Multi-level Management of Organizational Systems on the Basis of Risk Cascading, Logical-Probabilistic Modeling and Simulation

Irina Bondareva and Anna A. Khanova

Abstract A conceptual solution allows for multi-level risk management of an organizational system (for example, a cargo port) is presented. A step-by-step mechanism for the integrated use of risk cascading and Logical-Probabilistic modeling is proposed for a detailed and multifaceted description of cause-and-effect relationships, as well as simulation modeling as a tool for analyzing, assessing, and predicting the onset of risk situations. The described mechanism is displayed in the form of a structural diagram of multilevel risk management. The method for cascading risks at the strategic, tactical, and operational levels of management is described in detail. Each level considers as a risk situation failure to achieve goals, failure to achieve target performance assessment indicators of standard values, and failure to achieve detailed targets for assessing target implementation of standard values, respectively. A cascade logic-probabilistic model of the risk of failure to achieve the strategic goal of a cargo port is presented, detailing the scenarios of the first level of goal-setting and including all three levels of management. The logical and probabilistic models of various levels of management are formulated and described, the identified basic regularities are explained. The mechanism for fixing the onset of risk situations at the operational level using cascading and simulation technologies, identifying cause-and-effect relationships using logical-probabilistic modeling, as well as formulating recommendations to prevent the onset of risk situations in future periods is described in detail, i.e. at the tactical and operational levels of management.

Keywords Risk cascading · Logical-probabilistic modeling · Simulation modeling · Multilevel management

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1 Introduction

Studying the issues of effective technologies for managing enterprises, which are, thanks to a large number of interacting business processes, a complex organizational system (OS), today is associated with the identification, as well as a comprehensive analysis of goals, indicators of their achievement, as well as risks. Building logical relationships between planning and assessing the likelihood of the onset of the possibility of performing an urgent task, a promising and justified possibility of increasing the efficiency of management [1–11].

An approach using logical-probabilistic (LP) modeling [1, 2, 6, 7, 11] is used as a modern toolkit for describing this kind of relationship. One of its advantages is the ability to consider aspects of activities not only from the point of view of economic efficiency but also with a focus on the interests of all parties involved in this process.

Along with LP-modeling to trace the cause-and-effect relationships when a risk situation occurs, it is proposed to use the mechanism for representing the hierarchy of goals and indicators in the form of cascades [12–17].

Cascading initially appeared as a tool for specifying goals and indicators for assessing the performance of certain enterprises by specifying general performance criteria for specific divisions. Thus, the responsibility and contribution of each specialized division to the overall strategy of the enterprise are indicated in accordance with the specifics of the work carried out by it. That is, cascading allows you to formulate and clarify goals and indicators for more detailed and consistent tracking of possible deviations from the intended goals from the moment of their occurrence in order to adjust the functionality of the responsible units before correcting an unfavorable situation.

The analysis of the sources devoted to the cascading of goals and indicators allows us to judge its use in most cases in conjunction with a balanced scorecard, which is a strategic management tool [11, 12, 15]. Much more popular and justified in practice is the technology for implementing multilevel management—from strategic to tactical and operational and vice versa. That is an approach in which all strategic goals are subordinated to the evaluative mechanism for maintaining the overall strategy through the implementation of detailed goals at the tactical and operational levels. A description of this mechanism concerning the organization's risks was not found, and therefore the purpose of the work is to form a structure for multi-level management of organizational systems by the joint use of organization risks cascading and LP-modeling [14–21].

2 Risk Cascading

Multilevel cascading of risks consists in the formulation of the main strategic goal and its detailed goals at the strategic management level, where failure to achieve goals is considered as a risk. Then, at the tactical level of management, for each goal,

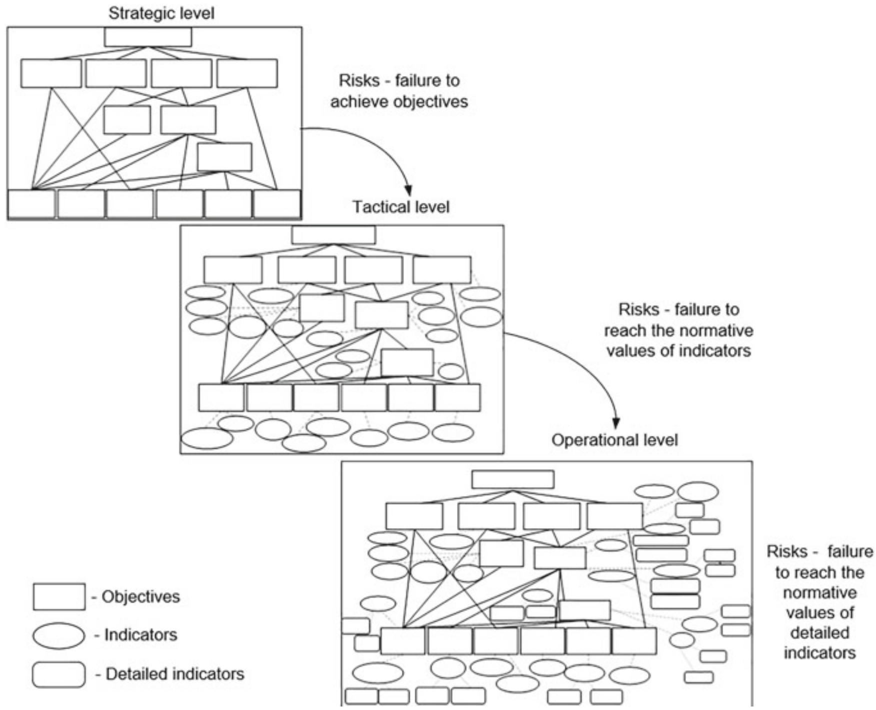

Fig. 1 Scheme of cascading risks

the indicators that evaluate it are formulated, and the failure of the indicators to assess the implementation of the goals of the standard values is already used as risks. The operational level of management complements the tactical detailed indicators for assessing the achievement of goals, i.e. breaks down several indicators of the tactical level, specifying them according to various criteria: concerning the structural units responsible for the achievement of the indicator of the normative value; concerning the type of work performed or services provided, etc. At the operational level, risks are the failure of detailed indicators to assess the achievement of targets of standard values. Risk cascading is shown schematically in Fig. 1.

3 Multi-level Risk Management Based on Cascading Risks

It is possible to calculate the detailed indicators for assessing the achievement of goals formulated at the operational level (block 1 “Cascading risks”) using simulation (block 2 “Simulation model”) [7, 10, 11]. Based on the results of simulation experiments, report statistics are generated, based on which a summary table of risk assessment is built, thus, deviations from the standard values of detailed indicators for

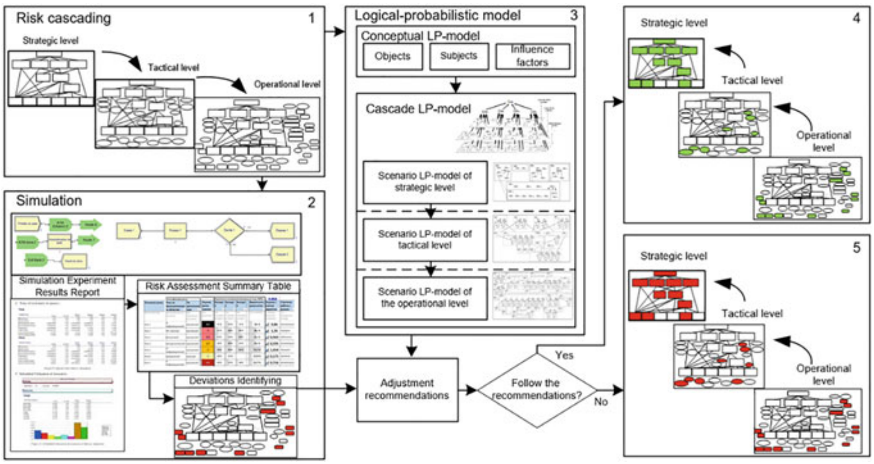

Fig. 2 Block diagram of multi-level OS risk management based on cascading risks, LP-model, and simulation

assessing the achievement of goals are revealed, i.e. possible operational level risks. Based on this information, taking into account the identification of cause-and-effect relationships of the LP-model (block 3), recommendations are developed to prevent the identified risk situations. Taking into account such recommendations allows you to adjust the values of detailed indicators at the operational level by influencing the objects of the system under consideration, which in turn favorably affects the elimination of risk situations at the tactical and strategic levels, i.e. allows you to achieve strategic goals in the future (block 4). On the contrary, ignoring recommendations for adjusting the behavior of the system negatively affects the risks of subsequent periods, provoking their inevitable onset (block 5). Consider the described integration of the proposed approaches for multilevel risk management of an organizational system (Fig. 2). As a subject area, we have chosen a transport logistics enterprise—a cargo port [13, 18, 19].

4 Logical-Probabilistic Modeling

The LP-risk model is a set of conceptual models that describe the relationship between OS objects (targets), subjects, and factors of influence [7, 22, 23].

For multilevel risk management, it is of greater interest to identify causal relationships presented on the cascade LP-model (Fig. 3), reflecting scenario LP-models of all three levels of management. Objectives $G_{ccp} = (GN_1, GN_2, \ldots, GN_4)$ correspond to the LP risk models. Objects-targets are the components of Gccp: GN_1—to reduce dependence on external loans, GN_2—to increase the efficiency of resource use, GN_3—to increase the level of corporate social responsibility, GN_4—to increase profitability

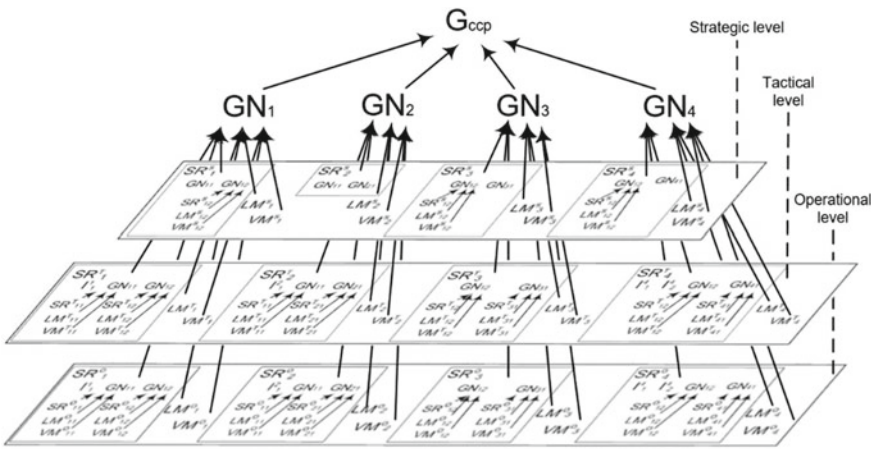

Fig. 3 Cascade LP-model of the risk of failure to achieve the strategic goal of the OS (detailed scenarios of the first level of goal-setting, three levels of management)

and solvency. According to the concept of using LP risk models for each i-th goal GN_i, it is necessary to sequentially construct a risk scenario SR_i, L-model LM_i, and P-model VM_i. Figure 3 shows scenarios of the first level of goal-setting, including the following elements: GN_{11}—to improve the qualifications of employees, GN_{12}—to increase the level of responsibility to consumers, GN_{21}—to optimize the number of port resources, GN_{31}—to increase the level of social protection of personnel, GN_{41}—to ensure the stability of sales, $I_1{}^1$—return on assets, $I_1{}^2$—the ratio of financial independence, $I_1{}^4$– the ratio of absolute liquidity, $I_2{}^4$—the ratio of return on equity.

At the strategic level, the logical model LM Sccp of event failure takes the form: $G_{ccp} = GN_1 \vee GN_2 \vee \ldots \vee GN_4$.

Probability function (P-model) VM S_{ccp} of event failure:

$$
\begin{aligned}
P\{G_{ccp} = 0\} = & P\{GN_1 = 0\} + P\{GN_2 = 0\}(1 - P\{GN_1 = 0\}) + P\{GN_3 = 0\} \\
& (1 - P\{GN_l = 0\})(1 - P\{GN_2 = 0\})P\{GN_4 = 0\}(1 - P\{GN_1 = 0\}) \\
& (1 - P\{GN_2 = 0\})(1 - P\{GN_3 = 0\}).
\end{aligned}
$$

The logical and probabilistic models of the first level of goal-setting at the operational level will be identical to the corresponding models of the tactical level. This is because the scenarios of the first level of goal-setting of the operational level of management did not change relative to the tactical level. After all, they contain indicators that are not detailed by any criteria (indicators of the first level). That is why the following is true.

$$
LM^o = LM^T_{ccp} : G_{ccp} = I^1_1 \vee I^2_1 \vee GN_3 \vee I^4_1 \vee I^4_2.
$$

$$VM^o_{cp} = VM^T_{ccp}:$$
$$P\{G_{ccp} = 0\} = P\{I^1_1 \neq I^1_{1norm}\} + P\{I^2_1 \neq I^2_{1norm}\}(1 - P\{I^1_1 \neq I^1_{1norm}\})$$
$$+ P\{GN_3 = 0\}(1 - P\{I^1_1 \neq I^1_{1norm}\})(1 - P\{I^2_1 \neq I^2_{1norm}\})$$
$$P\{I^4_1 \neq I^4_{1norm}\}(1 - P\{I^1_1 \neq I^1_{1norm}\})(1 - P\{I^2_1 \neq I^2_{1norm}\})$$
$$(1 - P\{GN_3 = 0\})(1 - P\{I^4_1 \neq I^4_{1norm}\}).$$

The remaining levels of goal-setting are represented by goals GN_{121}—increase the level of environmental protection, GN_{122}—increase the level of interaction with local authorities, GN_{123}—improve the quality of loading and unloading operations, GN_{1231}—timely execution of loading and unloading operations [24]. A complete list of indicators for assessing achievement with an indication of the criteria for their detailing (if any) at the operational level is presented in Table 1.

As the structural subdivisions of the port within the framework of this study, we will take the following: cargo operations department, warehouse complex, commercial department, tally department, technical department, supporting departments, and port management. The following are considered as interesting types of services provided by the port: transshipment of goods, storage of goods, freight forwarding by rail, and road transport. The considered cargo port carries out the loading of the following types of cargo: sand, asbestos, sheet iron, and iron channel.

Let us consider, for comparison, the scenario models of the risk of failure to achieve the strategic goal of the cargo port of the tactical (Fig. 4) and operational (Fig. 5) management levels, including all levels of goal-setting [6, 7, 10, 11].

A visual comparison of the tactical and operational level scenarios allows us to make sure that the operational level scenarios extend the tactical level scenarios by including new scenarios of detailed indicators that have a direct impact on the corresponding elements of the scenario of the previous goal-setting level. At the operational level, the failure of an event may be evidenced by the failure of at least one of the indicators detailing it according to the selected criterion (Tab. 1) indicators of its normative value.

As an example, consider the LP-model of the complex indicator $I_1{}^{12}$ "Number of regular customers", detailed at the operational level by type of service (transshipment, storage, and forwarding of goods) on $I_1{}^{121}$, $I_1{}^{122}$,and, $I_1{}^{123}$ respectively.

$$LM_{1^o12}: I^{12}_1 = I^{121}_1 \vee I^{122}_1 \vee I^{123}_1.$$

$$VM^o_{112}:$$
$$P\{I^{12}_1 \neq I^{12}_1 norm\} = P\{I^{121}_1 \neq I^{121}_1 norm\} + P\{I^{122}_1 \neq I^{122}_1 norm\}$$
$$(1 - P\{I^{121}_1 \neq I^{121}_1 norm\})\ P\{I^{123}_1 \neq I^{123}_1 norm\}$$
$$(1 - P\{I^{121}_1 \neq I^{121}_1 norm\})(1 - P\{I^{122}_1 \neq I^{122}_1 norm\}).$$

Table 1 Cargo port performance indicators and criteria for their detailing

Indicator symbol	Indicator, units	Indicator detail criterion
$I_1{}^1$	Return on assets	–
$I_2{}^1$	Financial independence ratio	–
$I_1{}^4$	Absolute liquidity ratio	–
$I_2{}^4$	Return on equity ratio	–
$I_1{}^{11}$	Percentage of employees whose qualifications are appropriate for the position held, %	Structural units
$I_2{}^{11}$	Employee training costs, cu	Structural units
$I_1{}^{12}$	Number of regular customers, units	types of services
$I_2{}^{12}$	Percentage of repeat clients, %	Types of services
$I_3{}^{12}$	Number of new clients, units	Types of services
$I_4{}^{12}$	Number of dissatisfied customers, units	Types of services
$I_1{}^{21}$	Equipment intensive use ratio	–
$I_2{}^{21}$	Equipment extensive use ratio	–
$I_1{}^{31}$	The number of tax deductions for the period, cu	–
$I_2{}^{31}$	The volume of social contributions for the period	–
$I_3{}^{31}$	The ratio of the minimum wage to the cost of living	–
$I_4{}^{31}$	The ratio of the minimum wage to the average, %	–
$I_1{}^{41}$	Provision with orders (contracts) in days, day	–
$I_1{}^{121}$	The proportion of ships meeting environmental standards, %	Types of cargo
$I_1{}^{123}$	Reliable loading, %	Types of cargo
$I_2{}^{123}$	THe amount of lost (damaged) when loading cargo, t	Types of cargo
$I_3{}^{123}$	Average loading time, h	Types of cargo
$I_1{}^{1231}$	Percentage of loading works completed on time, %	Types of cargo

5 Conclusion

A distinctive feature of the proposed mechanism is the ability to predict the occurrence of undesirable situations in subsequent periods at the operational stage of management, i.e. at other levels of government. Predictions of a similar nature by monitoring the corresponding values of risks of failure to achieve goals and standard values of indicators make it possible to develop recommendations for adjusting the values to prevent negative risk situations in future periods. It is this multilevel approach to management that will result in the achievement of the set strategic goals and, thus, lead the organization to consistently effective development.

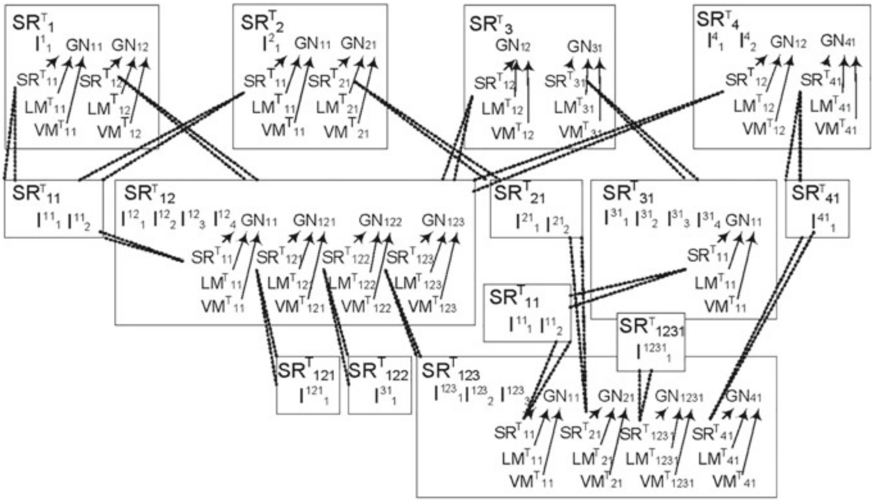

Fig. 4 Model of tactical scenarios of risks of failure to achieve goals associated with the main strategic goal of the cargo port

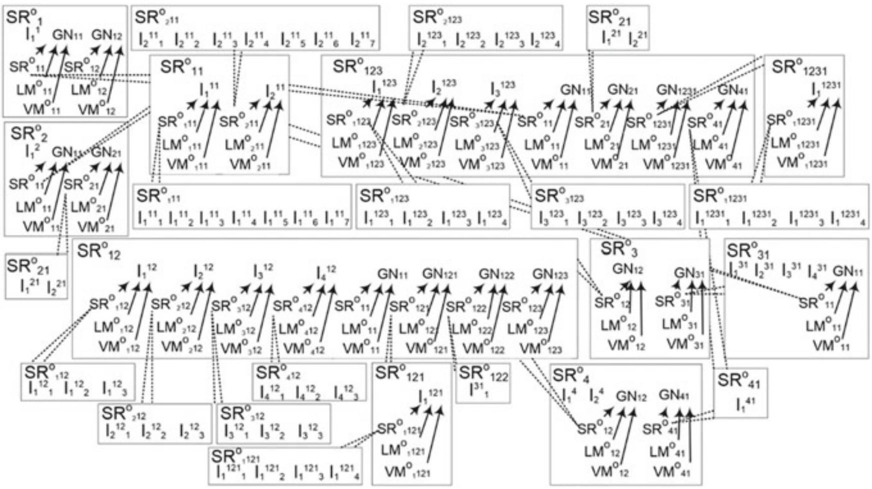

Fig. 5 Model of operational scenarios of risks of failure to achieve goals associated with the main strategic goal of the cargo port

References

1. Solozhentsev, E.: Logic and probabilistic risk models for management of innovations system of country. Int. J. Risk Assess. Manag. **18**(3–4), 237–255. https://doi.org/10.1504/IJRAM.2015.071211 (2015)

2. Solozhentsev, E., Mityagin, S.: Logical and probabilistic risk models for assessment and analysis of the drug addiction problem in a region. Int. J. Risk Assess. Manag. **18**, 1–20. https://doi.org/10.1504/IJRAM.2015.068153 (2015)
3. Durán, J.M.: What is a simulation model? Minds Mach.https://doi.org/10.1007/s11023-020-09520-z
4. Protalinskiy, O., Andryushin, A., Shcherbatov, I., Khanova, A., Urazaliev, N.: Strategic decision support in the process of manufacturing systems management. Eleventh International Conference "Management of Large-Scale System Development" (MLSD, Moscow, pp. 1–4. https://doi.org/10.1109/MLSD.2018.8551760 (2018)
5. Protalinsky, O., Khanova, A., Bondareva, I., Averianova, K., Khanova, Y.: Cognitive model of the balanced scorecard of manufacturing systems. In: Dolinina, O. et al. (eds.) Recent Research in Control Engineering and Decision Making. ICIT 2020. Studies in Systems, Decision and Control, vol. 337. Springer, Cham. https://doi.org/10.1007/978-3-030-65283-8_47 (2020)
6. Solozhentsev, E.: Karasev VHybrid logical and probabilistic models for management of socioeconomic safety. Int. J. Risk Assess. Manag. **21**(1–2), 89–110 (2018). https://doi.org/10.1504/IJRAM.2018.090258
7. Solozhentsev, E.: Karaseva E (2020) Data structures, logical-probabilistic models and digital management of the safety and quality of systems in the economics. Int. J. Risk Assess. Manag. J. **23**(1), 27–53 (2020). https://doi.org/10.1504/IJRAM.2020.106162
8. Ramírez-Nafarrate, A., González-Ramírez, R.G., Smith, N.R., et al.: Impact on yard efficiency of a truck appointment system for a port terminal. Ann. Oper. Res. **258**, 195–216 (2017). https://doi.org/10.1007/s10479-016-2384-0
9. Wee, H., Blos, M., Yang, W.-H.: Risk management in logistics. Intell. Syst. Ref. Lib. **33**, 285–305 (2012). https://doi.org/10.1007/978-3-642-25755-1_15
10. Bondareva, I.O., Shendo, M.V., Luneva, T.V., Khanova, A.A.: Logical-probabilistic and simulation modeling as a toolkit for complex analysis and risk management of a cargo port E3S Web Conf. 224 02027. https://doi.org/10.1051/e3sconf/202022402027 (2020)
11. Bondareva, I., Khanova, A., Khanova, Y.: Configuring systems based on petri nets, logic-probabilistic, and simulation models. In: Kravets, A.G., Bolshakov, A.A., Shcherbakov, M. (eds) Cyber-Physical Systems: Modelling and Intelligent Control. Studies in Systems, Decision and Control, vol. 338. Springer, Cham. https://doi.org/10.1007/978-3-030-66077-2_21 (2021)
12. Ho, M.W., Ho (David), K.H.: Risk management in large physical infrastructure investments: the context of seaport infrastructure development and investment. Maritime Econom. Log. **8**(2), 140–168. https://doi.org/10.1057/palgrave.mel.9100153 (2006)
13. Sarkar, D.: Simulation application in project risk management for infrastructure transportation project. Int. J. Project Organisation Manag. **3**(3/4), 374–392 https://doi.org/10.1504/IJPOM.2011.042039 (2011)
14. Gómez-Fuster, J.M., Jiménez, P.: Probabilistic risk modelling for port investments: A practical approach. Case Studies Transp. Policyю **8**(3), 822–831, ISSN 2213-624X. https://doi.org/10.1016/j.cstp.2020.06.001 (2020)
15. Dong, S., Yu, T., Farahmand, H., Mostafavi, A.: Probabilistic modeling of cascading failure risk in interdependent channel and road networks in urban flooding. Sustain. Cities Soc. **62**, 102398, ISSN 2210-6707. https://doi.org/10.1016/j.scs.2020.102398 (2020)
16. Dunant, A., Bebbington, M.: Tim Davies Probabilistic cascading multi-hazard risk assessment methodology using graph theory, a New Zealand trial. Int. J. Disaster Risk Reduct. **54**, 102018, ISSN 2212-4209. https://doi.org/10.1016/j.ijdrr.2020.102018
17. Khalil, M., Abdou, M.A., Mansour, M.S., Farag, H.A., Ossman, M.E.: A cascaded fuzzy-LOPA risk assessment model applied in natural gas industry. J. Loss Preven. Process Industr. **25**(6), 877–882, ISSN 0950-4230 (2012).https://doi.org/10.1016/j.jlp.2012.04.010
18. Cullinane, K., Bergqvist, R., Wilmsmeier, G.: The dry port concept—theory and practice. Maritime Econ. Logist. **14**(1), 1–13 (2012). https://doi.org/10.1057/mel.2011.14
19. Peng, Y., Wang, W., Xu, X., Chen, M., Song, X., Li, X.: A Simulation-based dynamic programming method for interchange scheduling of port collecting and distributing network. J. Adv. Transp., 1–17. https://doi.org/10.1155/2018/4805250 (2018)

20. Strohhecker, J.: Factors influencing strategy implementation decisions: an evaluation of a balanced scorecard cockpit, intelligence, and knowledge. J. Manag. Control. **27**, 89–119 (2016). https://doi.org/10.1007/s00187-015-0225-y
21. Sandkuhl, K.: Seigerroth, U: Method engineering in information systems analysis and design: a balanced scorecard approach for method improvement. Softw. Syst. Model. **18**, 1833–1857 (2019). https://doi.org/10.1007/s10270-018-0692-3
22. Orlova, Ekaterina synergetic synthesis of the mechanisms and models for coordinated control in production and economic system, 783–788. https://doi.org/10.1109/CSCMP45713.2019.8976801 (2019)
23. Solozhentsev, E., Karasev, V.: Hybrid logical and probabilistic models for management of socioeconomic safety. Int. J. Risk Assess. Manag. **21**(1–2), 89–110 (2018). https://doi.org/10.1504/IJRAM.2018.090258
24. Vaio, A.D., Varriale, L.: Federico Alvino, key performance indicators for developing environmentally sustainable and energy efficient ports: evidence from Italy. Energy Policy **122**, 229–240, ISSN 0301-4215. https://doi.org/10.1016/j.enpol.2018.07.046