AGENT-BASED MODELING OF STEEL PRODUCTION PROCESSES UNDER UNCERTAINTY

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Abstract

The paper refers to a general idea of the multi-agent method for modeling the logistics system in the steel industry. The advantage of the use of the agent-based approach as decision making system in transport, is that the agent-based systems are efficient (asynchronous independent operation), reliable (failure of one agent does not cause failure of the entire system), flexible (can adapt the system to a larger size by adding new agents without impact on existing) and have an ability to respond to changes occurring in the environment. The paper shows a scheme of the multi-agent system used for modeling, its basic goal, the range of knowledge, actions and states of its components, as well as the environment in which agents operate.

Keywords: Multi-agent system, transport, logistics system

1. INTRODUCTION:

In the logistic system of metallurgical plants there are two phases of physical flows, involving the time-spatial transformation and the qualitative transformation of the goods. The first phase includes the flow of the raw materials used in the production process, from suppliers to the stock of the company. In this phase the purchased goods flow from the stockpile to the area where the production process is carried out. To implement the manufacturing process it is required to provide the relevant raw materials to the steelworks. Companies are equipped with large, in terms of weight and capacity, amount of all kinds of raw materials. The raw materials, that have the strategic importance for the investigated company are: iron ore, coke, fly ash, lime stone. In the case of researched object about seven million tones of iron ore is delivered and consumed in metallurgic process every year [18]. The most important, due to the mass of the delivered goods as well as the costs of the delivery, is the transport of the iron ore. It represents about 72% among carriage of strategic raw materials, and over 23% of all transport actions carried out in the company. The railway is the main mean of transport used for the carriage of materials, both from external suppliers, as well as to the internal conveying. The materials required for production are delivered to the stockpiles which are characterized by a limited surface. The buffer for the averaged mixture/compound has an area of 69 300 m^2 and a storage capacity of 600 000 Mg, the remaining buffers have an area of 852 000 m^2 and a capacity of 1 000 000 Mg. The restricted capacity of the stockpile determines possible to maintain reserve, which, in the case of an averaged mixture is equal to 120 000 Mg. Maximum size of the reserve is very rarely kept because of the cost of collecting and storing the material. In the investigated steelworks, the limit of the stored mixture is set to the level of 65 000 Mg which, assuming the regular deliveries of the raw materials to the plant, should ensure the continuity of the production. The regularity of deliveries of raw materials is an important factor in maintaining the this continuity. Research has shown that assumed level of the stock does not fill out gaps, arising from different types of disruptions, in the supply of raw materials. Analysis of the historical data, regarding the real level of reserve of raw materials, has shown that company has not kept stocks at a required level (see **Fig. 1**). This situation occurred especially in the winter months, and an important role in the supply delays and declining safety stock levels have the weather conditions. The unloading of the frozen trains with supplied raw material is possible after thawing that lasts 3-4 days. To prevent this type of situation the assessment of the risk of disruption is required.

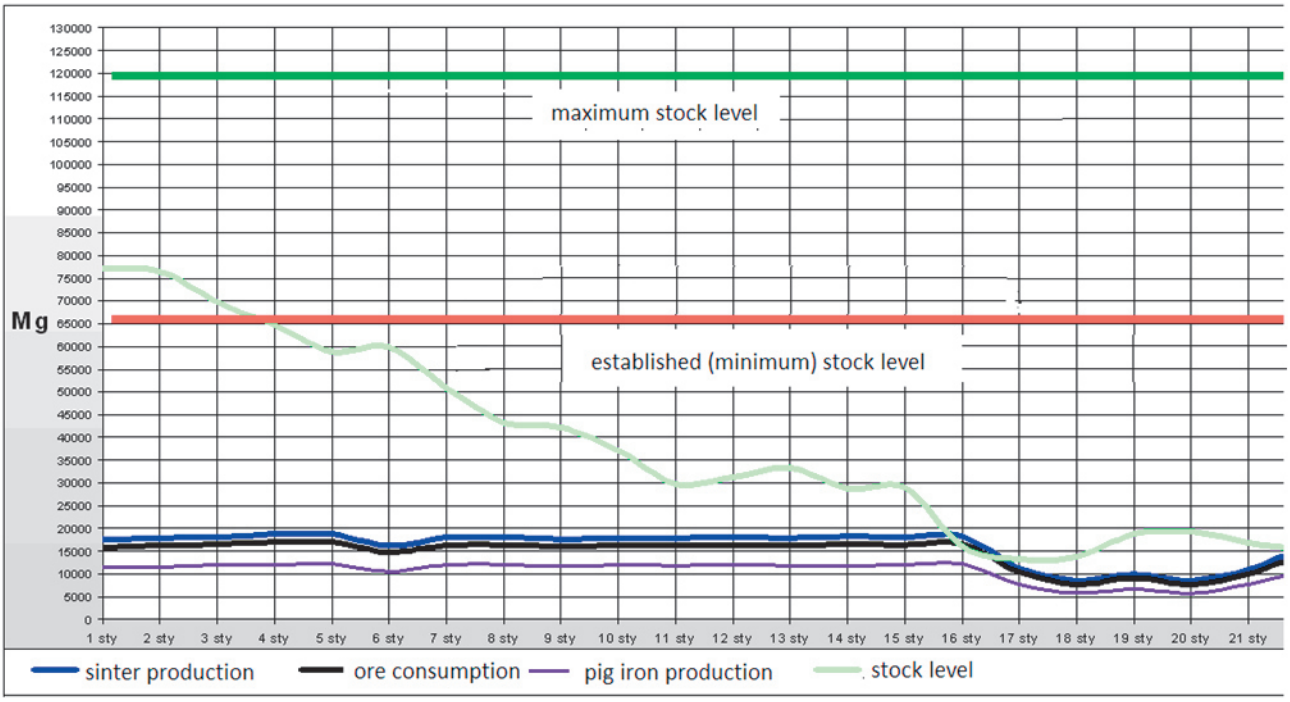

Fig. 1 The level of reserve and the use of materials (own elaboration)

The problems associated with the risk in the logistic systems are widely discussed in many publications. Their specificity is to combine the concepts of risk vulnerability and resilience as in selection of the publications in this field [1], [4], [5], [6], [7], [8], [19], [20], [21], [23], and in our own experience [2], [3], [12], [13]. Below the concepts of used agent-based approach in preventing interruptions in the continuity of supply of selected raw materials for steel mill is presented.

2. DESCRIPTION OF THE RESEARCH OBJECT

The subject of the research is the transport system of a steelworks located in Central Europe. The essential raw material for the company is the iron ore. It is mainly imported from abroad - from East Europe and Brazil. The ironworks can also be supplied with the ore from Serbia, although deliveries from this country are carried out only occasionally. In the case of the ore import from Brazil the information about the size of the ore contracts should arrive to supplier ahead of time of 4-6 weeks. Then the appropriate information should be also passed to the national carrier, which prepares the carriages for transporting the ore to the south of Poland. If the company has an excess of the ore in the buffers, the ore from Brazil can be stored in stockpiles in the port of Świnoujście, however no longer than 21 days. The transport of the ore from the East of Europe looks in another way. The company imports the iron ore mainly from Ukraine - about 5.5 million Mg every year, while from other sources only 1,5 million Mg. From Ukraine, ore is transported to Poland directly in railway carriages. The load capacity of a single train is about 1.5 thousand Mg and the loading operation lasts about 24 hours. Depending on the distance between the mine and Polish border as well as the weather conditions, the delivery time, i.e. an entry of the train into the steelworks area, varies from 4 up to 8 days. Due to many factors (often of the random nature) that may interfere with the delivery schedule it is very important to prepare the supply order ahead of time and in an appropriate amount of materials.

The model of the transport system was built with the use of system dynamic method and agent-based modeling technique. The methods of systems thinking provide us with tools for better understanding these difficult management problems. The methods have been used for over thirty years [10] and are now well established. However, these approaches require a shift in the way we think about the performance of an organization. In particular, they require that we move away from looking at isolated events and their causes (usually assumed to be some other events), and start to look at the organization as a system made up of interacting parts.

The basic elements used to describe the behavior of different kind of processes in the system are Stocks, Flows and Information. Most business activities include one or more of the following five types of stocks: materials, personal, capital equipment, orders, and money. The most visible signs of the operation of a process are often movements of these five types of stocks, and these are defined as follows:

Materials. This includes all stocks and flows of physical goods which are part of a production and distribution process, whether raw materials, in-process inventories, or finished products.

Personnel. This generally refers to actual people, as opposed, for example, to hours of labor.

Capital equipment. This includes such things as factory space, tools, and other equipment necessary for the production of goods and provision of services.

Orders. This includes such things as orders for goods, requisitions for new employees, and contracts for new space or capital equipment. Orders are typically the result of some management decision which has been made, but not yet converted into the desired result.

Money. This is used in the cash sense. That is, a flow of money is the actual transmittal of payments between different stocks of money.

Stocks define static part of the system. Flows define how values of stocks change in time and thus define the dynamics of the system.

Searching for the dependencies between flow points (e.g. materials) in systems and the existing feedbacks is the essence of system dynamics modeling. It is derived from the analysis of technical and industrial systems, but works perfectly also in a study of developments in the social, economic and others. The feedback loops occurring separately are devoid of possibility of the representation of the level structure and the flows in the system. Levels and flows form the core around which the whole concept of the system dynamics is focused. Integration, which is the basic idea of applications in flows and levels modeling, results in the temporary nature of the behaviors in the system and also is the source of the delays between the flowing streams. It decides about the dynamic behavior of the system.

The Modeling of dynamic processes using system dynamics methods carries with it some restrictions, e.g. resulting from the difficulties in taking into account the occurrence of the disturbances within logistics systems [26]. Disruptions often have random nature, belong to rare events and have a significant impact on the efficient functioning of the logistics system, especially on its operational level. To allow inclusion of such a type of cases one should combine dynamics system modeling with discrete system simulation and agent-based modeling techniques.

An intelligent agent is a computer software or device that works on its own in an open, distributed environment and solves a problem or perform a specific task [22], [9]. The agent perceives its environment and may interact with it, it is also characterized by the autonomy (it can operate without human involvement or other agent). Nowadays applications more and more often are based on multi-agent systems, i.e. a loosely affiliated networks of agents, which operate to solve the problems that lie beyond their individual capabilities and scope of knowledge. The advantage of this approach is the speed of obtaining results (each of the agents has to solve the problem of lesser complexity) and the use of a wider range of knowledge when making the final decision (knowledge of many agents). The control in the multi-agent system is decentralized [14], [15], [16], [17].

The model presented below, combines the two mentioned above ways of modeling. The main part of the model, reflecting the realization of supply chain, shown schematically in the **Fig. 2** was built from the elements used in the modeling of dynamic processes [25]. The model takes into account the relevant logistic delays.

The risks arising from the disruption within a supply chain and the ways of preventing their adverse effects were modeled using agent systems, while the moments, when threats occur were modeled as random discrete events with the use of the corresponding distributions [27, 28, 29]. The task of the agents is an appropriate (not too early or too late) response to the presence of distortions within the supply cycle in order to sustain continuity of a production by providing the required amount of raw materials to the plant.

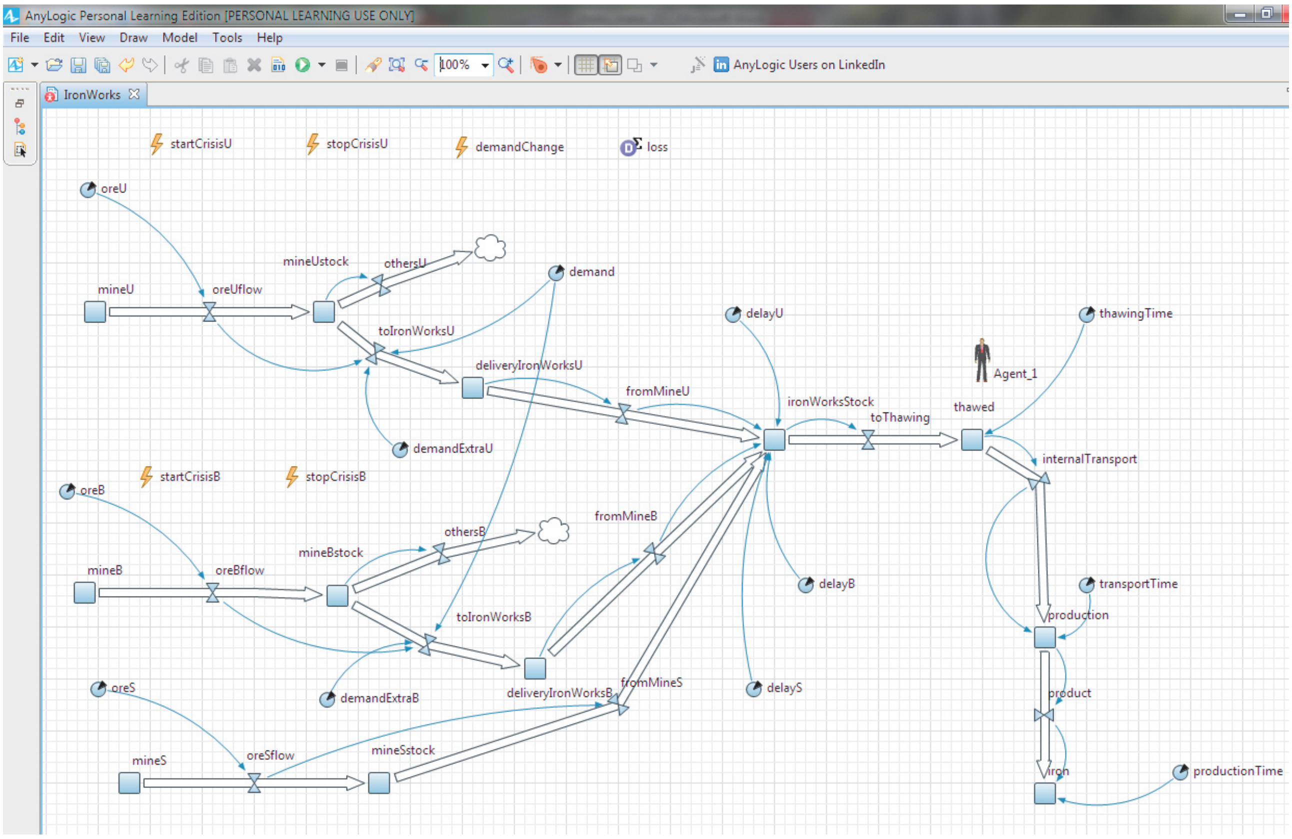

Fig. 2 The model of the system (own elaboration)

The main goal of the proposed multi-agent system is to secure the continuity of the production process. The system has the knowledge, among others, about transport situation (including the communication net, the political status, geographical disasters), the time and size of the delivery, the thawing time, the amount of raw material in the stockpile. It reacts depending on the level of the reserve and the weather condition. As an action to ensure the production continuity agent starts an extra deliveries. An agent can be in states of normal order realization, checking the condition, an extra order preparing and extra order realization.

The three following cases have been analyzed:

a) The real system, i.e. the reserve is set to about 65 000 Mg, an agent-system does not undertake any extra action;

b) The reserve is set to maximum of possible level, i.e. about 120 000 Mg, an agent-system does not undertake any extra action;

c) The reserve is set to 65 000 Mg and an agent-system react when the reserve is less than 30 000 Mg.

In all the cases it was assumed that the material is frozen. The results are shown in the **Fig. 3**. In the upper plots the continuous line represents the stock level, the circle-line the usage of the material and the triangle-line the completed product. In the lower plots the continuous line represents the demand for the product and the circle-line the production. The percentage loss in production are equal to: in case (a) 18.12% in case (b) 7.91% and in case (c) 7.67%.

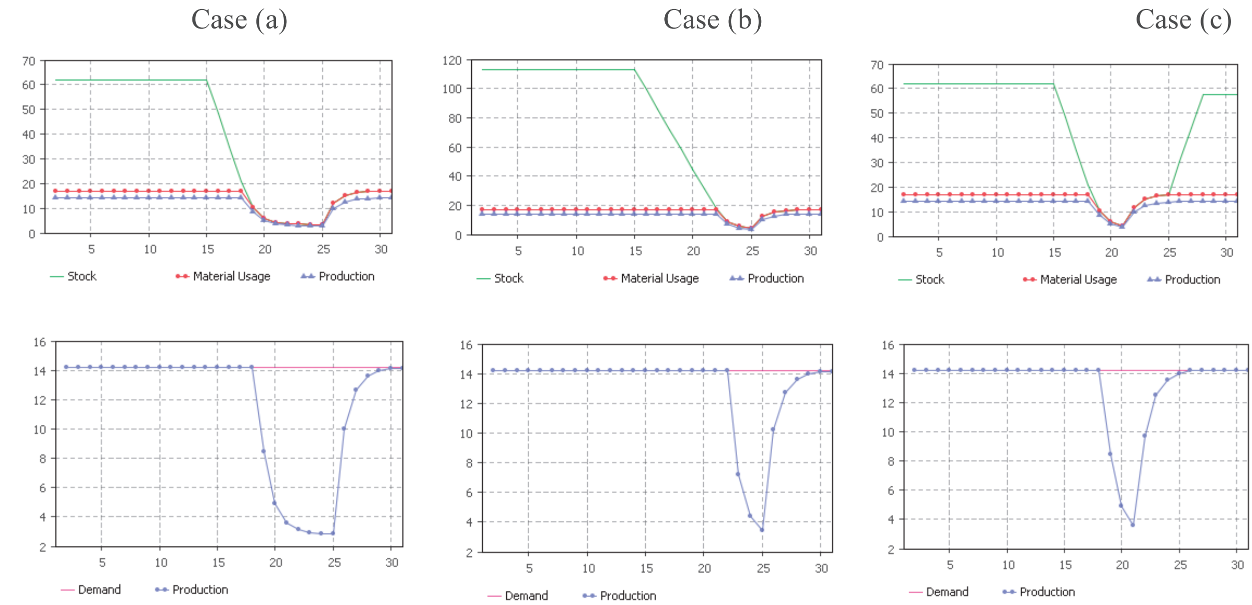

Fig. 3 Results of simulation of case a), b), c) (own elaboration)

3. CONCLUSION

Presented model allows to analyse the various scenarios of the impact of the disruption in the raw material delivery to the level of the production. The analysis of the results can give an answer to the question of what level of the reserve should be maintained in order to prevent the negative effects brought by the lack of the raw materials depending on the source, time and duration of the of disruption. Further research is planned in order to take into account the cost of implementation of different scenarios aimed to minimising the risk of losing the continuity of the production. Subsequently, it is planned to take into consideration in a model, the costs of transporting of raw materials and costs of its storage on the stockpile which will enable searching for the optimal solutions in terms of the efficiency of a whole system. Next stage of the research will take into account the distortion of the output side of the model, which will allow for the analysis of the effects of a demand change on a continuity of the operation of the system.

REFERENCES

[1] BOSMAN, R. (2006) The New Supply Chain Challenge: Risk management in a global economy, FM Global, Johnston, RI (and at www.fmglobal.com)

[2] BUKOWSKI, L. & FELIKS J. (2012) Multi-dimentional concept of supply chain resilience, Proceedings of the 2st Carpathian Logistics Congress, Jesienik

[3] BUKOWSKI, L. & FELIKS J. (2014) A unified model of systems dependability and process continuity for complex supply chains, Safety and Reliability: Methodology and Applications, 2015 Taylor & Francis Group, A Balkema Book, London, 2395-2403

[4] CAVINATO, JL. (2004) Supply chain logistics risks, International Journal of Physical Distribution and Logistics Management, 34 (5), 383-87

[5] CHOPRA, S. & SODHI M.S. (2004) Managing Risk to Avoid Supply-Chain Breakdown, MIT Sloan Management Rev. 46, 53-61.

[6] CHRISTOPHER, M. & LEE, H. (2004) Mitigating supply chain risk through improved confidence, International Journal of Physical Distribution and Logistics Management, 34 (5), pp 388-96

[7] DELOITTE (2012): Nine principles of a Risk Intelligent Framework for Risk Management - A briefing for Federal executives, https://www.deloitte.com/.../us_fed_Nine_Principles

[8] JÜTTNER, U. (2005) Supply chain risk management, International Journal of Logistics Management, 16 (1), pp 120-41

[9] FERBER J., Reactive distributed artificial intelligence, [w:] O'Hare G.M.P., Jenings N.R (eds.), Foundation of Distributed Artificial Intelligence, John Wiley, 1996.

[10] FORRESTER J. W., Industrial Dynamics, The MIT Press, Cambridge, Massachusetts,1961.

[11] GUTKNECHT O., FERBER J., MADKIT: Organizimg heterogeneity with groups in a platform for multiple multi-agent systems, Tech. Rep. 97188, LIRMM, Francja, 1997.

[12] KARKULA, M & BUKOWSKI, L 2012, 'Computational Intelligence Methods - Joint Use In Discrete Event Simulation Model Of Logistics Processes', 2012 Winter Simulation Conference.

[13] LENORT, R, GRAKOVA, E, KARKULA, M, WICHER, P, STAS, D & Tanger 2014, 'Model For Simulation Of Supply Chain Resilience', Metal 2014: 23rd International Conference on Metallurgy and Materials, pp. 1803-9.

[14] LUCK M., ASHRI R., d'Inverno M., Agent-Based Software Development, Artech House, 2004.

[15] MCARTHUR SDJ, DAVIDSON EM, CATTERSON VM, DIMEAS AL, HATZIARGYRIOU ND, PONCI F, et al. Multi-agent systems for power engineering applications - Part I: concepts, approaches, and technical challenges. IEEE Trans Power Syst. 2007; 22(4).

[16] NAWARECKI E., KOŹLAK J., Agentowy model systemu logistycznego, Automatyka 2009, tom 13, Zeszyt 2.

[17] ROSA, M. A., LEITE DA SILVA, A., MIRANDA, V., "Multi-Agent Systems Applied to Reliability Assessment of Power Systems", International Journal of Electrical Power & Energy Systems 2012, vol.42, p.367-374.

[18] SAMOLEJOVA, A, FELIKS, J, LENORT, R & BESTA, P 2012, 'A hybrid decision support system for iron ore supply', Metalurgija, vol. 51, no. 1, pp. 91-3.

[19] SHEFFI, Y. & RICE, JR J.B. (2005) A Supply Chain View of the Resilient Enterprise. MIT Sloan Management Rev., 47, 41-48

[20] SHEFFI, Y. (2007) The resilient enterprise: overcoming vulnerability for competitive adventage, MIT Press

[21] STEMMLER, L. (2006) Risk in the supply chain, in Global Logistics, 5th edn, ed D Waters, Kogan Page, London

[22] SWAMINATHAN J., SMITH S., SADEH N., Modeling supply chain Dynamics: A multiagent approach, Decision Sciences, 29(3), 1998.

[23] WATERS, D. (2007) Supply chain risk management: vulnerability and resilience in logistics, Kogan Page Limited, London & Philadelphia

[24] WOOLDRIDGE M., An Introduction to Multiagent Systems, John Wiley & Sons Ltd., 2009.

[25] HTTP://WWW.ANYLOGIC.COM/FEATURES - 15.11.2015.

[26] LENORT, R., BESTA, P. Hierarchical Sales Forecasting System for Apparel Companies and Supply Chains. FIBRES & TEXTILES IN EASTERN EUROPE. 2013, vol. 21, no. 6, pp. 7-11.

[27] SPICKA I., JANCIKOVA Z., HEGER M., ZIMNY O. Modern methods for identification of the dynamics of technological thermal units. In Metal 2014: 23rd International Conference on Metallurgy and Materials. Ostrava: TANGER, 2014, pp. 1516-1521.

[28] HEGER M., SPICKA I., FRANZ J. Possibility of continuous reheating furnaces control using simplified models. In Metal 2013: 22nd International Conference on Metallurgy and Materials. Ostrava: TANGER, 2013, pp. 1656-1661.

[29] KOSTIAL P., SPICKA I., JANCIKOVA Z., DAVID J., VALICEK J., HARNICAROVA M., RUSNAK V. Lumped Capacitance Model in Thermal Analysis of Solid Materials. *2014 Joint Imeko Tc1-Tc7-Tc13 Symposium: Measurement Science Behind Safety and Security* [online]. 2015, vol. 588, s. 012006. ISSN 1742-6588. Dostupné z: doi:10.1088/1742-6596/588/1/012006.