Faculty of Operation and Economics of Transport and Communications
University of Žilina
Žilina, Slovakia

TRANSPORT AND COMMUNICATIONS

Scientific journal

tac.uniza.sk

II/2016 Volume IV ISSN 1339-5130

TRANSPORT AND COMMUNICATIONS

Scientific journal intended to combine theory and practice in the field transport and communications and thus advancement of transport and communications sciences

DOI: 10.26552/tac.J.2016.2
ISSN 1339-5130

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Transport and Communications, 2016; Vol. II. DOI: 10.26552/tac.C.2016.2.1
ISSN: 1339-5130

Channel Coding in Optical Communication Systems

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Abstract In this paper, an overview of various types of error-correcting codes is present. Three generations of forward error correction methods used in optical communication systems are listed and described. Forward error correction schemes proposed for use in future high-speed optical networks can be found in the third generation of codes.

Keywords FEC, channel coding, LDPC, Turbo codes

JEL C690

1. Introduction

Forward Error Correction (FEC) is an important part of modern communication systems. Throughout history new types of channel codes and FEC schemes with higher error-correcting performance were introduced. In section 2 of this paper, an overview of different types of channel codes is shown. Methods of error correction used in optical networks are described and divided into generations in section 3. FEC schemes proposed to be used in future optical networks are also mentioned in section 3.

2. Overview of Channel Coding Methods

In 1948 Claude Shannon published his influential paper *A Mathematical Theory of Communication* on the limits of reliable transmission of data over noisy channels, which founded the fields of channel coding, source coding, and information theory. Shannon established the mathematical foundations for information transmission and derived the fundamental limits for digital communication systems. He formulated the basic problem of reliable transmission of information in statistical terms, using probabilistic models for information sources and communication channels [1-3].

Hamming codes are the first error-correcting codes. They are a class of linear block codes and were invented by Richard Hamming in 1950. Before them only a few simple error-detecting schemes were used e.g. parity bit, two-out-of-five codes, repetition codes. For each natural number m larger than 1, there exists a $(2^m - 1, 2^m - 1 - m)$ Hamming code. Every Hamming code is able to correct one error and detect two errors in each code word. The first introduced Hamming code had code word length of 7 bits and data word length of 4 bits, denoted (7, 4). Nowadays Hamming codes are still used in some types of ECC memories [2], [4-5].

In 1954 David E. Muller described a class of multiple-error-correcting codes [6] and Irving S. Reed proposed the first algorithm for decoding these codes (known as majority decoding) [7]. Today this class of binary linear block codes is called Reed-Muller codes. Their advantage is simple description and simple decoding algorithm [2].

Convolutional codes are a class of linear time-invariant tree codes and can be generated by a linear shift-register circuit that performs a convolution operation on the data sequence. They were first introduced in 1955 by Peter Elias. Convolutional codes were first decoded by sequential decoding, but they became popular only after the Viterbi algorithm was developed in 1967 by Andrew Viterbi. This algorithm is much simpler, but is preferred for convolutional codes of modest complexity. However it is impractical for stronger convolutional codes. Convolutional codes are used in various applications, e.g. multiple wireless systems, mobile communications and satellite communications [4], [8].

BCH codes are a wide class of linear block error-correcting codes. Reed-Muller codes and popular Reed-Solomon codes are both subclasses of BCH codes. They were invented in 1960 by Raj Bose and D. K. Ray-Chaudhuri [9] and independently by Alexis Hocquenghem in 1959 [10]. BCH codes played a fundamental role in research on algebraic coding techniques. There exist various simple methods for their encoding and decoding (e.g. syndrome decoding). They are used in applications such as satellite communications, compact disc players, DVDs, disk drives, solid-state drives and two-dimensional bar codes [2].

Reed-Solomon codes are a class of non-binary cyclic linear block codes and were introduced in 1960 by Irving S. Reed and Gustave Solomon [11]. They can correct multiple errors and are also effective against burst errors. Reed-Solomon codes are often used in concatenation with convolutional codes for added efficiency. Reed-Solomon codes are used in compact discs, DVDs, Blu-ray discs, data storage devices, data transmission technologies such as DSL and WiMax, broadcast systems such as DVB and ATSC, and satellite communications [2], [12].

Turbo codes are powerful forward error correction codes that are able perform very close to the Shannon limit. They were first publicly introduced in 1993 by Claude Berrou et al. [13]. Optimal algorithm for their decoding, the BCJR algorithm (named by its inventors: L. Bahl, J. Cocke, F. Jelinek and J. Raviv [14]), was originally intended for decoding of convolutional codes, but it was too complex compared to Viterbi algorithm with similar error-correcting performance. BCJR algorithm was therefore mostly ignored until the introduction of turbo codes. Turbo codes use several principles to achieve their performance: interleaving, iterative decoding, MAP (Maximum A Posteriori) algorithm, soft-decision decoding, concatenation of channel codes. Recursive convolutional codes are also an integral part of turbo codes. There also exists a class of block turbo codes known as TPC (Turbo Product Codes). Turbo codes are used in UMTS and LTE mobile communications, satellite communications, IEEE 802.11 (WiFi) and IEEE 802.16 (WiMax) standards [2], [5].

LDPC (Low Density Parity Check) codes are a class of linear block codes that are able to perform close to the Shannon limit. LDPC codes were developed by Robert L. Gallager in 1960 [15]. However, they were impractical to implement at the time, so they were forgotten until his work was rediscovered in 1996. Their architecture is efficient and supports parallelism in decoding, computational simplicity and various code rates. They can also employ several principles used in turbo codes to achieve high error-correcting performance. Multiple algorithms can be used for their decoding. LDPC codes are used for various applications, including satellite communications, Deep Space Network, DVB-S2 (Digital Video Broadcasting) standard, 802.11 standards [2].

In 2009 a new class of linear block error-correcting codes known as polar codes were introduced by Erdal Arikan. Polar codes can provably achieve capacity of binary symmetric memoryless channels and can be encoded and decoded with low complexity. These codes and their performance in concatenation with other channel codes are still being studied today [14].

3. Channel Codes in Optical Communications

In first optical networks no forward error correction was used. At the time 10^{-9} was the acceptable bit error rate. Channel codes used in fiber-optic communication are often divided into several generations. These will be described in the following paragraphs.

3.1. First Generation

First deployment of FEC (forward error correction) for optical transmission was in submarine systems developed in the early 1990s. First generation of channel codes for optics were linear block codes with hard-decision decoding, e.g. BCH (Bose–Chaudhuri–Hocquenghem) codes, RS (Reed-Solomon) codes or Hamming codes. Targeted overhead was typically 7% or less. Codes of this generation were successfully used in trans-Pacific and trans-Athlantic communication systems and provided data rates as high as 5Gbit/s.

RS(255,239) code is the most popular code of this generation and has been used in broad range of long-haul communication systems. It is described in ITU-T recommendation G.975 (Forward error correction for submarine systems) [17]. Reed-Solomon codes are suitable for mitigation of burst errors because of their nonbinary structure. RS(255,239) code was also successfully used to mitigate BER fluctuations caused by the polarization dependency effect in optical fibers. Net coding gain (NCG) achieved with this code is close to 6 dB, its overhead is 6.69% and required value for measured input BER is 6×10^{-5}. It can correct burst errors with maximum length of 1024 bits when advanced interleaving techniques are used. General expectation for this generation of codes is a coding gain near 6 dB at an output BER of 10^{-12} [12], [18-21].

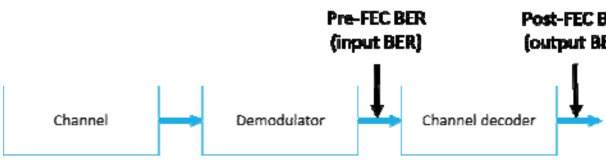

Figure 1. Explanation of Bit Error Rates.

3.2. Second Generation

This generation of codes focuses mainly on serially concatenated channel codes. Information bits are first encoded by the inner encoder and its output is encoded by the outer encoder. Concatenation of codes is also possible in a parallel way. These schemes allow for higher coding gain by increasing minimum Hamming distance. If inner code enables minimum distance d and outer code enables minimum distance D, the concatenation scheme of these codes results in minimum distance of at least $D \times d$.

Another important part of these coding schemes is interleaving with iterative and convolutional decoding techniques. These improvements allow technology to support 10G and 40G transmission systems. Hard-decision decoding is used in this generation of codes and recommended coding overhead is still 7% or less. Required input BER for these schemes is usually close to 3.8×10^{-3} and in many cases they achieve net coding gain higher than 8 dB at an output BER equal to 10^{-15}. ITU-T G.975.1 recommendation [22] (Forward error correction for high

Transport and Communications, 2016; Vol. II.
ISSN: 1339-5130
DOI: 10.26552/tac.C.2016.2.1

bit-rate DWDM submarine systems) describes several concatenated and also non-concatenated FEC schemes for 10G and 40G optical communication systems. Channel codes used in these schemes are RS codes, BCH codes, extended Hamming product codes, convolutional self-orthogonal codes (CSOC) and LDPC codes. Overview of codes from the ITU-T G.975.1 recommendation is in Tab. 1. Each of the described coding techniques satisfies demands on different parameters and features such as correction ability, latency, decoding complexity, etc. For example, concatenation of codes generally increases latency, so there are a few non-concatenated channel coding techniques present in the document. Other code schemes that belong to the second generation of channel codes for optical systems are RS(255, 239)+RS(255, 223), RS(239, 223)+RS(255, 239), RS(248, 232)+RS(144, 128) or RS(247, 239)+RS(255, 247). Codes of this generation are expected to correct burst errors at least 1024 bits long, but this highly depends on component codes used in each FEC scheme [12], [18-21].

Table 1. Overview of super FEC schemes from ITU-T G.975.1

FEC scheme	
Conctenated or non-concatenated	**Used FEC code**
Concatenated FEC	Outer code: RS(255,239) Inner code: CSOC ($n_0/k_0 = 7/6$, J = 8)
Concatenated FEC	Outer code: BCH(3860,3824) Inner code: BCH(2040,1930)
Concatenated FEC	Outer code: RS(1023,1007) Inner code: BCH(2047,1952)
Concatenated FEC (Soft Decision capable)	Outer code: RS(1901,1855) Inner code: Extended Hamming Product Code (512,502) × (510,500)
Non-concatenated FEC	LDPC code
Concatenated FEC	Two orthogonally concatenated BCH codes
Non-concatenated FEC	RS(2720,2550)
Concatenated FEC	Two interleaved extended BCH(1020,988) codes

3.3. Third Generation

Forward error correction schemes designed for future 100G optical transmission systems belong to the third generation of codes for optical communications. They are also suitable for 40G or even 400G long-haul transmission systems. Most of these are soft-decision FEC schemes. Mathematics and advantages of soft-decision decoding have been known for years, but their use in optical systems is now possible thanks to coherent detection and advancements in integrated circuit technologies. Limiting factor of optical networks was their very high transmission rates. Soft-decision codes are computationally intensive and limitations in ASIC (Application-Specific Integrated Circuit) and in other technologies prevented their hardware implementation.

Recommended code overhead was raised from 7% of previous generations to 20% or more (by Optical Internetworking Forum). Expected net coding gain is at least 10-11 dB at a 10^{-15} output BER, considering 20% overhead and soft-decision FEC. Channel codes are mostly judged by their net coding gain and some hard-decision FEC codes are also suitable for next generation optical networks. However in case of high net coding gain their BER performance is inferior to the soft-decision codes. Their usage can be desirable e.g. in cases when cheaper hardware implementation (thanks to less complex components) is more important than better BER performance. These hard-decision channel codes with high net coding gain can be considered 2.5th generation of codes for optical communications.

Long-haul optical transmission systems need FEC solutions with high net coding gain in order to ensure required BER with lower OSNR (Optical Signal-to-Noise Ratio). Requirements for measured pre-FEC BER (or input BER) of third generation codes are close to 2×10^{-2}. It should be mentioned, that most of the FEC codes guarantee their error correcting performance in uncorrelated channels like AWGN (Additive White Gaussian Noise). Their correction ability can be worse in a non-linear channel like optical fiber and also in the presence of error bursts.

Most of the third generation FEC solutions use iterative decoding and are based on LDPC (Low Density Parity Check) codes and Turbo Product Codes (TPC), which are also called Block Turbo Codes (BTC). Both of these code types can perform close the Shannon limit. Important part of these FEC schemes are techniques for further improvement of error-correcting performance such as interleaving, iterative decoding and soft-decision decoding. Iteratively decoded LDPC codes usually outperform turbo product codes in terms of BER performance, but hardware implementation of LDPC encoders and decoders is usually more complex than those of TPC, but their complexity is still comparable.

PCCC (Parallel Concatenated Convolutional Codes), which were first presented in 1993 in [11], and SCCC (Serial Concatenated Convolutional Codes) are classes of turbo codes that are based on convolutional codes. These are used in multitude of wireless systems, but generally aren't suitable for optical communication systems for the following reasons. Hardware complexity of their decoders is high when compared to LDPC and TPC codes, which makes their hardware implementation difficult in networks with very high transmission rates. A notable disadvantage of convolutional turbo codes is the fact that by design their coding rates are low. This makes them impractical for high-speed optical networks, because a redundant overhead of no more than 25% is highly desirable in optical communications at 10 Gb/s or more.

Some of the third generation FEC schemes also use BCH codes, RS codes and convolutional codes as a part of their design, such as various interleaved-concatenated coding concepts [12], [18-21].

In 2010 a field trial of a 100 Gb/s DWDM channel upgrade of an installed 900 km link took place. More advanced modulation format was needed to achieve higher spectral efficiency. The chosen modulation format was PM-QPSK (Polarization Multiplexed QPSK), also called DP-QPSK (Dual Polarization QPSK) or PDM-QPSK (Polarization Division Multiplexed QPSK). Different information is transmitted in each orthogonal polarization plane with this 8-state modulation format and it is capable of achieving 100 Gb/s bit rate in a single WDM channel. However its modulators and demodulators are very complex and expensive. Modulation formats with more constellation points are considered for future use (e.g. M-QAM), but with higher spectral efficiency the SNR requirements are growing. These requirements can be met by using FEC. The field trial proved that 100 Gb/s-channel upgrade for existing 10 Gb/s and 40 Gb/s DWDM systems is possible as far as forward error correction is used to reach desired bit error rates. FEC schemes designed for such 100G DWDM systems are listed in Tab. 2 [23-24].

Table 2. State-of-the-art and beyond FEC codes and comparison [18]

Name	HD	SD	NCG (dB)
Swizzle	•		9.45
Staircase	•		9.41
MTPC	•		9.3
GLDPC	•		9.6
SP-BCH	•		9.4
Two-iter. conc. BCH	•		8.91
UEP-BCH	•		9.35
TPC with shortened BCH comp.	•		> 10
CI-BCH 3	•		9.35/9.90/10.30
CI-BCH 4	•		9.55/10/10.50
TPC	•		9.30/9.80
TPC		•	10.30/11.10/11.40
Conc. QC-LDPC and SPC		4 bits	10.4/11.3
Single QC-LDPC		4 bits	11.3
LDPC-CC.		4 bits	11.5
Non-Conc. FEC		5 bits	11.3
Conc. LDPC and RS		2 bits	9
Spatially-coupled LDPC		4 bits	12
Conc. NB-LDPC and RS		5 bits	10.8
Large-Girth LDPC		4 bits	10.95
NB-QC-LDPC		•	10.8
Triple Conc. FEC		3 bits	10.8

5. Conclusions

A general overview of error-correcting codes was presented in this paper. FEC codes from the early ones such as the Hamming codes and the popular ones such as Reed-Solomon codes to the modern codes like turbo and LDPC codes are mentioned and described. Various methods of forward error correction used in high-speed optical networks are listed along with their performance and requirements for error correction in each generation of optical networks. Several hard-decision and soft-decision FEC schemes intended for use in future optical networks are also present, where LDPC-based schemes and TPC-based schemes are the most promising candidates for these networks.

ACKNOWLEDGEMENTS

This work is supported by the Slovak Research and Development Agency under the project APVV-0025-12 ("Mitigation of stochastic effects in high-bitrate all-optical networks").

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Trends and Concepts of Development of The Logistic System of Kazakhstan

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Abstract The world integration tendency goes on the way of creation of the integrated macrologistic systems, including transport and logistic systems of the country, logistic centers, terminal complexes and other links of the logistic system. The logistics has already gone far beyond the national borders of the states. The interstate and transnational macrologistic systems, designed to facilitate traffic of information, goods, equity, and people through borders are rapidly growing. Paper focuses on the analysis and trends of development of the logistics system of Kazakhstan.

Keywords development logistic network, logistic system, Kazakhstan

JEL L90, L98

1. Introduction

The logistics became the practical instrument of business long ago. Receipt of 20-30% of gross national product of the leading industrialized countries is connected with logistic systems. As international experience shows, reducing for 1% of logistic expenses is equivalent to increase in sales volume of the firm almost by 10% [1].

In 2016, Kazakhstan is celebrating its 25th Year of Independence. During those 25 years of Independence, Kazakhstan has reached its position among the top 50 most developed countries in the world by implementing 2030 - Strategy ahead of schedule. Today, Kazakhstan is ambitiously aiming to become one of the top 30 most developed countries by 2050. At the turn of a new stage of social and economic upgrade of Kazakhstan, dynamic development and effective functioning of an infrastructure complex are one of the crucial components for achievement of high and steady rates of economic growth.

2. Analysis of current situation

The Global Competitiveness Index (GCI) of the World Economic Forum (WEF) is the generally accepted assessment of the competitiveness of states. 12 factors of the competitiveness, thoroughly characterizing the competitiveness of the countries worldwide with different economic development levels, are taken from 114 estimated indexes. During the years of independence, in the rating of the competitive countries across the world, Kazakhstan moved ahead and achieved considerable results. The dynamic development of Kazakhstan is shown by the results of GCI rating. So, between 2009 and 2010, according to the rating Kazakhstan ranked 72nd, and in the period from 2015 to 2016, Kazakhstan was given the 42nd place among 140 countries with mean score of 4.5 (Fig.1). According to the GCI rating, Poland (the 41nd place) and Italy (the 43rd place) became the adjacencies of Kazakhstan. The states sharing borders with Kazakhstan, Russia holds the 45th place and China – the 28th place of the GCI rating. Rate of competitiveness does not so much reflect direct comparison of the countries in absolute physical and economic parameters, but to a greater extent, it gives an assessment to the grade of high-quality changes, the available tendencies, and the nature of development. This issue is also urgent in the infrastructure complex, which is the basis of transport and logistic systems of the countries.

The logistics is a peculiar catalyst of an industrial development, and its upgrading is of great significance for any country. This process is that mainstay, on which interstate integration is built.

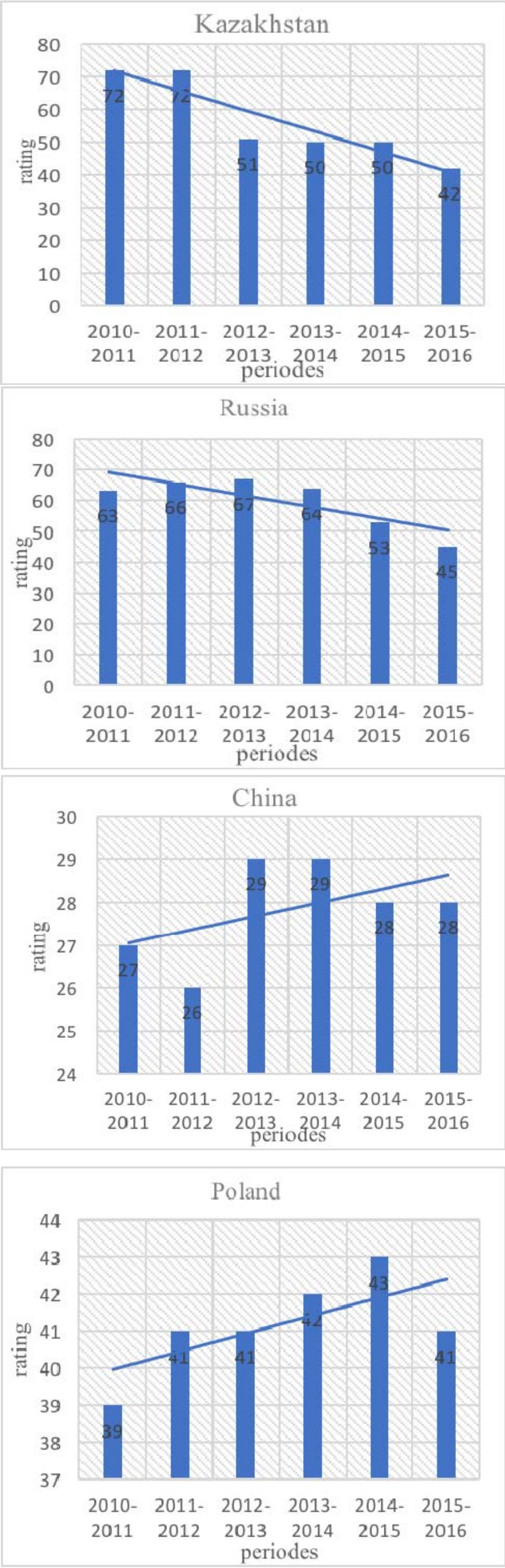

Figure 1. Dynamics of the change of GCI for the period from 2010 to 2016 (data of WEF)

The huge territory with low density of population (Table1), long distances of transportation and remoteness from the high seas borders make a transport and logistic issue one of the most urgent points of Kazakhstan. The main priorities of a transport and logistic system are providing Kazakhstan with uninterrupted, shortest and inexpensive transport routes with adjacent countries and international economic centers as well as the full use of the transit capacity of the country. The location of Kazakhstan in the center of the Eurasian continent predetermines its geopolitical role as the transit bridge between Europe and Asia, as well as between the adjacent states with which it has overland borders, such as Russia, Kyrgyzstan, Uzbekistan, China, Turkmenistan, and water borders – Iran. Kazakhstan holds the important place in the international transport and communication system and forms the territory, through which three main transit routes pass:

- Europe – Russia – China, the countries of Southeast Asia (SEA);
- Europe – China (through the countries of Organization for Economic Cooperation and Development- OECD);
- Russia – Central Asia

Table 1. Basic statistics about territory selected countries

Indexes		Kazakhstan	Russia	China	Uzbekistan	Kyrgyzstan	Poland
Territory	mil. km^2	2725	17098	9598	0,447	0,199	0,313
	World rank	9th	1st	3th	57th	87th	70th
Population	bln people	0,0177	0,143	1,362	0,03	0,0055	0,039
	World rank	62th	9th	1st	43th	110th	33th
	% of world population	0,24	2,03	19,3	0,42	0,08	0,54
Density	inhabitants per km^2	6,51	8,56	139	71	28,5	123
	World rank	184th	18th	56th	104th	148th	65th
Length of borders with Kazakhstan (km)		-	7513	1782	2300	1050	-

In light of this, the development of trade and economic relations of the countries of Southwest, South and Southeast Asia with the CIS countries (first of all, with partner countries in EEU) and Europe becomes the most important factor of the development of export-import and transit potential of Kazakhstan. In general, connecting traffic in the directions Southeast and East Asia–Europe is estimated approximately at 330 - 400 billion dollars of the USA, at the same time, according to experts, to 20% of this traffic can pass through the territory of Kazakhstan [1].

3. Results and Discussions

At the 25th plenary session of the Council of Foreign Investors (May, 2012), the president of Kazakhstan announced the launch of the project "Kazakhstan — New Silk Road", the creation of effective transport and logistic corridors on the territory of the country. Transit related aspirations of the authorities of Kazakhstan coincide with the Chinese vision of the region. Synchronization of transport drafts of programs "Nurly Zhol" and "New Silk Road Economic Belt " was discussed by heads of two states during the visit of the president of Kazakhstan to China. Infrastructure "five-year plan" of " Nurly Zhol " (calculated for the period from 2015 to 2019) will allow increasing amounts of transportations of transit freight through Kazakhstan twice by 2020. The cargo carriage volume between China and Europe will reach 170 million tons [2]. Cargo delivery speed is the main benefit of an overland route. The container train, going from Zhengzhou (China) to Hamburg (Germany), covers the distance of 10 500 km in 13-14 days. By sea, the Chinese goods reach the European markets in 40-60 days. Kazakhstan is developing transit corridors on its territory along two routes:

- "northern" one provides an exit to Russia and further to the European markets,
- "southern" — or trans-caspian — goes along the corridor TRACECA through Aktau port with an exit to Azerbaijan, further to Georgia and Turkey.

Upgrade of a traffic circuit within the program "Nurly Zhol" is carried out in several directions.

3.1. The development of a highway service

The program includes 11 projects of a road industry. In general, more than 7, 000 km of roads connecting Astana with the large logistic centers in Almaty, Ust-Kamenogorsk and Atyrau will have been reconstructed and constructed by 2020. The same highways will connect regional transport hubs in such cities as Aktau, Pavlodar, Kostanay, Semey, Aktobe, Atyrau, which are key points of freight distribution on the Russian and Central Asiatic markets (Fig. 2).

Figure 2. Scheme of the transport and logistic system of Kazakhstan

The largest project in the road branch is the international transit road corridor “Western Europe –Western China”, the final points of which are St. Petersburg (Russia) and Lianyungang (China). Actually, it is “A New Silk Road” from China to Europe. The total length of the route makes 8, 445 km, and the length of the Kazakhstani section of the highway (Horgoz–Border of Russia) is 2, 787km. In 2017, Kazakhstan completely finishes the construction of its highway section.

3.2. The development of a railway service

In the Soviet period, traffic with China was performed through the border railway station Dostyk (the former station Friendship). The length of the railway lines from station Dostyk till Almaty is 773 km. In 2012, the independent Kazakhstan put into operation Zhetygen — Korgas line, which is 293 km long. It provides the transit capacity of the country and reduces distance from China to the southern regions of Kazakhstan and to the countries of Central Asia by 480 km. Cargo transportation time from China to the southern regions of the country and transit time to Central Asia is reduced on average by 1.5 – 2.5 days. In 2020, the predicted annual cargo turnover of the section will be 15 million tons [3]. In 2016, in Western Kazakhstan region, the construction of a railway spur Borzhakta – Ersay has been finished. The railway spur is an infrastructure basis of the ferry complex “Kuryk” on the Caspian Sea.

The construction of Kazakhstan’s section of the railway line, connecting Kazakhstan, Turkmenistan and Iran, is completed. Railway transit, which is offered today by Kazakhstan and Turkmenistan, can also stimulate expansion of commercial ties between Russia and Iran, namely it can promote implementation of the Russian-Iranian trade agreement on supply of the Iranian oil in exchange for the Russian grain, equipment and other manufactured goods.

3.3. The development of the port infrastructure

Upgrading of the only Aktau seaport of the country situated on the Caspian Sea is an important part of the infrastructure program "Nurly Zhol". The cargo turnover of the port in 10 months of 2016 is over 4 million tons. Main transshipment freight includes grain, oil, steel products, ferry freights. Currently in Aktau, a number of projects on upgrade and expansion of transhipment capacities is being implemented that by 2020 port capacity is increased to 19 million tons. Aktau seaport is a strategic point in the "southern" route which makes a detour of Russia [4,5].

The construction of a dry port in Horgoz (Kazakhstan-Chinese border) is nearing completion.

The seaport in Aktau and the dry port in Horgoz are developed together with one of the largest world port operators DP World.

In the spring of 2016, the construction of a new ferry complex “Kuryk”, having capacity in 4 million tons of freights per year has been started on the bank of the Caspian Sea. The new project is aimed at the development of transportations in the Transcaspian International Transport Route (TITR). In Kazakhstan, under the jurisdiction of the national company JSC “Kazakhstan Temir Zholy” (JSC NC KTZh), a new organization "National Center of Development of Transport Logistics" is created. The Center is a partner in the field of transport and logistic researches, as well as the coordinator of business initiatives and projects in the field of transport logistics. Functions of the development of transport and logistic system and rendering a full range of

DOI: 10.26552/tac.C.2016.2.2

logistic services are assigned to the newly created organization [5]. Perspective activities of the new Center are planned, the main of which are:

- informational and analytical support;
- maintenance, development of practical recommendations for decision making, concerning transport policy.

Besides, the Center for logistics holds profile conferences and business forums for specialists of an industry, carries out advanced training of specialists, and creates the single information portal on transport logistics as well as reference books for logistic operators in Kazakhstan. In 2014, railway authorities of Belarus, Russia and Kazakhstan created the United Transport and Logistic Company. It is “one of the first integration projects in the sphere of transport logistics within the Eurasian cooperation (EEU)” [6,7].

4. Conclusions

Ultimate goal of the Logistic Strategy is to ensure progressive development of transport, communications and logistic complex in line with economic strategy of the state.

The Strategy implementation is expected to ensure bringing of the national transport system to a higher level, and forming of an optimum transport network. Financing of the infrastructure on the self-sufficiency principles will allow accommodating resources for its further sustainable development and maintenance at a high technical level.

Kazakhstan has an accurately formulated strategy both in economic, and in the geopolitical plan: cooperation with as wide as possible range of partners and with the maximum benefit for all parties. “Forget the concept of “the Big Game” — it became outdated; Kazakhstan follows the philosophy of “Big benefit” for all — “for Russia, China, the USA, Europe, India, Iran, Turkey, and naturally for Kazakhstan”, the Minister of Foreign Affairs of Kazakhstan Idrissov emphasized, addressing diplomats and journalists in Horgoz [8]. Kazakhstan, lying between promptly developing China and Russia with its largest natural resource stocks in the world, as well as in the context of " The Silk Road" connecting Europe and the countries of Central, Southern and South-eastern Asia, intends to use its transit potential as much as possible.

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Market Access in Freight Forwarding and Responsibility of Freight Forwarder

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Abstract The paper deals with the issue of different market access for the transport procurement in the EU in context of open market of providing forwarding services. The paper highlights different requirements of market access in freight forwarding. It also refers to the different responsibility of freight forwarder depending on membership in the national associations of freight forwarders. The contribution analyses the limitation of liability in freight forwarding and shows differences in contract of freight forwarding for particular shipments by model examples.

Keywords market, freight forwarding, business, responsibility, contract

JEL M10, R40

1. Introduction

Freight forwarders play an important role in transport chain. They provide professional services in national and international transport. The basic task of every freight forwarder is procuring of transport and providing of advisory service for all modes of transport. Freight forwarders seek to ensure non-tariff discounts on behalf of customer. They check invoices for transportation outputs and the other expenditures, carry out all kinds of discounts and their direct debits and give it to the customer according to previously agreed principles. Forwarders also ensure claim damages or may, in agreement with the customer handle complaints directly [12]. Another important task is drawing up the calculation of transportation outputs, recommendation of the optimal transport route and determination of the optimal tariff declaration for transported goods. A freight forwarder operates a collection service, carries out national collection and distribution of shipments, and ensures completion, distribution of general cargo, storing, signing and repairing of packaging. They are also responsible for providing various benefits for all modes of transports for example the issuing of documents. A freight forwarder can carry out, in agreement with customer, customs clearance of consignments and can represent customer in customs procedures. Last but not least, he can provide legal aid to the customer in defending his interests in disputes with his partners [13].

It follows that the role of freight forwarder is not easy and the freight forwarder has a high responsibility for his actions in these tasks. When ordering services, the customer expects to receive quality services which can be provided only by specialist.

Whereas the market access conditions in freight forwarding are significantly different in the EU, the aim of this paper is to highlight the importance of position of freight forwarder and define differences in market access.

The freight forwarding is not adjusted uniformly in the EU by common legislation in light of forwarding contract, for example like CMR Convention in the road transport. Given that the aim of this paper is also to point out different responsibilities of freight forwarders who conclude forwarding contracts under the national law.

2. Market Access and Status of Freight Forwarder in the Slovak Republic

Freight forwarding has an indispensable role in the framework of provision of transport and logistics services in developed market economy countries. Freight forwarding represents procuring of transport or other activities related to the transport under its own name, on its own responsibility and for a third account. Law no. 513/1991 Coll. The Commercial Code defines a forwarding contract in relation to the provision of transport. In light of Slovak legislation there is a distinction between intermediary of transport and freight forwarding. The Commercial Code also defines a brokerage contract, which has a significantly different relation between the contractual partners. In practice, mostly for subjects who act under the name of forwarders and provide forwarding, there may be deception of customer about providing services. There can be question whether provider of freight forwarding services provides freight forwarding or brokering. The difference is mainly that the freight forwarder is acting under his own name and on his own responsibility. It means freight forwarder concludes a contract of carriage with a carrier.

Intermediary of transport is not acting under his own name in case of brokering. Responsibility of intermediary of transport ends by ensuring carrier for a customer. In this case the customer becomes a transporter in relation to carrier.

For customer is important to ascertain whether the business partner is entitled to provide forwarding services, or is an intermediary of transport. Given that freight forwarding is a regulated trade in the Slovak Republic, business activities of each person providing freight forwarding can be checked in the Trade register or in the Business register. Registers are available on www.zrsr.sk and www.orsr.sk. Requirements for a freight forwarder in the Slovak Republic are established by Act no. 455/1991 Coll. On Trade Licensing. This act requires meeting criteria of specific conditions (in the form of professional competence) in addition to general business conditions by the applicant for freight forwarding. According to the Act no. 455/1991 Coll. on Trade Licensing is professionally qualified the applicant who has completed secondary education and has at least two years' experience in the field or a university degree in the field of study, and at least one year experience in the field. There are only general business conditions required in the case of transportation brokerage business by Trade Licensing. Brokering is classified as unregulated trade in the Slovak republic.

3. Market Access in Freight Forwarding in the Selected Countries

As the conditions of market access are not harmonized for freight forwarding in the EU, the aim of this paper is identify whether freight forwarders from the other selected countries have comparable conditions of market access. Access to the freight forwarding business is governed by national law. Because of this it is necessary to identify the specific national legislation of EU Member States by analysing market access in freight forwarding. Based on the analysis of national law which is available in [15] it is possible to divide the countries according to table 1.

Table 1. Comparison of requirements for market access in freight forwarding

Country	Required experience	Required education	Financial guarantee	Unregulated trade
Belgium	yes	yes	yes	
Bulgaria				yes
Croatia				yes
Czech Republic				yes
France	yes	yes		
Germany				yes
Netherlands				yes
Poland	yes		yes	
Portugal	yes	yes	yes	
Austria	yes	yes		
Spain	yes			
Sweden				yes
Italy	yes	yes	yes	
Great Britain				yes

In the position of freight forwarder may be the company or a person who has no professional training or professional representation in seven of analysed countries, as Bulgaria, Croatia, Czech Republic, Germany, Netherlands, Sweden and the Great Britain. In these countries is the freight forwarding unregulated trade, it means any person who meets the general business conditions, can make business in freight forwarding. In the other analysed countries are different conditions.

The mandatory conditions for obtaining a business license in Belgium are experiences of the last six years and at least:

- five continuous years in a company holding a license,
- three years, if was met a 3-year training,
- two years, if was met a 3-year training or if the applicant holds a university diploma
- six months if the applicant passes a professional examination in forwarding or if has own certificate of professional competence in transport (additional test for specific faculties of freight forwarding).

Another condition is a financial guarantee in amount of 12 394,68 € for the license, the integrity which is a proof of good moral conduct of public authorities and it is showing that the applicant did not commit any crime. The other duties include, for example, a certificate of professional experiences which is issued by person, who is assuring the daily management of the company [1].

In France, activity of freight forwarder is regulated by several conditions. The first condition is the registration in business register and second condition is the registration in a register of freight forwarder. The registration is conditional and is required qualification for profession and integrity. Requirement of registration is professional competence that is certified by the "Prefect of the regions". Conditions to achieve professional qualifications are the ownership level III diploma "Diplôme de niveau III (Bac + 2)" and also major in transport. There it is also required at least 200 hours of management experience and successful completion of a special written examination. The applicant must demonstrate five consecutive working-years in a transport company but no more than three years before filing the application. The other condition is an integrity, which is defined by clean criminal record. A professional qualification is certified for those who have mastered either a written test, have a sufficient expertise or demonstrate related diplomas [15].

Freight forwarding services in Poland can be provided only to entrepreneurs who meet the prescribed conditions of required competence. Professional competence in Poland, which is proved by certificate of professional competence, is identical to the certificate of professional competence for the road transport. The certificate of professional competence must be at least one person from the management company or a person who is working in a company that is responsible for operating road transport operations. Entrepreneur who wants to provide services related to the acquisition or brokering transport, must demonstrate a minimum share capital 50 000 € [14].

In Portugal, the professional competence is a mandatory condition for obtaining a business license in freight forwarding, which is obtained through a special examination by National Committee for Transport. National Committee for Transport is the authority in the field of freight forwarding. The applicant must also meet financial guarantee which is demonstrated by capital in amount of 50 000 € and a liability insurance in the amount of 100 000 €. Another important condition is to prove integrity. It means that the applicant has no criminal record for managers, board members, and technical directors [15].

In Austria, the applicant must meet the general conditions of business and professional competence. A technically competent person is one who has successfully completed the listed schools (transport, economic and law) and has one year of experience or passes the exam and has two years of experience in the field. The exam is organized annually by the Economic Chamber. The test consists of two parts. Written part of the exam includes as correspondence, drawing up documents, payments and lending, calculating performance, billing the customer and internal accounting evidence according to the special requirements of accounting. The oral part consists of 13 headings [5].

4. Responsibility of Freight Forwarder for the Transportation Procurement

In the Slovak Republic is the freight forwarding business regulated by Act no. 513/1991 Coll. Commercial Code and General conditions of Consignment, in which may modify the scope of their responsibilities. If it is based on the Act. 513/1991 Coll. Commercial Code (freight forwarders should not use any forwarding conditions) then each freight forwarder who breaches his obligations from the contractual relation contract is obligated to compensate damage caused to the other – to the customer. Except that the freight forwarder proves that the breach is caused by circumstances excluding his responsibility. These circumstances include for example. floods, fires and the like. The responsibility is not excluded by an obstacle which occurred during the time when the obliged party was already in delay with the performance of its obligation or arose out if its economic situation. The effects excluding liability are limited to the period of time during which exists the obstacle, with which such effects are connected. It means that the freight forwarder, who does not have a particular responsibility in forwarding the modified conditions is liable under law no. 513/1991 Coll. Commercial Code to the full damage.

The scope of the responsibilities may be adjusted by General conditions of Consignment. General Freight Forwarder's conditions are issued by Association of Logistics and Freight Forwarding of the Slovak Republic (hereinafter referred to as ALFF SR) and determinate responsibility of freight forwarder. Forwarding conditions ALFF SR are applicable to trade between the customers and freight forwarders in national and international freight forwarding, in case they become part of the contract of freight forwarding.

If the freight forwarder is responsible for damage, his duty to compensate is limited by General Freight Forwarder's conditions ALFF SR as follows [18]:

• in case of damage which is occurred on the consignment during carriage by means of transportation or at the handling operations connected with carriage (at loading, trans-loading, unloading), the amount of damage is limited to 8,33 XDR per 1 kg gross weight of the goods damaged, destroyed or lost, the maximum amount being 20 000 XDR per one case of damage,

• if the damage is caused by late delivery of the consignment, the freight forwarder's duty to compensate the damage is limited by the agreed amount of remuneration to the carrier.

• in case of storage the responsibility of the freight forwarder for the goods lost, damaged or destroyed is limited to the amount of:

• 3,925 XDR per 1 kg of gross weight of the goods damaged, lost or destroyed; however, the maximum amount being 3 925 XDR per one case of damage (one consignment),

• 19 625 XDR, if damage is caused to the depositor (the customer) consists of the difference between required and actual state of the stored goods,

• in cases of other damages the freight forwarder's duty to compensate the damage is limited to the amount of 20 000 XDR per one case of damage.

This scope of responsibilities of freight forwarder is in force only if the reference for General Freight Forwarder's conditions ALFF SR is part of the contract of freight forwarding. If the contract is included with freight forwarder in another country, it is possible that part of the freight forwarding contract are forwarding conditions of other associations, which are setting different responsibilities. In the Table 2.and Table 3 is processed the overview of limitations of freight forwarders on the basis of general freight forwarding associations in the analysed countries. Table 2 shows the limitation of damaged or destroyed shipment per kilogram (if XDR value is converted also into euro in General Freight Forwarder's conditions). In the Table 3 is the maximum limitation of responsibility per case of damage.

DOI: 10.26552/tac.C.2016.2.3

Table 2. The limitation of responsibility of freight forwarder per kilogram of lost, damaged or destroyed shipment

Country	XDR/kg	€/kg
Slovakia	8,33	9,36
Germany		5
Croatia	unlimited	unlimited
Austria	-	1,09
Belgium	-	5
Italy	8,33	9,36
Romania	4	4,49
Estonia	8,33	9,36
Netherlands	4	4,49
Slovenia	5	5,62
Poland	2	2,25
Czech Republic	8,33	9,36
Norway, Finland, Denmark, Sweden	8,33	9,36

The responsibility of freight forwarder is limited according to forwarding conditions and it can be in the amount from 1.09 €/kg (Austria) to unlimited responsibility of freight forwarder (in Croatia). In the most of analysed countries is the responsibility of freight forwarder limited to the amount of 8.33 XDR per kilogram of damage or destroyed of goods as in the Slovak Republic (Slovakia, Italy, Estonia, the Czech Republic, Finland, Norway, Denmark and Sweden).

Table 3. The limitation of responsibility of freight forwarder per one case of damage

Country	XDR	€
Slovakia	20 000	22 480
Germany	unlimited, in multimodal transport (including waterway transport) up to 1 million XDR or 2 XDR/kg - the higher responsibility is applied	
Croatia	unlimited	unlimited
Austria	-	1 090,09
Belgium	-	25 000
Italy	unlimited	unlimited
Romania	10 000	11 240
Estonia	50 000	56 200
Netherlands	10 000	11 240
Slovenia	25 000	28 100
Poland	50 000	56 200
Czech Republic	20 000	22 480
Norway, Finland, Denmark, Sweden	50 000	56 200

Table 4. The limitation of responsibility of freight forwarder per one case of damage

Country	Calculation of responsibility
Slovakia	22 480 €
Germany	40 000 €
Croatia	55 000 €
Austria	8 720 €
Belgium	25 000 €
Italy	55 000 €
Romania	11 240 €
Estonia	55 000 €
Netherlands	11 240 €
Slovenia	28 100 €
Poland	17 984 €
Czech Republic	22 480 €
Norway, Finland, Denmark, Sweden	55 000 €

The responsibility of freight forwarder is also limited by the maximum responsibility in the case of damage, which is bounded from 1 090.09 € per case of damage in Austria to unlimited liability (in Croatia, Italy). In the most analysed countries is the maximum responsibility of the freight forwarder in amount of 50 000 XDR pre one case of damage, which corresponds to the value of 56 200 €. Table 4 shows the impact of different responsibilities on the customer. In table 4 is processed comparison of the maximum responsibility of freight forwarder for the total damage of shipment weighing 8 000 kg in the value of 50 000 €. Less responsibility than in Slovakia is in Austria, Romania, Netherlands and Poland.

5. Conclusions

In the EU is not a position of market access in freight forwarding uniformly regulated.

Each country has its own specific conditions, which the applicant must meet. As the freight forwarder can provide his services in the EU, a potential customer receives a variety quality of services from freight forwarders.

It follows from the above that, the requirements of market access in freight forwarding is needed to harmonize. It is because of that the freight forwarders do not provide their services in local markets but provides transport services through the EU market. If this were to happen, the market would have served the same quality freight forwarder and customers should be ensured that they get the service to the extent and quality they expect.

Within the procurement of transport, there is also the problem of different responsibilities of freight forwarders, depending on the conditions under which they operate forwarding. For the customer who is not specialized in transport, it can be unclear. As in the case of the CMR Convention for road transport it would be appropriate to harmonize the responsibility of freight forwarders operating on the Community market. The analysis points out significant differences in limitation of responsibility of freight forwarder. It should be noted that other differences are in defined circumstances, which exclude the liability of freight forwarder. Also the responsibility of freight forwarder is affected by the national rules governing trade relations in the country.

ACKNOWLEDGEMENTS

The contribution has been elaborated with the support of Ministry of Education project VEGA no. 1/0320/14 Poles, M .: Improving road safety through the promotion of public transport services.

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Transport and Communications, 2016; Vol. II.
ISSN: 1339-5130
DOI: 10.26552/tac.C.2016.2.4

Benefits of Autonomously Driven Vehicles

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Abstract The vehicles with high grades have the embedded systems which are essential for the operation of a vehicle with higher standard of safety. This way road transport can significantly closer to the safety of rail and air transport because the error of driver is the main cause of the accident. The expected benefits of autonomous vehicles are their ability to observe small distances between the vehicles. Based on the information from stationary sources and vehicles running near adjust their route and speed of travel so as to minimize delays in congestions. This ensures greater continuity of driving, reducing consumption of vehicles and therefore the production of greenhouse gases from road transport. If the vehicles are capable of autonomous driving is achieved higher average speed and they have been removed the mandatory brakes within driving. It achieves the higher performance of individual vehicles and thus fewer number of vehicles on the roads and less traffic congestion.

Keywords: Accident, parking, vehicle assistant, brakes

JEL R41

1. Introduction

Autonomous vehicles are clearly near future of road transport. The rapid development of computers, their ability to communicate with each other using Wifi connections, various sensors allow this trend. In the following we approach the possible benefits for the company from their gradual implementation on practice.

2. Fewer accidents

If you look at statistics on traffic accidents, almost always is the cause of accident person. Whether it is due to incorrect assessment of the traffic situation, the laws of physic, the revaluation of the ability itself or the vehicle. Table 1 shows that a technical problem occurs only insignificantly.

Table 1. Traffic accidents in Slovakia [1]

Year	Completely		Including technical reasons	
	Traffic accidents	Killed in road accident	Traffic accidents	Killed in road accident
2014	11783	259	46	1
2015	13547	274	Don't enter	Don't enter

Based on this we can assume that autonomous vehicles bring a significant reduction in the number of fatalities in road accidents. Already are the vehicles dealt in a system which responds around to the situation. For example:

ABS Anti-block system (Anti-lock Braking System). This system is already compulsory equipment new registered vehicles. It can keep the wheels braked at the optimum slip 10 – 30%. Especially on the few adhesive surfaces ensures that the braked wheel moves in the area of maximum transmission of braking forces while the wheel is also able to pass a large enough force in the transverse direction. The system consists of a sensor which detects deceleration of the wheel, control unit, which based on the size of the wheel deceleration gives the command to change the pressure in the periphery of the braked wheel and thus the change of brake force. If each wheel is operated in this way independently, the result is a shorter braking distance and maintaining control of the vehicle direction at any moment within braking. This system is the cornerstone which can be built more sophisticated systems.

ACC – Adaptive Cruise control. This system helps to limit the risk of accident the vehicles running in columns. Company Volvo launched it in 2003 and was part of the offer for trucks manufactured by the company. It helps the driver maintain a safe distance from the vehicle in front and easily keep pace with the flow of traffic. ACC not keep a fixed rate, but to set a fixed time to the vehicle ahead. System keeps a distance through automatic control of acceleration, engine brake and auxiliary brake.

If the vehicle in front decreases its speed, reduces the speed a vehicle equipped with ACC. If control vehicle accelerates again, increases speed the vehicle with ACC until the default value. ACC can be deactivated by simply pressing the ACC control or by pressing the brake of clutch pedal. In situations where the auxiliary brakes are not able to keep distance, if the vehicle in front brakes suddenly, the driver is notifying by the alarm sound and light on the speedometer. Then the driver must use the service brakes. The control unit decides on the basis of information from the radar which operates in the frame 11 degrees ahead of the vehicle. The drive of this field divided into two categories – captured vehicle (up to 12 units). It selected one target vehicle by which regulates the driving speed. Vehicles in adjacent lanes are captured vehicles and do not affect advancing of the trailer. If such a vehicle changes lane and deflects before the trailer, it becomes a target vehicle. Based on the size of the lateral acceleration, the system recognizes that the car moves around a corner. It maintains speed even though the radar lost contact with the selected target vehicle.

Brake assist. A lot of drivers don't action on the brakes sufficient force when braking in danger which means that the braking distance of the vehicle is longer compared to the path which the vehicle was able to stop. Brake assist on the basis of a sharp and strong brake pedal automatically applies maximum braking force such as brake valve control braking it considered at risk. If the driver keeps the pressure to control, the vehicle brakes with maximum effect. Releasing the pressure on the driver brakes, the maximum braking force is automatically reduced as well. [5]

Hill-start assistant. Many drivers have problems when starting uphill. Their vehicle before starting stops the engine or backs away. Such a situation is risk because it can cause an accident. The system helps the driver so that when parking brake is released after releasing the brake pedal, brake are released with two-second delay, which gives the driver time to bring it to the wheels of a sufficient driving force and the vehicle didn't back.

Electronic stability program (ESP, DSC,ESC,VDC,DSTC). It is mandatory to newly registered vehicles. It should actively prevent uncontrolled skidding of the vehicle and helps the driver stabilize it if it gets to skidding. It direct cooperates with ABS and ASR. It compares the behaviour of the vehicle with the calculated values. It is checking the desired travel direction based on the steering angle, the actual speed based on the speed of the wheel. It compares the later acceleration and the vehicle rotation around the vertical axis with the calculated values.
The control unit automatically adjusts the torque of the engine and where appropriate brakes the wheel, which can help to balance over steer or under steer skid of the vehicle. The Federal Statistical Office of Germany has registered more than 42% decrease of an accident rate of vehicles equipped with ESP system approximately 3 years after its serial installation.
A traction control system (ASR, TSC, ETC, T C S). It helps wheels not to rotate on the spot when moving off on slippery surfaces. For that, it uses reduction of engine power. If one of the wheels slows down the slipping wheel on the slippery surface, a wheel on the fixed ground has a larger torque.

Distance Alert (DA). It uses for its operation an adaptive cruise control. If the distance from vehicle driving at the front falls to critical value, it alerts the driver by red flashing light. Some systems will slow down automatically to increase the distance at the safe level.

Advanced Emergency Braking System (AEBS). Autonomous Emergency Braking (AEB). 75% of car accidents happen up to 30 km/h speed. The system uses a camera which monitors 10 m space before vehicle. It warns drivers visually and acoustically if there is an obstacle in front of them. When there is no or inadequate reaction from driver, the system is able to activate brakes individually. It can stop vehicle before the obstacle up to 15 km/h speed and from 15 up to 30 km/h speed according to the roadway surface.

Line Departure Warning (LDW). It can detect the traffic lanes on the roadway. It is being activated at the speed above 60 km/h. If drivers attempt to change the traffic lane without signalling a change of direction, it warns them or slightly rotates wheels of the vehicle so that vehicle will not leave the current traffic lane.

Roll Stability Control (RSC). It uses information about lateral acceleration of vehicle and controls its stability against rollover. If there is a risk recognized, it reduces engine power and slows down vehicle wheels which can maintain vehicle stability. Rear wheels of semitrailer, for instance.
All of these systems will in the case of cooperation be able to drive a vehicle by utilising GPS even without driver. However, the current legislative allows such autonomous vehicles to be driven only in some countries (USA). In the EU, the testing of autonomous vehicles may only be performed outside the public transport. [2]

The statement that autonomous vehicles will bring a lower accident rate has been seen in the introduction. However, it should be stated that American authorities have started to investigate the first fatal accident in which a man died in a self-driving vehicle of Tesla Motors Company. The driver had an activated autopilot when he crashed with a lorry on one of Florida's roads on May. The cause of the accident was that the driver of oncoming tanker turned left on crossroads. Neither autopilot, nor driver saw the white side of tanker towards harsh sunlight, so the brake was not activated and the crash was unavoidable. Tesla Company states that it is the first known case of fatal accident after more than 200 million kilometres driven without directly human driving. Let us compare such defined safety of autonomous vehicles with vehicles driven by humans. An

DOI: 10.26552/tac.C.2016.2.4

average vehicle occupation is 1.6 people so Tesla vehicle carried out more than 320 million people (killed people) per kilometre. In 2014, there were killed 53 people per 10 billion kilometres in the EU. That means one killed person per 189 million kilometres. Autonomous Tesla vehicle is thus two times safer and in the future, vehicles will inform other vehicles about their position, so the probability of an accident will be significantly lower. [2]

3. Drivers will not be needed for vehicle driving

If vehicles are driving without a need of drivers, it means that they will be constructed only for replenishing working fluids and realising important maintenance. The safety breaks for drives will not be necessary and a limitation of working hours will not be in force. So, the vehicles could transport more goods and could be faster than with people. Mutual information about vehicle position can serve control unit to be able to choose the roadway that is less jammed so that vehicles will drive more fluently than with people. Even today the use of cruise control can reduce consumption about app. 5 %. If vehicles are aware of their position, they can optimise not only a route but also a driving speed. Computers have not a need to overtake slower vehicles and since safety breaks for drivers will not be required, they will be able to drive at lower speed. If today drivers may drive for 4 and half an hour and then can take a 45 minutes' rest, at the stable speed of 90 km/h they overcome the distance of 405 kilometres. The autonomous vehicle will be able to drive at the speed of 77 km/h and it will overcome the same distance. Vehicle combinations with 40 tons of weight will be expected to have a reduced consumption about 4.1 litres per 100 km. Only a change of speed was considered while estimating. However, the autonomous vehicles will not need a cab and thus can obtain a space for better shape of vehicle and a reduction of air drug coefficient. The consumption savings will be even higher. [4]
The regular trainings will be not required for autonomous vehicles and they will not take a holiday and income. Taking into consideration such personnel costs, the transportation will be significantly faster, cheaper and more punctual. This personnel advantage lies also in fact, that there is a lack of drivers seen in current practice.
Between autonomous vehicles will be communication so there will be no problem to create so called automobile trains when more vehicles driving in close proximity. Such driving will lead to further reduction of driving resistance and fuel consumption.

4. Parking

The complete implementation of autonomous vehicles should be also seen in the ownership of personal vehicles. There will be no need for owning a personal vehicle and paying depreciations, reparations, insurances and parking fees. The vehicles will be parked in parking lots and if somebody wants to get from place A to place B, there is a simple possibility of ordering a vehicle. The computer will choose a vehicle corresponding with a number of people and load transported as well as distance. The savings will be seen as a result of utilising electro mobiles for short distances and vehicles with required range for longer distances.
Being aware of a relative small number of personal vehicles that are driving and those vehicles that are taking up parking areas, the autonomous vehicles can also seem to be favourable in lesser demand on infrastructure space. [3]

5. Conclusions

This paper endeavours to point out the possibilities of autonomous vehicles and their contributions to higher road safety, faster goods transportation, delivery accuracy, higher utilization of car park, and last but not least in lower fuel consumption and thus in reduction of greenhouse gases. The autonomous vehicles may be seen in diminution in demand of parking areas, too and what is more, they could bring popularity to city transport since there could be vehicles driving with lesser number of seats. The passengers would be transported "from door to door" and their routes would be able to be connected, optimized and thus resulting in time shortening.

ACKNOWLEDGEMENTS

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Municipal Transport - Infrastructure

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Abstract One of the most important problems that we face in Poland, is a low degree of safety connected with municipal transport infrastructure. It stands out from numerous factors and conditions. That is why numerous actions aimed at improving transport safety are being undertaken. One of them is improved safety of vehicles that are directly connected with municipal transport safety.

Keywords transport infrastructure, crossing, roads, municipal transport

JEL L99, L99

1. Introduction

With the increase in the number of vehicles on the roads increases the likelihood of adverse events [8]. Road accidents are the cause of numerous deaths and disabilities in Poland. The price paid by our society for a rapid development of transportation is high. The situation concerning road traffic safety is serious, especially in large towns and cities. The development of automotive industry has led to the increase in traffic, traffic jams, and problems with parking, road accidents and pollution. It is now necessary to broaden a traditional scope of road engineering, which originally involved no more than the issues relating to roads construction and design, by the organization and safety issues. Methods that are used to counteract the threats are a part of the domain called safety [11]. There are many factors having influence on the status, opportunities and directions of creating transport systems in regions [6]. The most significant of them are: condition of transport infrastructure, both in quantitative and qualitative aspect, legal and organizational conditions, principles and methods of financing, domestic and international economic relations of the region, the nature of the region (industrial, touristic, agricultural), finally, the structure and nature of the transport needs of users of the systems, as well as continuity and regularity of the researches in this area [6].

2. Municipal Transport Infrastructure

Municipal transport comprises various means of transport from different branches of this domain. The basic ones are:

- means of rail transport, i.e.: subway, urban rail and tramway;
- means of road transport, i.e. bus, trolleybus, car.

Municipal transport infrastructure comprises various branches of transport, whose specificity roots from the adjustment to the transport needs that are typical for urban areas. They are the following:

- roads and streets with all fittings aimed at the organization of road and pedestrian traffic;
- railway, subway and tramway subgrades;
- energy network supplying subway, railway, tramways and trolleybuses;
- substations;
- stops, interchanges and stations;
- bus, tramway and trolleybus depots;
- parkings.

2.1. Crossings

A crossing is a road cross-cut, junction or fork with full or partial possibility of choosing the direction. Crossings should meet the requirements concerning:

- safety;
- traffic efficiency;
- adjustment to the pedestrian traffic;
- economic solutions.

The following recommendations should be taken into consideration:

- the number of inlets to crossings should not exceed four;
- crossing angles should be about 90 degrees, but must not be less than 60 degrees.
- intersections crossing angles should be ca. 90 degrees.

Traffic safety on the crossings requires to provide the drivers who are not on a major road with visibility of the crosswise road sections adhering to the crossing (Figure 1). Roadblocks higher than 0.75 m cannot be placed in a visual field. A minimal required length of Wr visibility of a bus section is Wr=150 m, assuming that a driver starting from the inlet without right of way is 2 m from the roadway edge, e.g. provided the road is 14 m wide and design speed on the road with right of way is 60 km/h. It is recommended to provide the biggest visual field possible that makes it possible to observe the road with right of way from the distance not shorter than 2 m from the road edge [1].

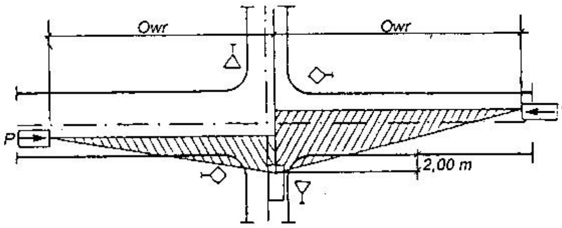

Figure 1. Visual field on the crossing while starting from a road without right of way [1]

The elements of urban system are parking places (along the curbs) and separated parkings. Figure 2 represents the schemes of typical parking places along the curbs [10].

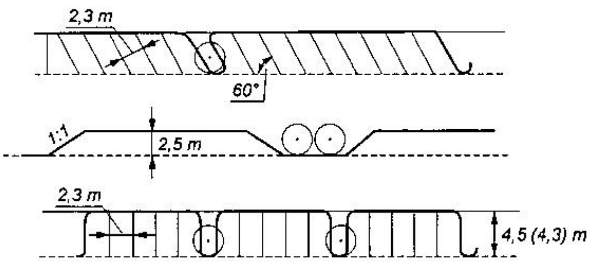

Figure 2. Typical curb parkings [1]

Parking needs are usually determined on the base of the number of drivers who want to use parking places in a particular area at the same time. As far as housing estates are concerned, there is one parking place per one flat and 20÷24 places per one thousand square metres of usable area of service facilities. Due to the proximity of destination and a short time of parking, curb parking is highly beneficial for its users, provided that the area is used well. However, it is a threat to traffic safety and flow.

Separate parking places are designed when the curb parkings capacity is too low. They can consist of one or many levels, and their functionality depends on the size of stands, manoeuvre roads and their system. An interesting solution of urban infrastructure system is the P & R (Park & Ride), whose objective is to reduce road congestion. The interest in P & R is increasing both in the country [5, 7, 9] and abroad [3, 4].

Due to the environment protection, it is unadvised to design parkings with more than 100 stands on the housing estate areas. Parking areas should be planted and artificially screened when necessary.

Bus stops are designed and used as far as bus transport is concerned (Figure 3). They should be located at least 20 m behind the crossing. Bus stops located before the crossing (at least 70 to 100 m) are more convenient for pedestrians, but they impede the traffic of cars that turn left on the crossing and within the whole area of before the crossing. Bus stops should not be placed opposite to each other. A shift between them has to be preserved so that the stopping buses do not impede the traffic.

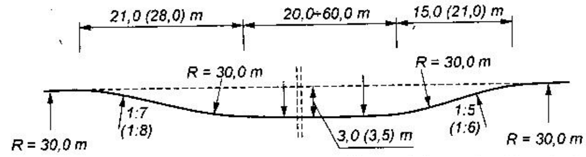

Figure 3. An example of a geometric lay-out of a bus buy (values for the GP class roads [speeded up roads] are given in brackets) [10]

In order to privilege municipal transport services, separate bus lanes or separate directions on unidirectional roads may be designed. As far as turnouts are concerned, they should be designed as the endings of L [local] and D [access] roads.

2.2. Roads

Qualification of roads is based on their communication functions and technical conditions connected with them. Roads also have composition, sociological and aesthetic functions, and mark out the areas of different use.

Considering functional reasons in the city communication system, there are the following:

- highways outside the urban area, aimed at communicating different metropolitan areas, connected in a collision-free way with the urban roads system;
- main arterial roads with considerable traffic;
- interdistrict arterial roads connecting particular towns;
- collective residential roads connecting residential estates;
- residential roads that are access roads to particular buildings, connected with collective roads.

According to indications relating to street design, the following division of streets creating a basic road system of a town/city has been introduced:

- urban express road (E);
- speeded up main road (GP);
- main road (G);
- collective road (Z);
- local road (L) [2];
- access road (D).

Roads of classes: E, GP, G and Z create, so called, basic system, and of L and D - service system.

Cars are ca. 2 m wide. Trucks' width does not exceed 2.6 m (with certain exceptions). Taking the above into consideration, lanes on the roads of basic system are 3.5 m wide, on the service system - 3 m wide. 2.5 metres-wide lanes are admissible only in exceptional cases.

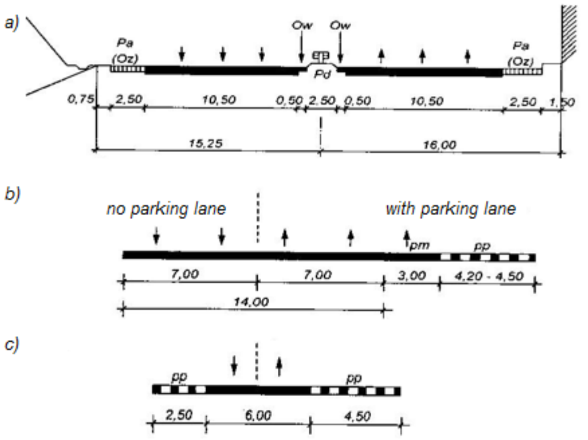

Figure 4. The examples of cross-sections of roads: a) E (urban express road); b) G (main road); c) L (local road) [1]

Urban express roads (E) are aimed at connecting remote urban agglomerations (Figure 4a). They can be the extensions of non-urban express roads and connect urban road with highways and non-urban express roads. They are only available for cars. There are two types of roadways used- with 3 or 2 lanes, so 11.5 m or 7 m wide. Connection with other roads is only possible on grade separate interchanges placed every 1.5 km to 3 km along the road. E roads do not serve the adjacent area. It is prohibited to stop and park. Design speed: 70 to 80 km/h.

Main speeded up roads (GP) are to connect remote cities. They can be the extensions of the 3rd class non-urban roads and connect urban roads with highways or express roads. There are two types of roadways used- with 3 or 2 lanes. Connections with other roads on crossings (horizontal) and on interchanges are placed every 0.6 km to 1.2 km. Basically, GP roads do not serve the adjacent area, so it is prohibited to stop and park. However, in case of modernization, it is allowed to create parking lanes and entrances. Design speed: 70 km/h.

Main roads (G) connect the areas within a city or a town. They can be the extensions of the 4th class non-urban roads and connect urban roads with non-urban roads and the 3rd class express roads. There are two types of roadways used, with 4 or 6 lanes in total, 21 m or 14 m wide in total (Figure 4b). Connections with other roads on crossings are placed every 0.4 km to 0.6 km. Main roads may serve the adjacent area, but it is recommended to park only on parking lanes and to limit the number of entrances. Design speed: 60 km/h.

Collective roads (Z) serve the housing estates or industrial districts. They can be the extensions of 5th and 6th class non-urban roads. Bidirectional roadways are usually designed for 4 lanes of the maximum width of 13 m. They may be connected with other Z or G roads (as well as L and D roads) on crossings places 0.15 km and 0.3 km along the road. Parking is allowed on parking lanes, a limited number of entrances is recommended. Design speed: 50 or 60 km/h.

Local roads (L) serve the housing estates. They are not designed to connect non-urban roads. Connections on crossings are allowed only with Z, G and D class roads. Parkings and entrances are not limited. Design speed: not determined. Roadway width for 2 lanes: 6 to 7 m (Figure 4c).

Access roads (D) serve the groups of buildings and objects. Connections on crossings are allowed only with L, Z and D class roads. Roadway width: 5 to 6 m. One-lane, 4.5 m wide roads with passing places every 100 m are also allowed, provided the whole section is visible.

The road system should be designed in a way that the lower-class roads are connected with only one or two classes upper roads. In particular, it is not allowed to connect L and D class roads directly with urban express roads (E) and speeded up roads (GP). Connections with main roads (G) should be limited, e.g. only turning right may be allowed [1]. Figure 5 presented the scheme of road system classification.

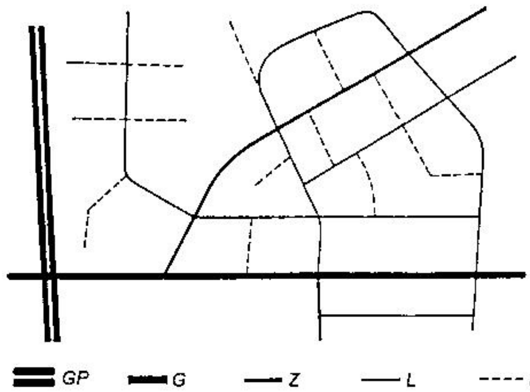

Figure 5. The scheme of road system classification [1]

A road is a parcel of land separated with lines, intended for car and pedestrian traffic, parking and for engineering territorial development. In a road's cross section, the following elements may appear:

- roadways;
- parking lanes;
- lanes dividing the two directions of traffic;
- emergency lanes, refuge islands;
- pavements;
- tramway subgrades;
- cycle tracks;
- green belts;
- cut and fill slopes;

Roadway is a part of road dedicated to vehicle traffic. In case of rail-vehicle traffic, a part of road dedicated to such traffic is called subgrade. Depending on its use, a road may not have a roadway, and then it works as an independent footway, tramway subgrade or cycle track.

A cross section (the number of lanes and their width) is designed considering the road's technical class (for E, GP, G and Z classes) and traffic volume.

Cycle tracks must be placed at similar distance (not shorter) from the road axis as pavements. It is allowed to design a cycle track on a unidirectional roadway.

Parking lanes may be placed on roads of G, Z, L and D classes, and everywhere else where it is necessary. However,

DOI: 10.26552/tac.C.2016.2.5

vehicles parked on such lanes must not disturb the visual field. In case of G class roads, it is recommended to increase the roadway width with the use of a manoeuvre lane; parking lanes should allow for angle parking.

Dividing lanes allow for dividing the two directions of traffic. Lamp posts, road signs etc. are placed on them in order to secure traffic.

Emergency lanes allow for emergency stopping and parking. When designing a road's cross section, one must take into consideration the requirements related to the roadway, pedestrian and cycle traffic outlines (Figure 6) [10].

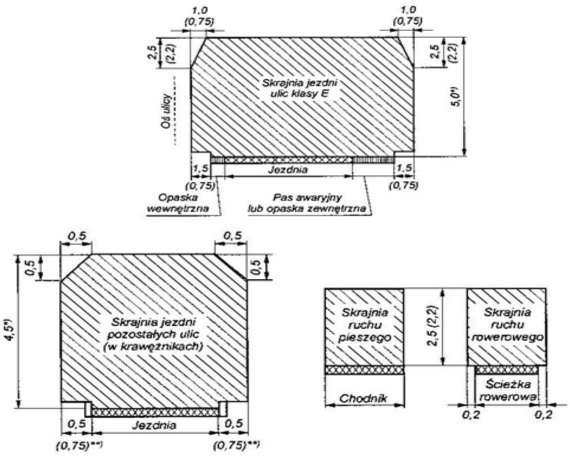

Figure 6. Roadway, pedestrian and cycle traffic outlines [10].

Figure 7 presents the infrastructure of conflict and typical crash types and the way to minimize the crashes.

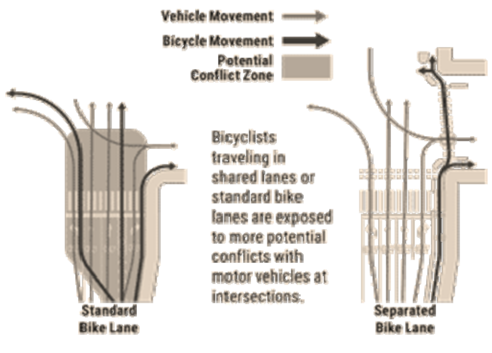

Figure 7. The infrastructure of conflict and typical crash types [12]

Ensuring the traffic safety needs the minimize bicyclist exposure to motor vehicles, decrease the speed differential at conflict points, and provide adequate sight distance for all roadway users. Fulfilling the criteria of safety should take place at the design stage.

3. Conclusions

A majority of Polish cities and towns struggle with serious communication problems. They are caused by, on the on hand, a rapid development of automotive industry and, on the other hand, unsustainable road engineering policy and underinvestment of road infrastructure. The number of cars in Poland has increased by almost 100%, and of trucks- by almost 90%. As a result, in the majority of cities, road system and their elements turned out to be insufficient. It caused, in turn, a high traffic volume. The consequence of this phenomenon is lower life quality of citizens and higher costs of transport in the cities and towns. The lack of appropriate hierarchy of sequences as far as their functions, tasks and, above all, speed and availability are concerned, is one of the biggest disadvantages of road networks in Poland. It makes it difficult to manage the network and provide a desirable safety level and sufficient road capacity [2], (Figure 7).

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Journal is excerpted in **Index Copernicus** database.

Frequency of publishing: Twice per year.

Publishing language:	English
Publisher:	The Faculty of Operation and Economics of Transport and Communications, University of Žilina, Univerzitná 1, 010 26 Žilina, Slovakia
Printed:	EDIS – Printing House of the University of Žilina, Univerzitná 1, 010 26 Žilina, Slovakia
IČO	00 397 563
Edition:	50 pc
Registered No:	EV 4902/13
Tel:	++421/41/5133051
Email:	tac@fpedas.uniza.sk
Web:	http://tac.uniza.sk

November 2016

DOI: 10.26552/tac.J.2016.2

ISSN 1339-5130

ISSN 1339-5130
DOI: 10.26552/tac.J.2016.2