ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1165453

THE LOGICAL CONTROL OF ROAD TRAFFIC NET AND RAILWAY JUNCTION

Krzysztof Wierzcholski

Technical University of Koszalin, Institute of Technology and Education
Śniadeckich Street 2, 75-453 Koszalin, Poland
tel.: +48 94 3478344, fax: +48 94 3426753
e-mail: krzysztof.wierzcholski@wp.pl

Abstract

The numerous tribology problems occurring in power-train and transport industry lead to wear of vehicles and trains as well as to wear of road or tracks. The choice of the proper way traffic or transport requires to select the kind of the way and the kind of the vehicles which shall be driving on the track. Especially the project designer demand the more and more information referring the wear of track anticipation in succeeding years of vehicle operation. Such wear of track anticipation is strictly connected with the choice of the kind of communication or traffic. To satisfy the abovementioned problem, it is necessary to construct the logical control system for road traffic. Mentioned logical system enables to control of management of the road traffic or railway junction. The presented in this paper logical system consists the description of the logical functors and their mutually connections. Here are introduced three kinds of functors namely, open functor, closed functor and special functor. Each logical functor describes the signal features which will be controlled.

The various functor connections occurring in considered communication systems are determined from practical problems where the influence of various operating parameters on the wear effects is taking into account. The influence of numerous operating parameters on the wear effects are experimentally determined and implemented into the systems in the case if mentioned parameters are independent as well if are mutually connected. Moreover in this paper the various communication systems will be presented and will be suggested an algorithm construction of the optimum problem solutions presenting the equivalent and simultaneously most simple communication system.

Keywords: *logical communication systems, tracks optimization, optimum road traffic, logical functors for traffic kind*

1. Introduction

The solutions of many transport problems connected with the road net and communication network for the movening of vehicles along the concrete track, without the logistic tools not always are possible [1-3]. Therefore in many logistic problems, very important is the signalization system and the control of this system. Moreover the knowledge of the anticipated traffic along the road net and logical description of the proper traffic functioning is very important during the design of the optimum shape of the various nets of the communication network. The configuration of roads and streets is presented in Fig. 1.

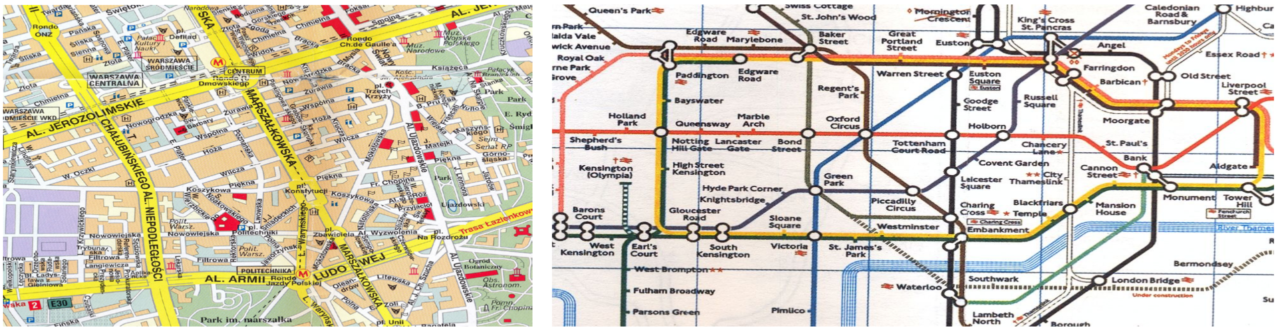

Fig. 1. The arrangement of the roads,tracks in Warsow and London subway lines

2. The elements of logical models for intelligent signals

At first in Fig. 2, we show three characteristic logical functors describing control signal features:

- **Closed functor** determined by **0** describes control signal, which stops each vehicle or train.
- **Open functor** determined by **1** describes signal, which allow passing each vehicle or train.
- **Special functor** determined by **p** or **q**, **s** or other letter for example **w** describes signal which allow to pass only vehicle or trains with features described by **p** or **q**, **s** or other properties for example **w**.

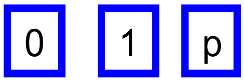

Fig. 2. Three functors with the control signal features description

Figure 3 presents two typical connections of the signal functors.

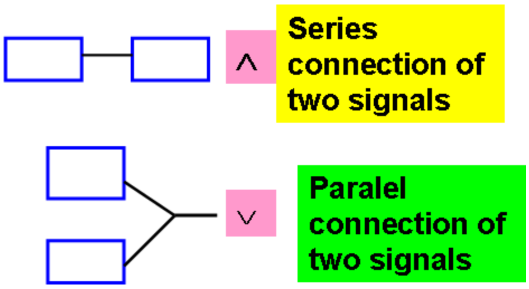

Fig. 3. Typical series and parallel connection of two control signal functors

The first series connection is known as the conjunction, which is described by the logical symbol $\wedge$ and it denotes the logical product of two united functors for example **p** and **q**. Hence this connection shows the signal which allow pass the vehicles presenting simultaneously the features **p** and **q**.

The second parallel connection is known as the alternation, which is described by the logical symbol, $\vee$ denotes the alternative of two united functors for example **p** or **q**. Hence this connection shows the signal which allow pass the vehicles presenting the features **p** or the features **q**.

Figure 4 illustrates the series connection of the logical open functor with the logical special functor for feature **p**.

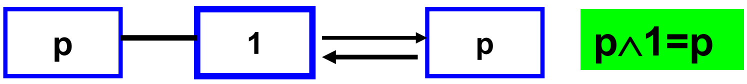

*Fig. 4. Logical special functor **p** as the result of the series connection of the open functor **1** with the special functor for feature **p***

The arrow direction in Fig. 4 denotes the direction of the succession of obtained result. The reason of obtained result in Fig. 4 is confirmed by the formula $\mathbf{p \wedge 1 = p}$ which is good known in basic set theory and topology [4]. The result of signal traffic node or railway junction presented in Fig. 4 allow pass only the vehicles or trains for feature **p**.

Figure 5 illustrates the parallel connection of the logical open functor with the logical special functor for feature **p**.

The arrow direction in Fig. 5 denotes the direction of the succession of obtained result. The reason of obtained result in Fig. 5 is confirmed by the formula $\mathbf{p \vee 1 = 1}$ which is good known in basic set theory and topology [4].The result of signal traffic node or railway junction presented in Fig. 5 allow pass all vehicles or trains.

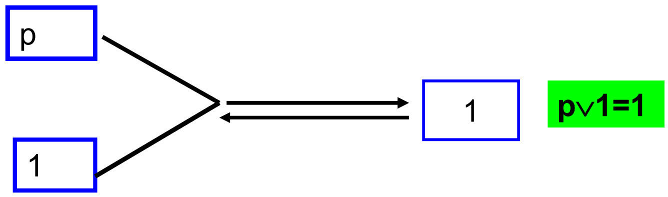

*Fig. 5. Logical open functor **1** as the result of the parallel connection of the open functor **1** with the special functor for feature **p***

Figure 6 illustrates the series connection of the logical closed functor with the logical special functor for feature **p**.

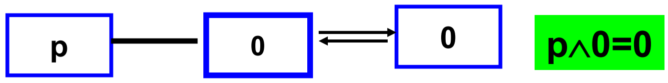

*Fig. 6. Closed functor **0** as a result of series connection of closed functor **0** with functor of arbitrary feature **p***

The arrow direction in Fig. 6 denotes the direction of the succession of obtained result. The reason of obtained result in Fig. 6 is confirmed by the formula $\mathbf{p}\wedge\mathbf{0} = \mathbf{0}$, which is good known in basic set theory and topology [4]. The result of signal traffic node or railway junction presented in Fig. 6 stops each vehicles or trains.

Fig. 7 illustrates the parallel connection of the logical closed functor with the logical special functor for feature **p**.

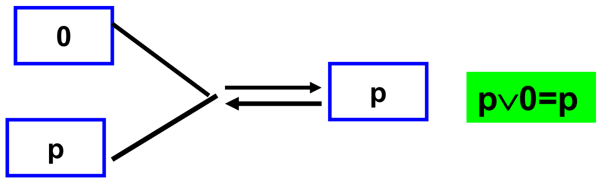

*Fig. 7. Functor feature **p** as a result of parallel connection of closed functor **0** with functor of arbitrary feature **p***

The arrow direction in Fig. 7 denotes the direction of the succession of obtained result. The reason of obtained result in Fig. 7 is confirmed by the formula $\mathbf{p}\vee\mathbf{0} = \mathbf{p}$ which is good known in basic set theory and topology [4]. The result of signal traffic node or railway junction presented in Fig. 7 allow pass only the vehicles for feature **p**. Fig. 8a, b illustrates the series (a) and parallel (b) connection of the two different logical special functors for the feature **p** and feature **q**.

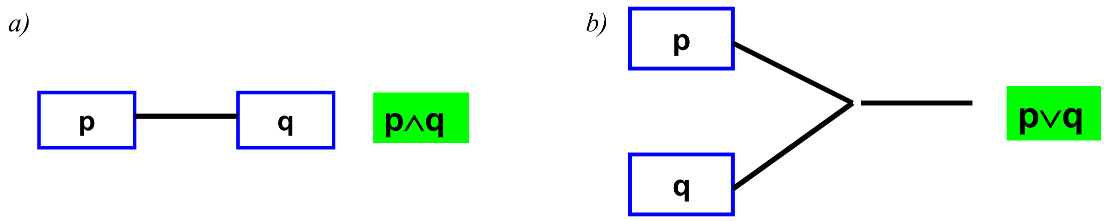

*Fig. 8. Two connections of two different special functors for two various features **p**, **q**: a) series connection **p** and **q**, b) parallel connection **p** or **q***

The system for signal traffic node or railway junction presented in Fig. 8a as a result of two series connection of functors **p** and **q**, allow pass the vehicles or trains, which have only simultaneously the feature **p** and **q**.

The system for signal traffic node or railway junction presented in Fig. 8b as a result of two parallel connection of functors **p** and **q**, allow pass the vehicles or trains, which have the feature **p** or feature **q**.

3. The signals equivalence for functor traffic node or railway junction

The system of some connected functors creates the logical signal node [5-6]. The node signals are included in the system. Now we show the very simple equivalent signals. Fig. 9 shows two equivalent signals for traffic node or railway junctions. Each signal node consists of functors with features: **p**, **q**, **s**. The equivalence of above-mentioned signals denotes that both nodes have the same logical meaning hence through the mentioned communication system can be going the same vehicles or trains [6-8].

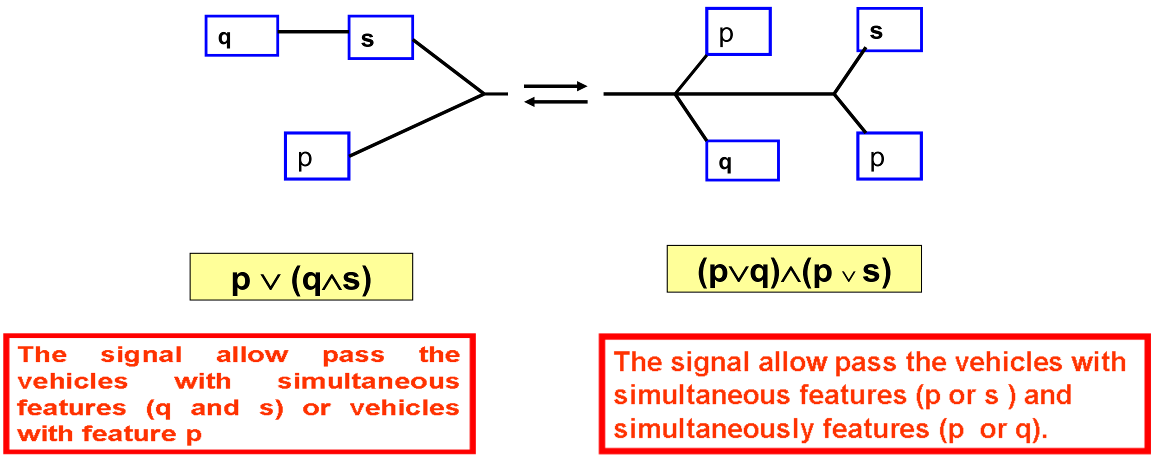

Fig. 9. Two equivalent signals of nodes on the left and right hand containing three various special functors: ***p, q, s***

The system on the left side of Fig. 9 shows firstly the series connection of the two special functors for various features **q** and **s**. Such element is connected parallel with the special functor **p**. Now we explain the technical interpretation for obtained result. Such signal traffic node or railway junction allows pass the vehicles or trains, which have simultaneously features **q** and **s** or vehicles (trains) with feature **p**.

The system on the right side of Fig. 9 shows firstly two parallel connections of two signal functors with various features namely connection **p** or **q** with connection **p** or **s**. Next, the mentioned connections are subsequently connected by the series means. Now we have the following technical interpretation. Such signal traffic node or railway junction allows pass the vehicles or trains with simultaneous features (**p** or **s**) and simultaneously features (**p** or **q**).

The logical equivalence of above mentioned signal nodes on the left and right side is confirmed by set theory i.e. by the good known distributive law expressed by the following propositional equation [4, 9]:

$$\mathbf{p}\vee(\mathbf{q}\wedge\mathbf{s}) = (\mathbf{p}\vee\mathbf{q})\wedge(\mathbf{p}\vee\mathbf{s}). \tag{1}$$

It is easy to see that with respect of the technical meaning the signal node on the left side of Fig. 9 has the less connections between functors in comparison with the equivalent signal node lying on the right side. Hence, the signal node on the left side is simpler than the signal node on the right side. Moreover, the vehicles or trains, which are realizing the drive after signal node on the left side tends to the less, wear than after drive realized by the signal node on the right side.

The system on the left side of Fig. 10 shows two logical equivalent signal nodes (where each consists of three special functors with various features: **p**, **q**, **s**).

The system on the left side of Fig. 10 shows firstly parallel connection of two special functors with various features **q** or **s**. Such element is subsequently connected in series with in the special functor **p**. The technical interpretation is as follows. Signal traffic node or railway junction allows pass the vehicles or trains with features **p** and simultaneously with features **q** or **s**.

The system on the right side of Fig. 10 shows at first two series connections of two special functors namely with various features connection **p** and **q** with additionally connection **p** and **s**. Such elements subsequently mutually are next parallel connected. We read following technical interpretation. Such signal traffic node or railway junction allows pass the vehicles or trains with simultaneous features **p** and **q** or vehicles or trains with features **p** and **s**.

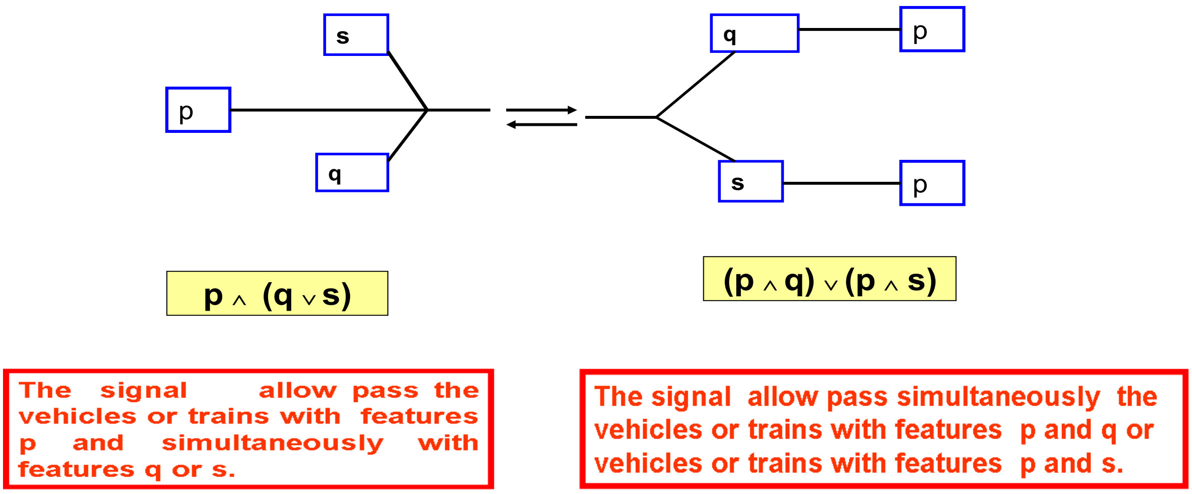

Fig. 10. Two equivalent system nodes on the left and right hand containing three various special functors: ***p, q, s***

The equivalence of above mentioned signal nods on the left and right side is confirmed by set theory i.e. by the good known propositional equation [4, 9]:

$$\mathbf{p}\wedge(\mathbf{q}\vee\mathbf{s}) = (\mathbf{p}\wedge\mathbf{q})\vee(\mathbf{p}\wedge\mathbf{s}). \tag{2}$$

It is easy to see that with respect of the technical meaning the signal node on the left side of Fig. 10 leads to the less connections between functors in comparison with the equivalent signal node lying on the right side. Hence, the vehicles or trains, which are realizing the drive after signal node on the left side tends to the less, wear than after drive realized by the signal node on the right side.

4. System, subsystem and its particular cases

Figure 11 shows more extended system-presenting signals described by the functors **p**, **q**, **s**. Signal node presented in Fig. 11a we can describe by the following logical formula [4, 9]:

$$(\mathbf{p}\wedge\mathbf{q})\vee(\mathbf{p}\wedge\mathbf{s})\vee(\mathbf{q}\wedge\mathbf{s})\vee[\mathbf{p}\wedge(\mathbf{q}\vee\mathbf{s})]\vee[\mathbf{q}\wedge(\mathbf{p}\vee\mathbf{s})]\vee[\mathbf{s}\wedge\mathbf{p}\wedge(\mathbf{q}\vee\mathbf{s})]\vee[\mathbf{s}\wedge\mathbf{q}\wedge(\mathbf{p}\vee\mathbf{s})]. \tag{3}$$

If we assume the following subsystem:

$$\mathbf{A} \equiv \mathbf{p}\wedge(\mathbf{q}\vee\mathbf{s}), \quad \mathbf{B} \equiv \mathbf{q}\wedge(\mathbf{p}\vee\mathbf{s}), \tag{4}$$

then the signal system (3) is reduced to the following form (5) and graphically presented in Fig. 11b.

$$(\mathbf{p}\wedge\mathbf{q})\vee(\mathbf{p}\wedge\mathbf{s})\vee(\mathbf{q}\wedge\mathbf{s})\vee\mathbf{A}\vee\mathbf{B}\vee(\mathbf{s}\wedge\mathbf{A})\vee(\mathbf{s}\wedge\mathbf{B}). \tag{5}$$

If we assume, that the **Closed functor s** = **0** describes control signal, which stops each vehicle or train, then:

$$\mathbf{A} \equiv \mathbf{p}\wedge(\mathbf{q}\vee\mathbf{0}) = \mathbf{p}\wedge\mathbf{q}, \quad \mathbf{B} \equiv \mathbf{q}\wedge(\mathbf{p}\vee\mathbf{0}) = \mathbf{p}\wedge\mathbf{q}, \quad \mathbf{A} = \mathbf{B}. \tag{6}$$

In this case, the signal system constructed in Fig. 11 a, b tends to the following form [4, 9]:

$$
\begin{aligned}
&(\mathbf{p}\wedge\mathbf{q})\vee(\mathbf{p}\wedge\mathbf{s})\vee(\mathbf{q}\wedge\mathbf{s})\vee\mathbf{A}\vee\mathbf{B}\vee(\mathbf{s}\wedge\mathbf{A})\vee(\mathbf{s}\wedge\mathbf{B}) = \\
&= (\mathbf{p}\wedge\mathbf{q})\vee(\mathbf{p}\wedge\mathbf{0})\vee(\mathbf{q}\wedge\mathbf{0})\vee\mathbf{A}\vee\mathbf{A}\vee(\mathbf{0}\wedge\mathbf{A})\vee(\mathbf{0}\wedge\mathbf{A}) = \\
&= (\mathbf{p}\wedge\mathbf{q})\vee\mathbf{0}\vee\mathbf{0}\vee\mathbf{A}\vee\mathbf{0} = (\mathbf{p}\wedge\mathbf{q}\vee\mathbf{A} = \\
&= (\mathbf{p}\wedge\mathbf{q}\vee(\mathbf{p}\wedge\mathbf{q}) = (\mathbf{p}\wedge\mathbf{q}).
\end{aligned} \tag{7}
$$

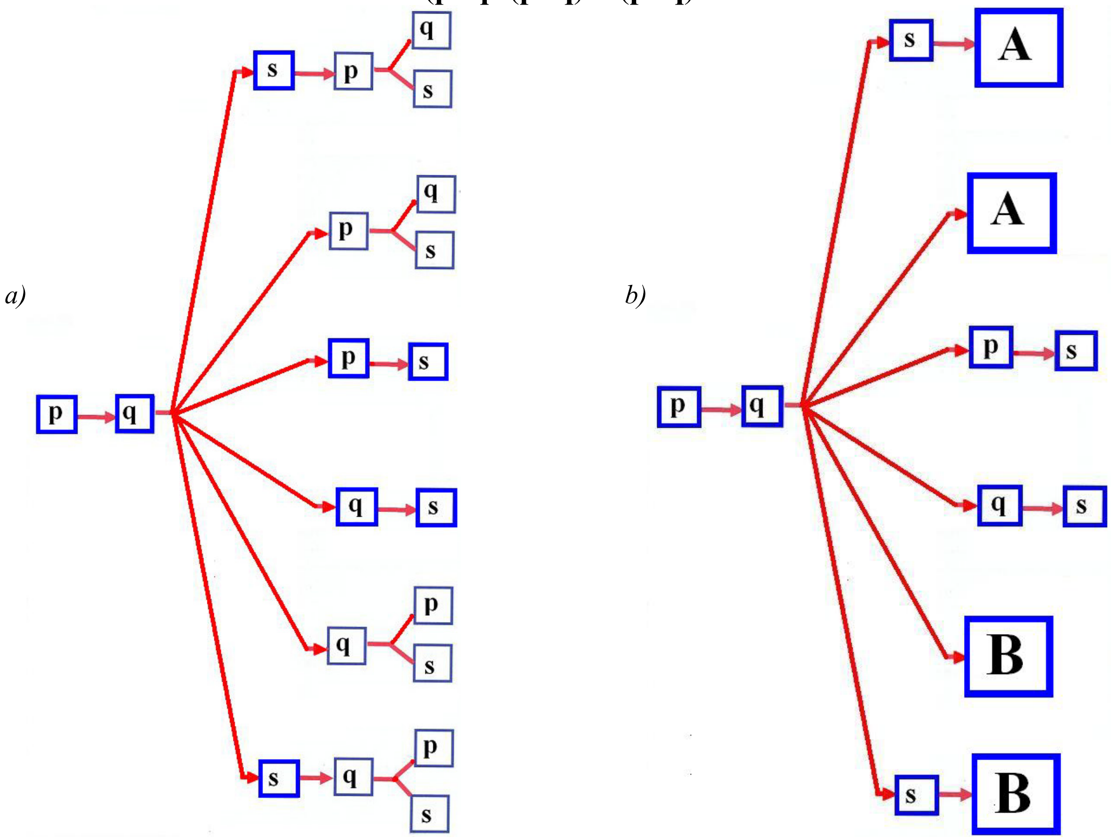

*Fig. 11. Signal node system containing three various special functors: a) three functors **p**, **q**, **s** located on the twenty various places, b) five functors **p**, **q**, **s**, **A**, **B** located on the twelve various places*

The result obtained after terms ordering in equation (7), presents the reduced, equivalent and simplified form compared with the system (3) illustrated in Fig. 12a:

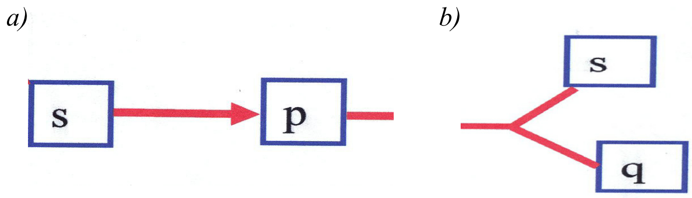

*Fig. 12. Equivalent simplification of the signal system presented in Fig. 11a, b: 12a) for **s** = **0**, 12b) for **s** = **1***

If we assume, that the **Open functor s** = **1** describes control signal, which allow passing each vehicle or train, then:

$$\mathbf{A} \equiv \mathbf{p}\wedge(\mathbf{q}\vee\mathbf{1}) = \mathbf{p}\wedge\mathbf{1} = \mathrm{p}, \quad \mathbf{B} \equiv \mathbf{q}\wedge(\mathbf{p}\vee\mathbf{1}) = \mathbf{1}\wedge\mathbf{q} = \mathbf{q}. \tag{8}$$

In this case, the signal system constructed in Fig. 11 a, b tends to the following form [2, p. 16]:

$$
\begin{aligned}
&(\mathbf{p}\wedge\mathbf{q})\vee(\mathbf{p}\wedge\mathbf{s})\vee(\mathbf{q}\wedge\mathbf{s})\vee\mathbf{A}\vee\mathbf{B}\vee(\mathbf{s}\wedge\mathbf{A})\vee(\mathbf{s}\wedge\mathbf{B}) = \\
&= (\mathbf{p}\wedge\mathbf{q})\vee(\mathbf{p}\wedge\mathbf{1})\vee(\mathbf{q}\wedge\mathbf{1})\vee\mathbf{p}\vee\mathbf{q}\vee(\mathbf{1}\wedge\mathbf{p})\vee(\mathbf{1}\wedge\mathbf{q}) = \\
&= (\mathbf{p}\wedge\mathbf{q})\vee\mathbf{p}\vee\mathbf{q}\vee\mathbf{p}\vee\mathbf{q}\vee\mathbf{p}\vee\mathbf{q} = \\
&= (\mathbf{p}\wedge\mathbf{q})\vee(\mathbf{p}\vee\mathbf{q}) = (\mathbf{p}\vee\mathbf{q}).
\end{aligned}
$$

The result obtained after terms ordering in equation (9), presents the reduced, equivalent and simplified form compared with the system (3) illustrated in Fig. 12b.

It is easy to see that with respect of the technical meaning the signal nodes presented on the Fig. 12a for **s** = **0**, and on the Fig. 12a for **s** = **1** have less connections between functors in comparison with the equivalent signal node lying in Fig. 11. Hence, the vehicles or trains, which are realizing the drive after signal node on the Fig. 12 tends to the less, wear than after drive realized by the signal node on the Fig. 11.

However both above considered signal systems (i.e. in Fig. 11a and Fig. 12a for **s** = **0**, and in Fig. 11a and Fig. 12b for **s** = **1**) are mutually equivalent and have the same logical meaning in the transport. The signal system in Fig. 12a shows the series connection of the two special functors for various features **p** and **q**. The signal system in Fig. 12b shows the series connection of the two special functors for various features **p** and **q**.

5. Practical example

After practical transport field experiences we assume [3], that each connection between functors illustrated for example in Fig. 10 causes the possibility of road accident with average probability value about P = 0.00001. The signal node on the left side of Fig. 10 has one parallel and one series connection i.e. has together two connections. Thus this signal node has the probability value of accident equals 2P = 0.00002. The signal node on the right side of Fig. 10 has one parallel and two series connection i.e. has together tree connections. Thus such signal node has the probability value of accident equals 3P = 0.00003. We put on the signal node and we switch off the signal node n = 100000 times on the left and right side. Such problem presents the Poisson's random variable distribution. Calculate the probability value of the one (k = 1) road accident existence after n = 100000 times of excluding and including the signal nodes occurring in Fig. 10 on the left and right sides.

Solution

The probability of the one road accident occurring after n = 100000 times of excluding and including the signal node on the left hand P_{1L}, and on the right hand P_{1R}, have accordingly with the probability Poisson theory the following value:

$$P_{1L} = \frac{(2P \cdot n)^k}{k!} e^{-nP} = \frac{(2 \times 0.00001 \times 10\,000)^1}{1!} e^{-2 \times 0.00001 \times 10\,000} = 0.1637\,, \tag{10}$$

$$P_{1R} = \frac{(3P \cdot n)^k}{k!} e^{-nP} = \frac{(3 \times 0.00001 \times 10\,000)^1}{1!} e^{-3 \times 0.00001 \times 10\,000} = 0.2222\,. \tag{10}$$

The one road accident probability for using the signal node occurring on the right hand is larger compared to the one accident probability which take place if we use the signal node on the left hand after n = 100000 times of the signal excluding and including.

6. Conclusions

In this paper is presented the possibility of logistic description of the signal systems and signal nodes occurring in train and road transport. On the ground of propositional calculus description and logical transformation, abovementioned system for the road net, communication network and railway junctions enables to indicate the equivalent and various and proper kinds of signals. Elaborated signal system describes the tools to obtain the optimum value of the velocity of convoy, wear and road accident probability of vehicle during the traffic. Moreover, presented propositional description indicates the proper way for the real and substantial vehicles in communication network and enables the traffic control.

Acknowledgement

This paper was supported by UE Grant IRSES,612593, 2013-2016.

References

[1] Cupryjak, P., Wasiak, M., *Uwarunkowania modelowania przewozu ładunków*, Prace Naukowe Politechniki Warszawskiej, Transport, Z. 97, pp. 63-71, 2013.
[2] Gaca, S., Suchorzewski, W., Tracz, M., *Inżynieria ruchu drogowego, Teoria i praktyka,* Wydawnictwo Komunikacji i Łączności, Warszawa 2014.
[3] Koziarski, S., *Transport lądowy w świecie*, Państwowy Instytut Naukowy, Instytut Śląski w Opolu, 2007.
[4] Kuratowski, K., *Introduction into set theory and topology*, PWN, Warszawa 1970.
[5] Lipiński, P., *Watermarking software in practical applications*, Bulletin of the Polish Academy of Sciences: Technical Sciences, Vol. 59, No. 1, pp. 21-25, 2011.
[6] Towards Intelligent Micro-Bearing, UE Grant IRSES,612593, 2013-2016.
[7] Wierzcholski, K., *Logical network of data transmission impulses in journal-bearing design*, Miscellaneous Problems in Maritime Navigation Transport and Shipping, pp.145-148, CRC Press/Balkema 2011.
[8] Wierzcholski, K., *Logical network design of microbearing systems*, Journal of KONES Powertrain and Transport, Vol. 18, No. 2, pp. 455-462, Warsaw 2011.
[9] Wierzcholski, K., Miszczak, A., *Logical network of vector spaces for intelligent optimum values of operational slide bearing*, Tribologia, Vol. 6 (246), pp. 169-176, 2012.