encoding information to TCCIUA>, <the information of allowing departure in interval, Interval state information, Disaster protection information, Status acquisition information of no wiring station signal machine, Temporary speed limiting state, Track section state, Interval direction information, Initial state information, Safety information between stations to SDNCCIUA>, <Interval block section status information, Interval signal machine status information and Equipment status information to CTCCIUA>, <Driving relay command information to DUA>, <agent Status information and alarm information of TCC to AMUA>}

SHUA_Rec==[env?: Environment

---

INTERNATIONAL COOPERATION ISSUE OF TRANSPORTATION - Especial Issue - No.07 141
The main content of SHUA_Perceiver is to perceive the information contained in SHUA_Input from the external environment.

The main content of SHUA_Control is to manipulate SHUA_Rule to generate action control commands, according to the content of rule. At the same time manipulating SHUA_Rule also need to check SHUA_State and SHUA_Time.

The main content of the SHUA_Act is to perform the function in SHUA_Action according to the action control command.

The main content of SHUA_Send is to send the results information that is contained in the SHUA_Output to the external agent.

The main content of SHUA_Update is to switch the state contained in SHUA_State, according to his feedback that includes the state of sending success and the sending content.

**Execution flow of SHUA**

1. Input=SHUA_Rec(Environment) SHUA_Time=t(i)
//SHUA perceives external information.
2. Command=SHUA_Control(input, rule, time, state)  SHUA_Time=t(i+1)
   //According to the perception of information, rules, state, time, control command is generated.
3. Output=SHUA_Act(Command, Input)  SHUA_Time=t(i+2)
   //Control commands activate the corresponding action and produce result information according to input information.
4. feedback=SHUA_Send(Output)  SHUA_Time=t(i+3)
   //The result information is sent to the agent external
5. SHUA_Updata(feedback)  SHUA_Time=t(i+4)
   //Update state of agent

**Design and description of TCCIUA**

TCCIUA is defined as the 6 tuple model. TCCIUA::<Name, Time, Input, State, Rule, Action, Output>. In addition, TCCIUA also includes 5 actions, which are TCCIUA_GetEnv, TCCIUA_Control, TCCIUA_Act, TCCIUA_Send, TCCIUA_Updata. TCCIUA's tuple and actions are defined as follows.

- Name={TC-TA};
- Time={t0, t1, t2⋯};
- Input={Track segment status information and Track circuit device status information from environment, Track circuit carrier frequency and low frequency coding information from TCC-KA}
- Rule={Rule-R1: if{[Track segment status information and Track circuit device status information from environment] then (data transfer)}
- Rule-R2: if{[Track circuit carrier frequency and low frequency coding information] then (data transfer)}
- Rule-R3: if{[Don’t receive information over a certain time] then(Communication exception handling)}
- State={<Normal communication>,<Communication exception>}
- Action={data transfer, exception handling} ;
- Output={Track segment status information and Track circuit device status information from environment to TCC-KA, Track circuit carrier frequency and low frequency coding information to environment}

The formal description of actions and execution flow of TCCIUA is similar to SHUA, here no longer to repeat.

**Design and description of similar agent**

Since the internal structure, state and function of the second kind of agent are similar and only the content of the transitional information is different, Internal description and execution flow of LEUCIUA, AUA, DUA, SDNCIUA, CTCCIUA and AMUA is similar to TCCIUA, here no longer to repeat.
**Data exchange in multi-agent model of TCC**

Since the function of TCC is numerous, the data exchange of the model is illustrated by the example of the interval track circuit code.

Input1=TCCIUA_Rec; Input2=AUA_Rec; Input3=SDNCIUA_Rec  \( \text{Time}=t(i) \)

//At the same time each agent parallel work. TCCIUA perceives track segment status information and track circuit device status information from environment as input1. AUA perceives directional relay status information, interval track relay status information, interval foreign matter intrusion relay status information from environment as input2. SDNCIUA perceives route information, temporary speed limit information, the signal state of inbound signal, the boundary information of the adjacent station, the interval direction information from environment as input3.

TCCIUA_Command1=TCCIUA_Control(input1, TCCIUA_rule, TCCIUA_time, TCCIUA_state)

AUA_Command1=AUA_Control(input2, AUA_rule, AUA_time, AUA_state)

SDNCIUA_Command1=SDNCIUA_Control(input3, SDNCIUA_rule, SDNCIUA_time, SDNCIUA_state)  \( \text{T}=t(i+1) \)

//According to the perception of information, rules, time and status of each agent, Action control commands are generated.

input1_t=TCCIUA_Act(TCCIUA_Command1, input1)

input2_t=AUA_Act(AUA_Command1, input2)

input3_t=SDNCIUA_Act(SDNCIUA_Command1, input3)  \( \text{T}=t(i+2) \)

//Control command activates the corresponding function, which is the information transfer function and injects the time stamp into the information.

feedback1=TCCIUA_Send(input1_t); feedback2=AUA_Send(input2_t);
feedback3=SDNCIUA_Send(input3_t);  \( \text{T}=t(i+3) \)

//The information that is injected to the time stamp is sent to the agent external.

TCCIUA_Updata(feedback1); AUA_Updata(feedback2);  SDNCIUA_Updata(feedback3);  \( \text{T}=t(i+4) \)

//Update state of agent according to the feedback of the transmission.

Input=SHUA_Rec;  \( \text{T}=t(i+5) \)

//SHUA perceives of input1_t, input2_t and input1_t.

SHUA_command=SHUA_Control(input, SHUA_rule, SHUA_time, SHUA_state);  \( \text{T}=t(i+6) \)

//According to the perception of information, rules, time and status of each agent, control command of interval track circuit code is generated.

output=SHUA_Act(SHUA_command, input);  \( \text{T}=t(i+7) \)

//Control command activates the function of interval track circuit code, which generates coding information.

feedback=SHUA_Send(output);  \( \text{T}=t(i+8) \)
//Send interval coding information to SHUA external.
SHUA_Updata(feedback); T=t(i+9)

//Update state of SHUA
output=TCCIUA_rec; output=CTCCIUA_rec; output=SDNCIUA_rec; T=t(i+10)
TCCIUA_command2=TCCIUA_Control(output, TCCIUA_rule, TCCIUA_time, TCCIUA_state);
CTCCIUA_command2=CTCCIUA_Control(output, CTCCIUA_rule, CTCCIUA_time, CTCCIUA state);
SDNCIUA_command2=SDNCIUA_Control(input3, SDNCIUA_rule, SDNCIUA_time, SDNCIUA_state) T=t(i+11)
output_t=TCCIUA_Act(TCCIUA_Command2, output)
output_t=CTCCIUA_Act(CTCCIUA_Command2, output)
output_t=SDNCIUA_Act(SDNCIUA_Command2, output) T=t(i+12)
Feedback4=TCCIUA_Send(output_t)
Feedback5=CTCCIUA_Send(output_t)
Feedback6=SDNCIUA_Send(output_t) T=t(i+13)
TCCIUA_Updata(feedback4);
CTCCIUA_Updata(feedback5);
SDNCIUA_Updata(feedback6); T=t(i+14)
//Interval coding information through TC-TA, CTC-PA, SDN-QA transmits to the external environment, whose process is similar to t(i) to t(i+4).

IV. HAZOP ANALYSIS OF MULTI-AGENT MODE OF TCC

The elements are given priority in the process of combining the elements with the guide words. Using HAZOP to analyze the multi-agent model of TCC can be divided into two layers. The first layer is that the agent layer is as the element to analyze risk. The second layer is that the content in a action of the agent is as the element to analyze risk.

The first layer

SHUA is as an example to carry out HAZOP. The HAZOP of other agent is similar to it. The example of the first layer hazard log is in table 2.

**Table 2. The example of the first layer hazard log table**

<table>
<thead>
<tr>
<th>node</th>
<th>element</th>
<th>Guide Words</th>
<th>deviation</th>
<th>Cause of occurrence</th>
<th>Possible consequences</th>
<th>recommended measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHUA</td>
<td>Host board</td>
<td>In error</td>
<td>Host board failure</td>
<td>Host board reliability is bad</td>
<td>TCC is out of service, endangering the safety of train operation</td>
<td>Using host board with high reliability; Regular maintenance; Output alarm when failure</td>
</tr>
</tbody>
</table>

The second layer

There are 4 typical contents selected from SHUA_Rec, SHUA_Control, SHUA_Act and SHUA_Update being carried out HAZOP. In each agent, HAZOP of SHUA_Rec is similar to that of SHUA_Send. The analysis of other agent actions is similar to that of SHUA. The example of the second layer hazard log is in table 2.
<table>
<thead>
<tr>
<th>node</th>
<th>element</th>
<th>Guide Words</th>
<th>deviation</th>
<th>Cause of occurrence</th>
<th>Possible consequences</th>
<th>recommended measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHUA_Rc</td>
<td>perceiving track segment status information and track circuit device status information from TCCIUA</td>
<td>No</td>
<td>Did not receive this information</td>
<td>TCCIU not working; SHU not working; Communication interrupt</td>
<td>Unable to track track circuit code; endangering the safety of train operation</td>
<td>Improving the reliability of TCCIU and SHU; Regular monitoring of communication lines; Real time monitoring equipment and transmission channel; When coding is abnormal, maintain the original coding sequence and give the alarm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In error</td>
<td>Receive this information in error</td>
<td>TCCIU processing error; SHU receiving error; communication transmission error</td>
<td>Track circuit coding update in error, threat to the safety of train operation</td>
<td>Improving the reliability of TCCIU and SHU; Regular monitoring of communication lines; Real time monitoring equipment and transmission channel; When an error is found, the coding is not updated.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part of</td>
<td>Receiving part of this information</td>
<td>TCCIU’s processing is not complete; SHUA’s receiving is not complete; the content of communication transmission is not complete</td>
<td>Unable to track track circuit code; endangering the safety of train operation</td>
<td>Improving the reliability of TCCIU and SHU; Regular monitoring of communication lines; Real time monitoring equipment and transmission channel; The missing information regard as a dangerous state.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Later</td>
<td>The delay of receiving this information</td>
<td>processing delay of TCCIU, receiving delay of SHU; Communication transmission delay</td>
<td>Unable to track track circuit code; endangering the safety of train operation</td>
<td>Improving the reliability of TCCIU and SHU; Regular monitoring of communication lines; Real time monitoring equipment and transmission channel; add a time stamp to the message; throwing away expired information and giving alarm.</td>
</tr>
<tr>
<td>SHUA_Action</td>
<td>Interval track circuit code</td>
<td>No</td>
<td>Don’t perform Interval track circuit code</td>
<td>SHU not working; program having bug</td>
<td>Interval track circuit coding is not updated; endangering the safety of train operation</td>
<td>Improving the reliability of TCCIU and SHU; standard program design; Improving program test; When the track circuit does not receive the code, the default code is JC.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In error</td>
<td>Interval track circuit code is false</td>
<td>program having bug</td>
<td>Interval code sequence is false; endangering the safety of train operation</td>
<td>standard program design; Improving program test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part of</td>
<td>Interval track circuit code is not complete</td>
<td>program having bug</td>
<td>Part of interval track circuit code is missing</td>
<td>standard program design; Improving program test; The missing code defaults to JC.</td>
</tr>
<tr>
<td>SHUA_Control</td>
<td>The condition of Interval track circuit code in SHUA_Rc</td>
<td>No</td>
<td>Don’t perform this condition</td>
<td>SHU not working; program having bug</td>
<td>Interval track circuit code is missing or not complete; endangering the safety of train operation</td>
<td>Improving the reliability of SHU; standard program design; Improving program test; When the coding is not updated, the code function can not be performed and the alarm is sent out.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In error</td>
<td>This condition is performed in error</td>
<td>program having bug</td>
<td>Interval track circuit code is error, endangering the safety of train operation</td>
<td>standard program design; Improving program test</td>
</tr>
<tr>
<td>SHUA_Update</td>
<td>Update to normal operation state</td>
<td>No</td>
<td>Don’t update to normal operation state</td>
<td>program having bug; having disturb</td>
<td>Unable to complete the function of the normal operation state; endangering the safety of train operation</td>
<td>standard program design; Improving program test; excluding disturb; forced system restart</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Earlier</td>
<td>Update to normal operation state in advance</td>
<td>program having bug; initialization is not complete</td>
<td>endangering the safety of train operation</td>
<td>standard program design; Improving program test; forced system restart</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Later</td>
<td>Delay of updating to normal operation state in advance</td>
<td>Abnormal operation environment</td>
<td>endangering the safety of train operation</td>
<td>keep a good operation environment</td>
</tr>
</tbody>
</table>
V. CONCLUSION

TCC is the key system of the ground equipment in the train operation control system, which plays a key role in ensuring the safety and efficiency of train operation. In this paper, multi-agent model theory and technology are introduced into TCC, exploring the method that is using multi-agent to model and describe TCC. According to the characteristics of the structure and function of TCC, the multi-agent model of TCC is established.

In this paper, the definition of each agent is in terms of function, state, information input, information output, functional constraints and system clock. Through the collaboration between the various agents, the description of TCC is implemented.

By taking the function of the interval track circuit code as an example, the whole data exchange and work flow of the model are discussed in detail. Because the multi-agent model of TCC can describe TCC from several angles. In this paper, the combination of HAZOP method and multi-agent model is used to carry out risk analysis from several angles, getting the security risk log of TCC.

In this paper, by using the HAZOP method, the risk analysis of the multi-agent model of TCC is carried out. Therefore, a risk analysis method that is the combination of HAZOP and multi-agent model is proposed. This method is highly adaptable and can carry out the risk analysis of the system from several angles. At the same time, by using the multi-agent model to describe TCC, laying the foundation for further simulation.

References


[4]. Cui J F. Research on risk analysis of train control center[D]. Southwest Jiaotong University, 2013: 14-20
In September 2015, Heads of State and Government who gathered at the UN General Assembly adopted the historical Agenda for Sustainable Development [1]. The document reflects a new task of halving the number of deaths and injuries from road traffic crashes by 2020. The adoption of the task with respect to road injuries means the recognition of substantial research data on measures facilitating the reduction of these injuries. There is considerable data on effective measures on road safety enhancement, and the countries where these measures are successfully implemented are facing a corresponding reduction of deaths resulting from road traffic crashes. Global implementation of these measures will provide a huge potential for lowering future costs and saving people’s lives.

In order to reduce injuries and accidents, the Federal Targeted Program “Road safety improvement in 2013-2020” has been implemented in Russia since 2013 [2]. The program’s effectiveness is guaranteed by applying the program-based method as the basis for state control in the sphere of road safety enhancement through the adoption and further implementation of the Program, because it will make it possible to:

Establish unified goals and objectives on road safety enhancement up to 2020;

Build up a system of priority measures on road safety enhancement which would influence the causes of accidents reasonably and systematically;

Improve the control efficiency in the sphere of road safety enhancement on the federal, regional and local levels, as well as in the sphere of interdepartmental interaction and coordination of federal executive bodies, the bodies of executive authority of the subjects of the Russian Federation and local self-government bodies;

Abstract: The article considers a solution to the problem of road traffic safety control. The principles of creating an expert system, its functioning, peculiarities and merits are described. The “driver-vehicle-road-environment” subsystem as an object of an expert system is briefly described.

Key words: Expert system, road safety, road accident, human error, motor vehicle safety, road.
Focus the state resources on implementing measures in accordance with the priority goals and objectives in the sphere of road safety enhancement;

Apply the result-oriented budgeting principles.

However, according to the leading researchers of Saint Petersburg State University of Architecture and Civil Engineering S.A. Yevtyukov, P.K. Kravchenko and the authors V.N. Burkov, V.D. Kondratyev and A.V. Shchepkin [3], at the moment the state policy in the sphere of road safety enhancement is only being formed and is characterized by a lack of cooperation and an insufficient coordination among public authorities, which leads to general discord and incoordination. Hence the conclusion on the necessity to significantly strengthen control in the sphere of road safety. The authors believe that in the country as a whole the road safety enhancement problem is solved by raising control efficiency, with functions being redistributed from the federal center to the regional and local levels.

An effective way of reducing the number of accidents is the application of the systemic approach to the problem of road safety control, which requires a joint effort of several sectors (transport, police, health care, education, mass media). The agreement and correlation of economic and socio-natural potentials should be regarded as an object for research and analysis. It is common practice to analyze road accidents by applying the “driver-vehicle-road-environment” system. Therefore, it is suggested to regard the “driver-vehicle-road-environment” (DVRE) subsystem as an element of the socio-natural-economic system (SNES) comprising the social, ecological and economic components [4].

The DVRE subsystem is a complex dynamic system including the combination of elements “person”, “motor vehicle”, “road”, all functioning in a certain environment [5, p. 16]. Road safety is guaranteed by the quality of these elements.

The motor vehicle’s influence on road safety is determined by its safety. Motor vehicle safety is secured in legislation at the production stage and is controlled throughout its operation. That is why the number of road accidents due to the vehicle’s failure or faults of its safety is traditionally quite low. Storing information about such road accidents will make it possible both to improve the motor vehicle safety system requirements and the contents of tool control over the state of these systems during their operation.

Human error is thought to be the major factor causing road accidents. The driver is both the most significant and the most unstable element of the DVRE system. By their nature, people are unstable, changeable, poorly predictable, due to which the problem of evaluating the stability of this element’s functioning is complicated by its ambiguity. In the suggested system, the driver is the only control element without which the system cannot function [6, p. 13].

The driver’s behavior is of peculiar importance in cities in conditions of high intensity and non-uniformity of traffic and higher driver error significance. In this case, the driver’s behavior is reflected in breaking traffic rules prior to road accidents. The impact of this or that traffic violation is impossible to evaluate quantitatively because of road users’ subjectivity, which, in
its turn, leads to ambiguity. Indeed, a complex system, where people play a most active part, is characterized by the so-called incompatibility principle: “in order to obtain significant conclusions as to the behavior of a complex system, it is necessary to abandon the high standards of precision and rigor which are characteristic of relatively simple systems and to analyze it with approaches which are approximate in their nature” [7, p. 10].

Researches show that “frequently, a person’s behavior is more effectively influenced by improving road traffic conditions than by training or by police control” [8, p. 54]. This stresses the relevance of the safety level provided by a road.

At present, the method based on road accident statistic analysis, the accident rate method, and the safety factor method are used to evaluate road traffic safety [9, p. 6]. The methods of finding dangerous road sections on the basis of road accident statistics are used to evaluate road safety on the existing roads with complete and reliable information available on road accidents over a period of not less than 3-5 years. When the data is not available or when it is necessary to evaluate design decisions in constructing new roads or reconstructing the existing ones, the accident rate method is used which is based on the analysis and summary of road accident statistics. The safety factor method is based on the analysis of speed-time charts for road traffic. These methods make it possible to evaluate how geometric features of the road, condition of the road surface, traffic density influence road safety. However, the information obtained in applying these methods does not provide for direct decisions, instead it requires additional research, which does not make it possible to use the methods for operating control over road safety.

Artificial intelligence methods are being increasingly used for solving problems in complex systems. Expert systems are among the most developed directions of artificial intelligence. They are complex software applications aimed at storing knowledge on a certain sphere and manipulating knowledge in order to solve problems of their domain [10, p. 60].

Expert systems are used in solving complex practical tasks; in the quality and effectiveness of decision-making, expert systems match the decisions of human experts, they can be explained to the user on the qualitative level and can enrich their knowledge [11, p. 9]. These opportunities dictate the need for the Road Safety Expert System (RSES) (Figure 1).

The RSES includes the following components: 1) the knowledge base with regulatory documentation, expert evaluation and scientific research as its foundation; 2) the database accumulating the outside information, including the information on road accidents; 3) the solver (controlling component) determining the necessary actions on road safety control by using the knowledge base and the database; 4) the explanatory component explaining the decision-making process; 5) the interface connecting the user and the expert as parts of a single information environment with the RSES; 6) the component of knowledge acquisition through the dialog with the expert.

The informal character of the problems being solved in designing expert systems implies
the use of the “rapid prototype” principle. It means that at the initial stage an expert system prototype is created to meet two opposite requirements: on the one hand, it is to solve typical problems, on the other hand, its development effort must be quite insignificant. The means of speeding up the design process are generally called tools [11, p.13]. As the knowledge grows, the prototype can reach the state of successful problem-solving.

![Diagram](image)

**Figure 1.** A generalized road safety expert control system diagram.

The main task of the RSES is to search for decisions on road safety improvement. The RSES is intended to provide counseling on field-specific issues in decision-making in the sphere of road safety in order to enhance and widen its users’ professional capabilities.

Peculiar features of the RSES are:

1. Expert examination can be conducted in one specific field only.
2. The expert system explains the course of solving a problem (reasoning chain) in a way which is clear to the user (they may ask how and why this particular solution was obtained and get a clear answer).
3. The output results are qualitative, not quantitative (numerical).
4. The system is modular, which allows the extension of the knowledge base.

The RSES merits are:

1. Storage and extension of experience and knowledge of highly skilled specialists.
2. The opportunity to solve practical tasks.
3. The efficiency of decisions made by the expert system which match the decisions made by a human expert.
4. “Transparency”, i.e. the opportunity to explain the causes and mechanisms of decision-making.
5. The ability to enrich and to correct knowledge during the dialog with the expert.
6. Availability for solving road safety control problems at any level.
7. Applicability as a training program.

The RSES formation and maintenance is based, on the one hand, on scientific research in the field of road safety and, on the other hand, on the opportunities of organizations working with government institutions responsible for road safety. The task of leading universities should be to generate and accumulate scientific researches in the sphere of road safety and to provide their objective evaluation.

CONCLUSIONS

The development and implementation of the road safety expert system will make it possible to solve the following problems: to form decisions at all levels of road safety control with account of their peculiarities and state; to monitor the efficiency of the decisions and, if necessary, correct and improve them; to provide rapid and wide implementation of new road safety control methods. The data required for the preparatory stage (expert evaluation and its results’ processing) can be reused. The statistics stored in the Road Safety Expert System database will provide for the timely evaluation of the road safety level.

The RSES application in road safety control is an effective way of reaching the main goal: to reduce the number of deaths, to lower road injuries and accidents.

References
[4]. Korchagin, V.A., Lyapin, S.A., Klyavin, V.E., Sitnikov, V.V. Road Safety Improvement on the Basis of Road Accident Analysis and Simulation // Fundamental Research. 2015. # 6-2. pp. 251-256. (In Russian)
CONCEPT OF PREVENTIVE MOTION CONTROL APPLIED TO BUSES AND COMMERCIAL VEHICLES

Dr. Mikhail Malinovsky
State Technical University - MADI, Moscow, Russia

Abstract: Despite numerous inventions have been introduced in the field of active safety during past two decades, insufficient safety of buses and commercial vehicles still remains an actual problem. Accidents involving urban and interurban buses, as well as heavy articulated trucks cause many more victims than those involving passenger vehicles. The aim of work has been to define functional compound of innovative complex active safety system based on method of preventive motion control in order to improve the road traffic safety level by avoiding accidents. The author has summarized new links in the driver - automobile - road - environment system conditioned by human factor influence, and fulfilled evolitional analyze of active safety systems development, having applied method of scientific deduction. Principles of the human factor problem solution in the field of road traffic safety have been designated, a new classification of active safety systems has been charted, and functions of preventive motion control system have been enumerated.

Keywords: Road traffic safety, active safety systems, constructive safety, driver - automobile - road - environment system, method of preventive motion control, driver attention monitoring.

1. INTRODUCTION

The automobile construction has changed significantly in the past 50 years. It is hard to overestimate positive influence of different solutions in the active safety field on decrease of number of accidents and deaths on roads of the world, such as, for example, compulsory application of anti-lock braking system and electronic stability control in light passenger vehicles. Unfortunately, one has to face the facts that active safety systems, more and more widespread in passenger vehicles, are introduced in buses and cargo vehicles with considerable retardation. Meanwhile accidents involving those, as a rule, have more severe consequences, and drivers of those work in harder conditions. Amount of victims in an accident involving two light passenger vehicles can reach 8 or 10, whereas up to 80 persons risk their lives in a collision of two buses! While a commercial articulated vehicle driver loses control, chances of persons standing in his way vanish. Besides, in practice, modern road barriers that retain light vehicle successfully fail to resist impact of a heavy articulated vehicle. Therefore obligatory application of such systems should be legislated, first of all, in buses and commercial cargo vehicles (as it happened in Russia, for example, to ABS that was prescribed obligatory since 15.08.2004 exactly in buses).

Fixed - route buses and commercial articulated vehicles have their own specificity [1]. As a rule, drivers of those perform long rides of several hours with rigid timetable in hard conditions [2]. Work in such conditions, despite modern, partially automated control systems and high
usability of driver’s workbench, leads to high rate of driver fatigue causing driver reaction time increase and high probability of distraction from road situation. Numerous cases of heart attacks, loss of consciousness, falling asleep that led to accidents have been fixed.

Besides, the global statistics of accidents show an interesting phenomena: in a few years after introducing of any active safety system happens an increase of accidents number. The thing is that every invention, after initial positive effect, over a period of time forces a negative inverse effect. Inverse effect from introduction of any active safety system has four directions:

1. Uncoordinated and restricted trend of inventions in the field of active safety.
2. Correcting character of active safety systems’ action leads to drivers’ intentions to find and exceed stability limit that is provided by the given system.
3. Effect from action of a corrective system is annihilated by drivers’ intentions to exceed other stability limits of vehicle.
4. Application of active safety systems leads to decrease of drivers’ attention concentration on the road and common level of drivers’ abilities.

The task of the author’s research is to find solutions for the problems mentioned above.

II. FACTORS INFLUENCING ON ROAD TRAFFIC SAFETY

Consideration of the driver – automobile – road – environment system (DARES) in the last several decades has reached a new level in comparison to 1970’s when Robert Rotenberg explored this question [3]. In order to improve road traffic safety the author offers to take new links into consideration, especially those involving influence of the human factor.

1. Factors influencing on the driver subsystem:
   - Law sphere, such as conflict situations in the traffic rules [4], responsibility for violation of the traffic rules, introduction of motor third-party liability (MTPL) insurance;
   - Quality of education in driving schools;
   - General level of individual behavior culture in the society.

2. Factors influencing on the automobile subsystem:
   - Quality of production and assemblage of vehicles;
   - Timeliness and quality of technical service and repair of vehicles;
   - Organization of technical revision of vehicles;
   - Active and passive safety level.

3. Factors influencing on the road subsystem:
   - Quality of road traffic organization, including lights regulation, drawing of road marking, road works designation;
   - Quality of roads building and repair;
   - Road infrastructure development level;
   - Introduction of intellectual transport systems (ITS);
   - Road cleaning and anti-icing meanings.

All the foresaid problems are hard-to-solve. Exist organizational and technical ways to solve those. Once the potentialities of the former ways are exhausted, the government swaps to the latter ones, and there are two principles of solving the DARES problems:
1) To help a driver to violate the traffic rules and speed limits safely if it is impossible to make him follow those;

2) To restrict engines’ power (as it is done, for example, in Japan) and introduce different intellectual systems limiting vehicles’ velocity.

There are not many countries ready to follow the second principle, and Russians with their mentality would be last in the list. Therefore most countries follow the first principle, inventing active safety systems that are designed to minimize the human factor influence on vehicle control process. However, anti-lock braking system, anti-spin regulation, electronic stability control, etc., all these systems increase maximal safe speed of vehicle, but not the safety itself [5]. On the contrary, introduction of those rather promotes obtrusion of danger sense and decreases concentration of attention behind the wheel to most of the drivers. In this situation it is necessary to find a reasonable balance between restrictions and permits, or to introduce rigid limits without any possibility to switch those systems off. And if some “popular skilled craftsmen” unplug safety fuses, the engine simply should not start. The only hidden problem is in certification testing, but it can be easily solved by application of special set-ups for electronic control units that are known to nobody but manufacturer or automatic switching on after a certain period of time.

Also, drivers’ attention is significantly distracted by mobile phones, multimedia devices in modern vehicles, application of navigators during motion (the route should be explored before a ride), and so on.

Automated vehicle control, nowadays already possible from the technical point of view, is considered a heal of any disease on the road, but it cannot become such a heal unless all the vehicles at once become automated. However, at first such technologies should get no more expensive than mobile phones, so that those could be introduced on all the vehicles without exception. Otherwise application of fully automated systems is unacceptable.

III. PREVENTIVE MOTION CONTROL METHOD

In order to solve the problems formulated above, a modern active safety system should be based on the method of preventive motion control suggested by the author in 2009 [6], that is to imply:

1) Preventive character of action;
2) Unlimited adaptability to driver’s actions;
3) Complex functional compound.

Basing on evolutional analyze of vehicle control systems development, the author has derived four directions of active safety systems development that are conditioned by links in the DARES:

1. Behavioral micro level (wheel behavior). Includes anti-lock braking system, brake assist, electronic brake distribution, anti-spin regulation, hill assist, active front steering, active geometry control suspension.
2. Behavioral macro level (vehicle body behavior). Includes electronic control system, dynamic stability control, trailer assist, active suspension.
3. Internal level (driver and technical state of vehicle). Includes tire pressure regulation system, tire pressure monitoring system, onboard diagnostics, driver monitoring system.
4. External level (distance and side gap). Includes active cruise control, collision mitigation.
system, engine start-stop system, blind spot assist, lane-keeping assist, cross-traffic assist, intellectual transport systems, traffic sign recognition.

Modern preventive motion control system (PMCS) should synthesize all those four levels, implying a complex of functions, presented on Fig 1. Sensors and actuators can be divided into PMCS functions (Fig 2). Functions interfere each with other, receive signals from needed sensors, and send control signals to needed actuators.

Functions linked directly to actuators are considered primary. Secondary functions connect actuators via other functions. For example, course stabilization function realizes control signal to brake mechanisms via adaptive braking function, to engine revolutions and active differentials via acceleration regulation function, and to steering gear via active steering function.
Sergei Buznikov mentions such destabilizing factors as loose wheel and suspension or steering destruction, and offers to use backlash sensors in order to prevent accidents forced by those reasons [7]. Backlash sensors relate to onboard diagnostic function.

Speed limitation and spatial orientation functions interfere closely. The former is capable to distinguish road signs by means of video camera or receive signals from external transponders. The latter is meant to define vehicle’s location on map correcting basing on result of visual recognition of environment. Thus, the functions mentioned above interfere actively with different intellectual transport systems, related to transport telematics [8].

IV. DRIVER STATE MONITORING

Researches show that 20% of accidents, especially during the night and the morning hours, happen due to fatigue and drowse of drivers [9]. In 1977 an engineer of “Nissan” received patent for a vehicle drive alertness apparatus monitoring steering wheel oscillations [10]. However works were postponed and restored almost 30 years later.

Engineers and scientists switched their efforts towards systems that register and correct vehicle behavior directly. In 1978 anti-lock braking system appeared the first ever active safety system. Basing on anti-lock braking system, anti-spin regulation (in 1986), electronic stability control (in 1995) and active cruise control (in 1998) were invented. Such innovative systems as blind spot assist (in 2000) and lane-keeping assist (in 2001) were applied in series production. Popularization of those became an important step towards accident rate reduction.

In the middle of 2000’s driver attention monitoring systems (DAMS) of two types appeared, direct and indirect. Direct DAMS control driver’s pulse, behavior of eyes and eyelids, head position, mimicry. Indirect DAMS estimate adequacy of driver’s action by indirect signs such as vehicle behavior or effect on controls (for example, a long-time constant pedal position). Also remote DAMS are being invented [12].

Initially, blind spot assist, lane-keeping assist, and DAMS were strictly informational. In this case those only warn the driver and do not interfere in work of other control systems. But modern tendency is introduction of preventive systems capable to correct vehicle’s trajectory by influencing on anti-lock braking system modulators or active steering system.

Vigilance systems widely used in the railway transport have two features in comparison to DAMS:

1) Interval between trains is calculated subject to the float for driver’s vigilance check. On the road distance changes unpredictably and at any moment is able to shorten down to the critical one;

2) A train follows the rails while stops automatically without driver’s action. For a vehicle it is not always right decision to keep going straight as the road can become bent or some obstacle can arise.

Driver vigilance system can also be applied in motor transport. But its pushbutton must be situated under driver’s hand, not under foot. It is advisable to have two pushbuttons under each hand that are activated by turns in random order. The system should warn after several minutes of driver’s inactivity. Reaction of the system should be vibration of driver’s seat and acoustic signal. Vigilance system is effective on falling asleep prevention, but useless against loss of
consciousness, because the road situation changes abruptly and unpredictably, as opposed to the railroad where no other train is expected on the distance of two light signals.

Installation of tachograph is considered one of important measures on decreasing rate of accident by controlling driver’s actions. However, in general, any controlling measures are always less effective than preventive ones and not able to solve the problem. Accidents should be prevented.

Analysis of accidents involving fixed-route buses happened in Russia during last several years shows that introduction of any named active safety system separately is only a partial measure and will not allow to reach desirable effect on rate of accident decrease. For example, switching turning signals on deactivates lane-keeping assist system, and if driver feels bad right after that (as it happened in Saint-Petersburg in June of 2014) it would not help. Besides, those systems are not designed to stop the vehicle.

Late accidents involving buses show high importance of driver monitoring function that should fulfill all the tasks of direct, indirect, and remote DMS, as well as driver vigilance system. Driver monitoring function controls the vehicle via side gap function that overlaps tasks of blind spot assist, lane-keeping assist and cross-traffic assist. The mission of driver monitoring function is to determine driver’s disability, send signals to distance regulation function that should stop the vehicle smoothly, while course stabilization and side gap control functions help to keep it in the chosen lane (fig 3). Thus, driving monitoring is the key function of preventive motion control system.

![Functional diagram of driver monitoring](image)

**V. CONCLUSION**

During the research executed the author has formulated:

1) Problems of inverse effect from active safety systems introduction;
2) New links in the DARES, conditioned by the human factor;
3) New classification of active safety systems by development directions;
4) Set of primary and secondary functions of preventive motion control system;
5) Connection of preventive motion control system functions with sensors and actuators of vehicle.

The aspects gained in the current research provide improvement of algorithms for the modern preventive motion control system.

The complex approach allows optimizing the ratio of efficiency of an active safety system to set of sensors and software taking links in DARES and directions of development of vehicle control systems into consideration.

Efficiency of an active safety system is calculated by the following formula:

\[ \varepsilon = \frac{S}{C} \]

Where \( S \) – number of critical situations solvable by given system; \( C \) – total multiplicity of critical situations.

The author considers invention of a preventive motion control system and its introduction in buses and commercial vehicles one of the priority tasks in the field of road traffic safety improvement.

References
[5]. Majboroda O.V., Bragina I.V., Barkov A.A. Avtotransportnoe predprijatie. 2015, no. 6, p. 45-50.
<table>
<thead>
<tr>
<th>MADI’s Editorial</th>
<th>SWJTU’s Editorial</th>
<th>UTC’s Editorial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Dr.Sc. N. Baurova</td>
<td>Prof. Dr. Zhao Yong</td>
<td>Assoc. Prof. Dr. Nguyen Van Vinh</td>
</tr>
<tr>
<td>Prof. Dr.Sc. A. Buslaev</td>
<td>Prof. Dr. Zhai Wanming</td>
<td>Assoc. Prof. Dr. Tran Dac Su</td>
</tr>
<tr>
<td>Assoc. Prof. Dr. A. Chubukov</td>
<td>Prof. Dr. Qiu Yanjun</td>
<td>Assoc. Prof. Dr. Nguyen Duy Viet</td>
</tr>
<tr>
<td>Prof. Dr.Sc. I. Demyanushko</td>
<td>Prof. Dr. Li Qiao</td>
<td>Assoc. Prof. Dr. Nguyen Ngoc Long</td>
</tr>
<tr>
<td>Prof. Dr.Sc. D. Yefimenko</td>
<td>Prof. Dr. Gao Shibin</td>
<td>Assoc. Prof. Dr. Nguyen Van Hung</td>
</tr>
<tr>
<td>Prof. Dr.Sc. A. Ivakhnemko</td>
<td>Prof. Dr. Peng Qiyuan</td>
<td>Assoc. Prof. Dr. Nguyen Van Long</td>
</tr>
<tr>
<td>Prof. Dr.Sc. A. Ivanov</td>
<td>Prof. Dr. Pan Wei</td>
<td>Assoc. Prof. Dr. Bui Ngoc Toan</td>
</tr>
<tr>
<td>Prof. Dr.Sc. M. Karelina</td>
<td>Prof. Dr. Li Fu</td>
<td>Assoc. Prof. Dr. Nguyen Duy Tien</td>
</tr>
<tr>
<td>Prof. Dr. G. Kustarev</td>
<td>Prof. Huang Nan</td>
<td>Prof. Dr. Pham Duy Huu</td>
</tr>
<tr>
<td>Prof., Dr.Sc. A. Makovskiy</td>
<td>Prof. Dr. Liu Xueyi</td>
<td>Prof. Dr. Nguyen Viet Trung</td>
</tr>
<tr>
<td>Prof., D.Sc. A. Nikolaev</td>
<td>Prof. Dr. Zheng KaiFeng</td>
<td>Prof. Dr. Do Duc Tuan</td>
</tr>
<tr>
<td>Prof., Dr.Sc.V. Nosov</td>
<td>Prof. Dr. Zhang Jin</td>
<td>Prof. Dr. Sc. Nguyen Huu Ha</td>
</tr>
<tr>
<td>Prof., Dr.Sc.A. Ostroukh</td>
<td>Prof. Dr. Liu Dan</td>
<td>Prof. Dr. Pham Huy Khang</td>
</tr>
<tr>
<td>Prof., Dr.Sc. L. Petrova</td>
<td>Prof. Dr. Yang Yiren</td>
<td>Prof. Dr. Bui Xuan Cay</td>
</tr>
<tr>
<td>Prof. D.Sc. T. Polyakova</td>
<td>Prof. Liu Bin</td>
<td>Assoc. Prof. Dr. Le Hai Ha</td>
</tr>
<tr>
<td>Prof. Dr.Sc.P. Pospelov</td>
<td>Prof. Dr. Song Jirong</td>
<td>Assoc. Prof. Dr. Dao Manh Hung</td>
</tr>
<tr>
<td>Prof. Dr.Sc.V. Prikhodko</td>
<td>Dr. Nguyen Canh Minh</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr.Sc. A. Rementsov</td>
<td>Assoc. Prof. Dr. Vu Trong Tich</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr.Sc. M. Shatrov</td>
<td>Assoc. Prof. Dr. Le Hong Lan</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr.Sc.A. Solntsev</td>
<td>Assoc. Prof. Dr. Ngo Dang Quang</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr.Sc.Yu. Trofimenko</td>
<td>Dr. Pham Thanh Ha</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr.Sc. V. Vlasov</td>
<td>Dr. Nguyen Tuan Anh</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr.-Ing. Frank-Detlef Wende</td>
<td>Dr. Nguyen Sy Trung</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr.Sc. S. Zhankaziev</td>
<td>Assoc. Prof. Dr. Tran Tuan Hiep</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr.Sc. V. Zorin</td>
<td>Assoc. Prof. Dr. Do Viet Dung</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assoc. Prof. Dr. Tu Sy Sua</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECRETARY SECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assoc. Prof., Dr. M. Malinovskiy</td>
</tr>
</tbody>
</table>