Simulation of Supply Chain with Disturbances Using Flexsim - Case Study

Patycja Hoffa(✉) and Pawel Pawlewski

Poznan University of Technology, ul.Strzelecka 11, 60-965 Poznań, Poland
patrycja.hoffa@doctorate.put.poznan.pl,
pawel.pawlewski@put.poznan.pl

Abstract. The aim of the paper is to present a simulation model of transportation which includes different disturbances. The paper describes in detail modeled route and way of modeling some disturbances. In article authors presented influence of distinguished distortion to time of realization transport task. Authors create own object with using Discrete Event Simulation and Agent Based Simulation approach. The research highlights of the performed works are as follows: showing influence of disturbances to transportation time and present a description to build objects, which represent disturbances.

Keywords: Supply chain · Disturbances · Creation of special objects · Simulation

1 Introduction

Paper presents author's work on supply chain modeling method with including the some disturbances. Given the wide range of aspects included in the supply chain, authors decided to concentrate on the selected area - transport processes and disturbances occurring in them and how they can be modeled. In the literature, many articles about modeling a supply chain can be find. Popular methods of modeling route/supply chain are: creation paths by using graph, by using algorithms and neural networks and others. However, describing the disruptions in transportation and how they can be modeled is not enough.

Authors in this article are presenting a simulation model of realization a transport order (route of this transport). This model takes into account some disturbances. It was created by using a modern software Flexsim, that allows build models of various degrees of complexity [26]. In order to present a discussed issues, authors integrate Discrete Event Simulation (DES) with an Agent Based Simulation approach (ABS). Authors created their own objects, which map some interference. This objects have a certain intelligence, which have been given by creator.

The main aim of this article is to present a simulation for chosen transport route, taking into account some disturbances and detailed description of a method of modeling those distortions. Authors also demonstrate in practice how they create these objects, not just a theoretical description. Important is also to show the relationship between disturbances and time of realization the transport task.

J. Bajo et al. (Eds.): PAAMS 2015 Workshops, CCIS 524, pp. 90–101, 2015.
DOI: 10.1007/978-3-319-19033-4_8

An article consists of six parts. Section 2 contains a literature background about a supply chain, way of route modelling and about disturbances in transport. A Section 3 presents detail descriptions of planned route as a case study. It includes description of method of modeling disturbances, and how they can be modeled in practice. Parts 4 and 5 refer to simulation experiments and results of them. An article ends with conclusions and plans for further work.

2 Supply Chain and Disturbances – Literature Background

Modern supply chains are dispersed systems [6, 19, 23]. In order to confirm the complexity of aspects in supply chain, few definition about them are presented. Recalling Umeda: “A supply chain system is a chain of processes from the initial raw materials to the ultimate consumption of the finished product spanning across multiple supplier-customer links. It provides functions within and outside a company that enable the value chain to make products and provide services to the customers.” [22]. Other definition is: „a supply chain is a worldwide network consisting of suppliers, manufacturers, warehouses, distribution centers and retailers through which raw materials are purchased, transformed and delivered to customers” [10]. So, the supply chain is represented by a number of actors and many factors (inside and outside the company [13]) which have an impact of its functioning. It can consist of two participants (sender and receiver), but it is more complicated often, as: wholesalers, storage or transport service providers.

Because of wide range of supply chain issue, in the literature can be found many articles about methods of describing and modeling a network. The most known are:

– modeled transport routes by using different type of network, for example Petri net [20];
– by using algorithm like Dijkstra and/Floyd-Warshall algorithms [9];
– and of course in mathematical description [24].

To model processes in supply chain, two methods are using: Discrete-Event Simulations (DES) and Agent-Based Simulation (ABS). DES models are characterized by the process approach – they focus on the modeling of the system in detail, not on the independent units. More information about this method can be found in [3, 7, 18]. Whereas, ABS focuses on individual elements (resource, participants in the process), which are characterized by their own distinct behaviors [14]. In ABS approach we should pay attention to: attributes and behaviors of individual agents, relations and interactions between agents and the environment that we model. Agent-Based Simulation is discussed in more detail in [2, 8, 13, 14].

Describing about disturbances in transportation issues, it should be noted that usually they involve of the transport of hazardous materials and the associated with this transport risks [5, 11, 16, 21]. Of course, it can be find articles about disturbances not related to transportation of hazardous material, for example about car accident [1, 17]. Very interesting approach to robustness of Multimodal Transportation Networks is presented in [4]. Author distinguished two types disruptions in supply and demand: structural and behavioral.

But there is a little number of articles devoted to modeling a disturbances, describing how to model them, not only to calculate the risk of their occurrence. Therefore, the authors decided to engage in the topic of disruptions modeling. A list of featured disturbances by authors with method of modeling them can be found in [12].

3 Simulation Model of Supply Chain - Description

The simulation model of the selected transport route was built using the Flexsim software. In this software we can simulate, analyze, optimize every systems and processes. The model is created in 3D visualization. Using Flexsim is very simple by build-in tool and objects [26]. In order to make the best representation of reality, some assumptions were made, for example about vehicle speed and the presence of interfering elements transport mileage. Detailed assumptions are described in the next part of article.

3.1 Model of Transport Route - Definition of the Problem and the Assumptions

General information about the modeled transport routes are included in Table 1. This route includes travel from Jarogniewice city to Zgierz city, both of them are located in Poland.

Table 1. Modeled transport route – general information.

Transport route				
Loading place	Zip code	Unloading place	Zip code	Distance [km]
Jarogniewice	64-020	Zgierz	95–100	222

Figure 1 presents the route.

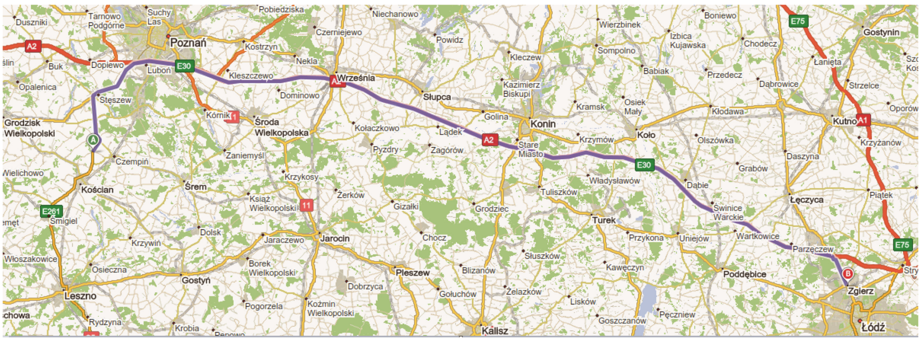


Fig. 1. Jarogniewice – Zgierz route. Source: [30].

The planned route includes journey using motorway A2. Part of the road (from Komorniki to Konin) is managed by Autostrada Wielkopolska [25]. At this section of route some toll collection points are, so fee should be pay. Further section (Konin - Emilia node) is managed by GDDKiA, and therefore fees are collected through an electronic system viaTOLL [27]. Table 2 shows the places where there are manually toll point. In those points, in relation to pay a fee, there is slow traffic. Therefore, authors treat these situations (these points) as a disturbance.

Table 2. Manual Toll Collection Point at the route. Source: based on [25, 27].

Toll collection point	
Administrator	Place
AW	Nagradowice
AW	Lądek
GDDKiA	Konin Wschód
GDDKiA	Emilia

In present simulation model, assumes that speed of a mean of transport is 80 km/h (+ - Acceleration/Deceleration). This speed is intentionally not a random value, because authors want to clearly show the influence of various disturbances on the modeled route - at the time of realization the transport order.

The purpose of the simulation model is show the transport time from the start to the final point, in the event of the occurrence of different, random disruptions. In this model includes three types of disturbances:

(1) Driver working time - in conjunction with the applicable provisions [29] time of driver working should be considered; authors treat this as a certain disruption (time of working between next break are well known and duration of break are know too; these breaks increase the time interval of the order realization);
(2) Time of fee payment in Toll Collection Point (TCP) - in connection with moving by motorway, we are faced with a manual toll collection points; time spent at these points is variable - it depends on the volume of traffic;
(3) Road accident - List of “Black points”, which is widely available, can be used for defining the dangerous places in Poland [28]. At the planned route the black point doesn’t exist, but authors decided to take into account this disturbance in some point as a random incident.

3.2 Selected Disturbances - Description and Method of Modeling

For the above-mentioned interference, detailed method of modeling will be presented. Authors, in order to model a particular interference, created own objects with special labels and some assigned intelligence. Each disruption is described in detail in next part of this work.

Driver working time. In accordance with current regulations, the driver at the specified interval has to stop and make a break (during which he can not to do any other operations - e.g. loading processes) [29]. In the present model, the time of driver working starts at time, when vehicle received the message about new transport order to its completion. Therefore, loading and unloading operations are included. The authors treat the break as the disturbance - an element extending the time of realization order. But they have to be made. Analyzing the driver work time, in the basic terms, the driver after 4.5 hours of driving/work is required to make a 45 minutes break, then after a further 4.5 hours driving/working a break is equal 11 hours. This approach has been simulated in the model (the authors did not take into account other cases of breaks in work, because this disturbance is like a reminder to modeler that the driver must have breaks!! Besides at the market, specialized programs for time management driver can be founded.

Driver working time in the simulation model is mapped by using individually created object called Driving_Work_time_Measure (Fig. 2). This object has 7 labels: the first specifies the time interval between subsequent measurements, the second and the third contains information on what time after the start of the work is have to be a break; lables 4 and 5 contain information about time duration of each break; 6 and 7 are supplemented with the start time (time of receipt message about starting transport order by the vehicle = start time), and with the end time (end of transportation order = stop time).

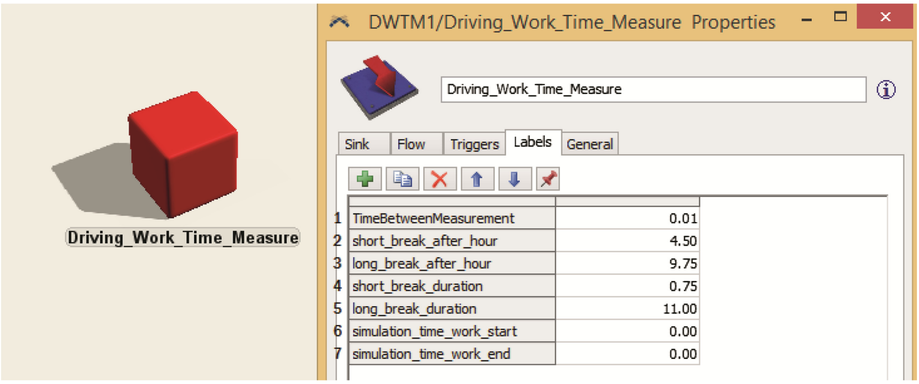


Fig. 2. Driving_Work_Time_Measure-Object.

In presented labels, important information are written. Thanks to them object manages of mean of transport, when the break have to be made. This object contact with vehicle by sending messages. Driving_Work_time_Measure Object, after receiving information from a vehicle that it started a work - sends information to itself about next break (break type and duration). In situation when a break should be made, created object sends a message to vehicle (about stop it) and to itself. And after appropriate time (equal time of break) it sends next message to mean of transport about unlocking and to itself about next step in measurement. This cycle is shown schematically at Fig. 3.

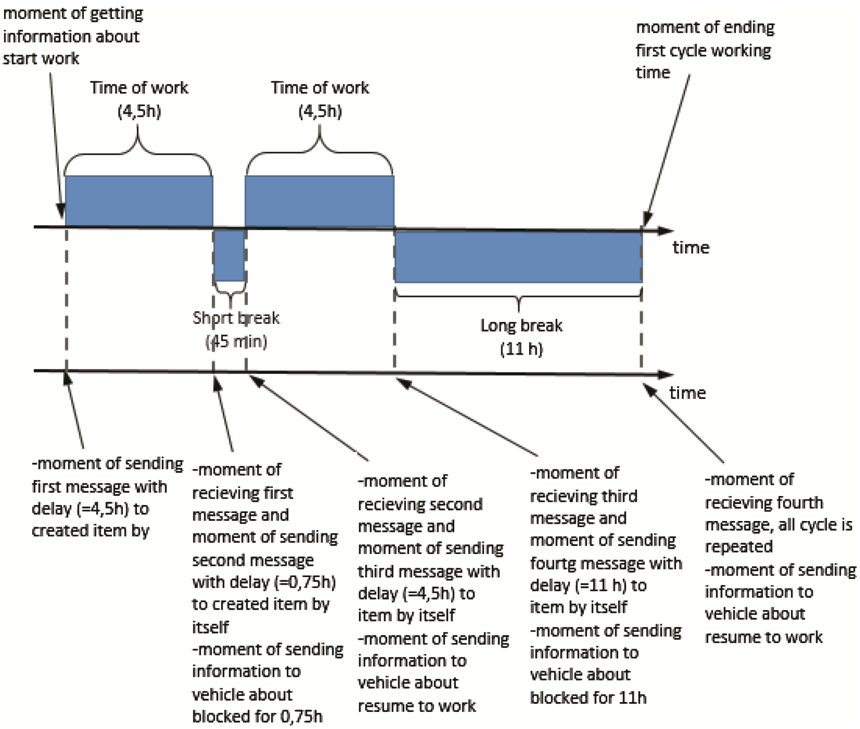


Fig. 3. Driving_Work_time_Measure Object - mechanism of sending message.

Toll collection point. In connection with moving motorways in the presented case study, toll collection points should be take into account. In these points, speed of travel are slowed down because of stop for the fee payment. Authors had created new object (TCP) to map this situation. TCP has four labels, in which the values for the stop operations at the fee payment point are defined (mean, deviation, min, max). On the basis of these labels, value of the blocking time is defined with using normal distribution. When the vehicle comes to toll collection point, it is stopped for established time. The slow down of the speed around the toll point is not included - it is included to stop time at point.

Disruption is modeled as follows: created object named TCP is combined with network, in which is a toll point. At the moment of the reset a model, a stop time at TCP is defined, by using normal distribution (in relation to values in labels). At the time of arrival the vehicle to the point, information about this situation is sending to TCP object (1). In response, the TCP object sends the information about stopped to the vehicle, and it sends to itself delayed information, delay is equal defined time of stopping (2). After this time, the TCP object receives a message from itself and sends information to vehicle to unlocked it (3). The described situations are shown in Fig. 4.

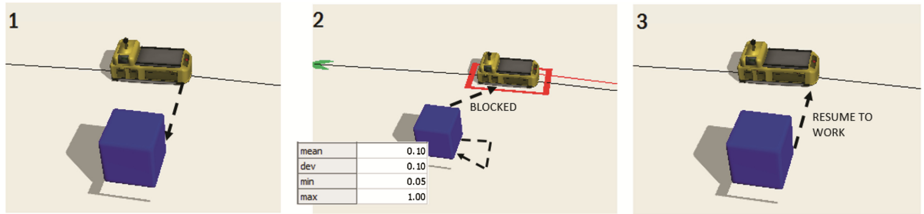


Fig. 4. TCP_Object – situations of sending message.

Car accident. Another modeled disturbance in the present case study, is the occurrence of a car accident. Due to the existence of a public list of so-called black spots, it is possible to define dangerous places [31]. Based on historical data it can be estimate the probability of collision at this point. In the case of described disruption, two situations has been distinguished:

(1) the vehicle reduces its speed at range of the collision (the range depends on traffic);
(2) the vehicle is involved in an accident - it was assumed that the vehicle is unable to continue the transportation task (speed of travel = 0 km/h).

Extent of this disturbance is expressed by a circle with a given radius. Each traffic accident is mapped on a single object named Collision. Authors created this object with using TaskExecuters Object in flexsim. They used this type because it has additional function – definition of collision and possibility to check if other object are in this area. In situation when the road is blocked in connection with a traffic accident, it should be take into account the additional time required to complete the order (in the event of failure to comply with the delivery date could mean a financial penalty).

Authors, using the ABS approach, created object with defined properties, which are stored in the labels. This created object has 17 labels (Fig. 5).

Label 1 contains information about type of accident (involving a car which realizes the order or no) - this value is defined according to the information contained in the other labels.

Label 2 - is a part of the information that describes the type of accident.

Labels 3 and 4 - they are places, where the probability of occurrence of a given type of accident at a given point, have to be defined.

Labels 5–8 - they are contained information about the speed of the vehicle in the event of a car accident without the participation of our vehicle; a speed is defined on the basis of these data.

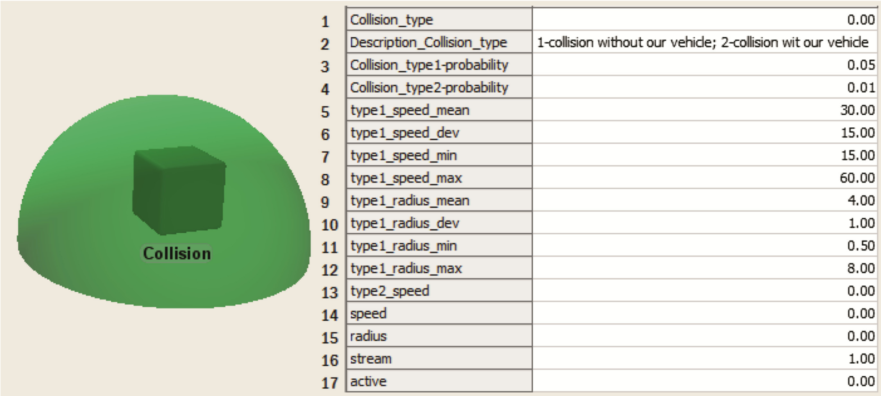
Labels 9–12 - they included information about car accident range (radius), a radius is defined by this information, with using a normal distribution.

Label 13 - is equal 0 - in the case of an accident involving our car, it is assumed that it can not to continue further drive (does not move).

Labels 14–15 contain randomly selected values for each elements. In case of accident type 2 radius is 1.

Label 16 - allows you to change the stream of random numbers.

Label 17 - it gets information about that if in a disruption range is another object or not.



1	Collision_type	0.00
2	Description_Collision_type	1-collision without our vehicle; 2-collision wit our vehicle
3	Collision_type1-probability	0.05
4	Collision_type2-probability	0.01
5	type1_speed_mean	30.00
6	type1_speed_dev	15.00
7	type1_speed_min	15.00
8	type1_speed_max	60.00
9	type1_radius_mean	4.00
10	type1_radius_dev	1.00
11	type1_radius_min	0.50
12	type1_radius_max	8.00
13	type2_speed	0.00
14	speed	0.00
15	radius	0.00
16	stream	1.00
17	active	0.00

Fig. 5. Created collision object.

In case of a traffic accident, the range of them is defined by values in labels and with using normal distribution. In the same way the speed in range of disturbances is defined. This object, of every certain time interval, checks if in defined range appeared another object, if so then performing a specific action - changes the speed of travel in a foreign object. In the moment, when it is determined that the foreign object (mean of transport) is no longer in a disturbance range, created object again changes the speed of the vehicle, to value as which a vehicle had before it came to this disruption. Checking the area of interference occurs very often (currently 0.01 time unit). Thanks to this, the moment when the vehicle has left the disturbance is quickly noticed. Figure 6 shows described situations.

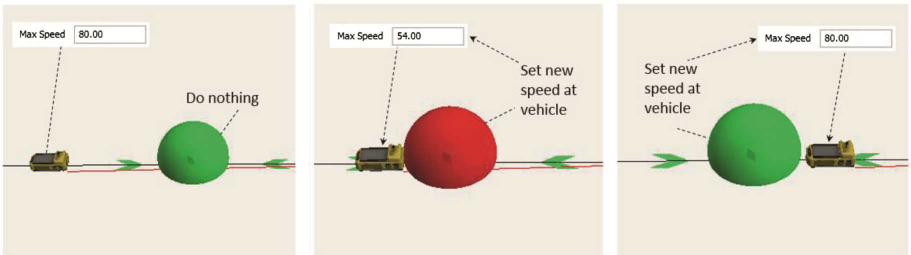


Fig. 6. Collision object – mode of action.

4 Simulation Experiment – Description

Simulation model with a selected route (described in Sect. 3) was created, in order to show the effect of various disturbances on the duration of the transport order. For a choosen route, few experiments were made, in which the values of the different variables have been changed. In preset case authors do not take into account the possibility of a detour - alternate route. The issue of seeking a new route, because of disturbances, is not the aim of this study. In order to carry out experiments, authors have used a built-in experimenter tool. Each experiments were made 10 times (replications) because of occurrence of normal distributions in the model. The aim was to show differences in the analyzed a transport time, which depends of the duration of each activities (which are random values). To not make a model too difficult, some simplifications were made. Thanks to them analysis about relations between disturbances and time of transportation are possible. Therefore some variables in the model left unchanged (like values for deviation, min, max in the presented disturbances).

Information about the experiments are summarized in Table 3. Important information is the fact, that the travel time from point A to point B without any disturbance is equal 2.78 hour.

Table 3. Definition of simulation experiments.

Experiment				
No	Take into account the driver's working time	Mean Time in every TCP	Probability of type 1 collision	Probability of type 2 collision
1	yes	0,1	0,1	0,01
2	yes	1	0,8	0,01
3	yes	1	0.1	1

5 Experiments - Results

The purpose of the experiments was to determine the transportation time and show the impact of disturbances to this time. Experiments were made by using the built-in experimenter tool in Flexsim software. Table 4 shows results of each experiments and each replication. As we can see, in situation with taking into account driving work time and disturbances like waiting in TCP and little probability of car accident in one point, the transportation time is bigger (scenario 1). We have to remember that result are different because of random values. In case with longer spending time in TCP and bigger probability of type 1 car accident, the time of transport is much longer. Of course in normal situation we will not stay in every TCP about 1 hours – it was defined so big to show a relation and to show the defined state at graph (Fig. 7). For scenario 3 the transport time is equal 0 – it is true, because mean of transport is involved in a car accident and can not continue the realization of work – it never comes to unload point. By using built-in experimenter tool we have information about interval of values of the analyzed time for the confidence interval as 90 % (Fig. 8).

Table 4. Results of simulation experiments. Source: results obtained from Flexsim model.

	Transportation Time [h]				
	Rep 1	**Rep 2**	**Rep 3**	**Rep 4**	**Rep 5**
Scenario 1	3,34	4,96	3,09	3,22	3,22
Scenario 2	8,55	8,98	7,34	7,39	8,72
Scenario 3	0	0	0	0	0
	Rep 6	**Rep 7**	**Rep 8**	**Rep 9**	**Rep 10**
Scenario 1	3,28	3,27	3,25	9,15	3,20
Scenario 2	29,37	23,84	24,04	23,31	7,39
Scenario 3	0	0	0	0	0

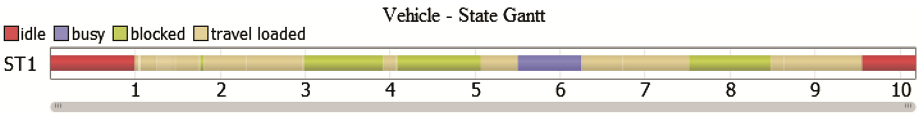


Fig. 7. State of vehicle. Source: results obtained from Flexsim model.

	Mean (90% Confidence)					Sample Std Dev	Min	Max
Scenario 1	2.9	<	4.0	<	5.1	1.9	3.1	9.1
Scenario 2	9.7	<	14.9	<	20.1	9.0	7.3	29.4
Scenario 3	N/A	<	0.0	<	N/A	0.0	0.0	0.0

Fig. 8. Confidence interval for analyzed time. Source: results obtained from Flexsim model.

Figure 7 present states of vehicle. State BLOCKED is when mean of transport is waiting in TCP. State BUSY is when the driver has a break (in accordance to law regulation).

6 Conclusion and Further Investigations

This article presents in detail a method of transport routes modeling, including disturbances. In the case study authors show the effect of disturbances on the duration of the transport task. Using the simulation model, we can observe and experiment with the process - which gives a chance to improve it. Besides using the built-in Experimenter tool, it is possible to determine the range of values describe transport time for a given confidence interval. An important aspect of this article is a detailed description of way of modeling the individual disturbance and present how they work in practice (in the model) and not just in theory (description).

Obviously, there is an opportunity for further development of the proposed work: modelling next disturbances in described way (with combining ABS and DES approach). Besides experiment with them at created routes, and check influence of them to the transport time. By building a library of possible disruptions, we can fast build a model of routes and play (experiment) with them. And then, search a range of the time needed to travel by vehicle from point A to B at a given confidence interval will be possible. Information about needed time to travel from point A to B taking into account different disturbances, are very useful for transport companies and other.

Acknowledgements. Presented research are carried out under the LOGOS project (Model of coordination of virtual supply chains meeting the requirements of corporate social responsibility) under grant agreement number PBS1/B9/17/2013.

References

1. Alteren, B., Hokstad, P., Moe, D., Sakshaug, K.: A barrier model for road traffic applied to accident analysis. In: Spitzer, C., et al. (eds.) Probabilistic Safety Assessment and Management, pp. 3603–3608. Springer, London (2004)
2. Bae, J.W., Lee, G., Moon, I.: Introductory tutorial: agent-based modeling and simulation. In: Winter Simulation Conference, pp. 3809–3820 (2012)
3. Banks, J., Carson II, J.S., Nelson, B.L., Nicol, D.M.: Discrete-Event System Simulation, 4th edn, pp. 68–86. Prentice Hall, Upper Saddle River (2004). ISBN 0-13-144679-7
4. Bocewicz, G.: Robustness of multimodal transportation networks. Eksploatacja i Niezawodność-Maintenance and Reliability **16**(2), 259–269 (2014)
5. Brussaard, L.A., Kruiskamp, M.M., Oude Essink, M.P.: The Dutch Model for the quantitative risk analysis of road tunnels. In: Spitzer, C., et al. (eds.) Probabilistic Safety Assessment and Management, pp. 2660–2665. Springer, London (2004)
6. Caddy, I.N., Helou, M.M.: Supply chains and their management: application of general systems theory. J. Retail. Consum. Serv. **14**, 319–327 (2007)
7. Cassandras, C.G., Lafortune, S.: Introduction to Discrete Event Systems, 2nd edn, pp. 557–615. Springer, Heidelberg (2008). ISBN 978-0-387-33332-8
8. Chan, W.K.V., Son, Y., Macal, C.M.: Agent-based simulation tutorial – simulation of emergent behavior and differences between Agent-Based Simulation and Discrete-Event Simulation. In: Winter Simulation Conference, pp. 135–150 (2010)
9. Chen, S., Peng, H., Liu, S.: Yang, Y.: A Multimodal Hierarchical-based Assignment Model for Integrated Transportation Networks. J. Transp. Syst. Eng. Inf. Technol. **9**(6), 130–135 (2009)
10. Fung, R.Y.K., Chen, T.: A multiagent supply chain planning and coordination architecture. Int. J. Adv. Manuf. Technol. **25**(7–8), 811–819 (2004)
11. Gheorghe, A., Birchmeier, J., Kröger, W.: Advanced spatial modelling for risk analysis of transportation dangerous goods. In: Spitzer, C., et al. (eds.) Probabilistic Safety Assessment and Management, pp. 2499–2504. Springer, London (2004)
12. Hoffa, P., Pawlewski, P.: Agent based approach for modeling disturbances in supply chain. In: Corchado, J.M., et al. (eds.) Highlights of Practical Applications of Heterogeneous Multi-Agent Systems. The PAAMS Collection, pp. 144–155. Springer, Heidelberg (2014)
13. Jasiulewicz-Kaczmarek, M.: Role and contribution of maintenance in sustainable manufacturing. In: Bakhtadze N., Chernyshov K., Dolgui A., Lototsky V., (eds.) 7th IFAC Conference on Manufacturing Modelling, Management, and Control, part 1, vol. 7, pp. 1146–1151 (2013)
14. Kim, S.-H., Robertazzi, T.G.: Modeling Mobile Agent Behavior. Comput. Math. Appl. **51**, 951–966 (2006)
15. Macal, C.M., North, M.J.: Introductory tutorial: agent-based modeling and simulation. In: Winter Simulation Conference, pp. 362–376 (2013)

16. Marseguerra, M., Zio, E., Bianchi, M.: A fuzzy model for the estimate of the accident rate in road transport of hazardous materials. In: Bedford, T., van Gelder, P.H.A.J.M. (eds.) Safety and Reliability, pp. 1085–1092. Swets & Zeitlinger, Lisse (2003)
17. Orlandelli, C.M., Vestrucci, P.: Development of a road transportation risks data base for Italy: methodology, models and results. In: Spitzer, C., et al. (eds.) Probabilistic Safety Assessment and Management, pp. 2269–2274. Springer, London (2004)
18. Siebers, P.O., Macal, C.M., Garnett, J., Buxton, D., Pidd, M.: Discrete-event simulation is dead, long live agent-based simulation! J. Simul. **4**(3), 204–210 (2010)
19. Sitek P., Wikarek J.: A hybrid approach to supply chain modeling and optimization. In: Federated Conference on Computer Science and Information Systems, pp. 1223–1230 (2013)
20. Skorupski, J.: Sieci Petriego jako narzędzie do modelowania procesów ruchowych w transporcie, Prace Naukowe Politechniki Warszawskiej, Transport, z.78, pp.69–84 (2011)
21. Tixier, J., et al.: Development of a risk knowledge platform dedicated to accident of dangerous goods transportation. In: Guedes Soares, G., Zio, E. (eds.) Safety and Reliability for Managing Risk, pp. 117–122. Taylor & Francis Group, London (2006)
22. Umeda, S.: Simulation analysis of supply chain systems with reverse logistics. In: Winter Simulation Conference, pp. 3375–3384 (2013)
23. Wieland, A., Wallenburg, C.M.: Supply-Chain-Management in stürmischen Zeiten, Berlin. (2011)
24. Wilhelm, T., Hollunder, J.: Information theoretic description of networks. Phys. A **385**(1), 385–396 (2007)
25. http://autostrada-a2.pl. Accessed Jan 2015
26. https://www.flexsim.com/. Accessed Jan 2015
27. http://www.gddkia.gov.pl. Accessed Jan 2015
28. http://gddkia.gov.pl/pl/aprint/6636/mapa-i-spis-czarnych-punktow. Accessed Jan 2015
29. http://isap.sejm.gov.pl/. Accessed Jan 2015
30. https://mapa.targeo.pl. Accessed Jan 2015
31. http://www.rmf24.pl/fakty/polska/news-szokujacy-raport-o-polskich-drogach-zobacz-mape-czarnych-odc,nId,769924. Accessed Jan 2015