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Modelling, Analysis and Risk Assessment in the Technology Process Control

Lily Chernyakhovskaya
The Faculty of Informatics and Robotics
Ufa State Aviation Technical University
Ufa, Russia
e-mail: lrchern@yandex.ru

Alsu Atnabaeva
Sector of economic and mathematical modeling
Institute of Social and Economic Research USC RAS
Ufa, Russia
e-mail: alsouy@mail.ru

***Abstract*–The present article is dedicated to the research in the field of analytical support of hazard management decision-making in the technological process. The essential component of qualitative and safe products manufacturing is on-line (immediate) and proper decision-making. Difficulties arising in the course of decision-making are lack of knowledge regarding objects characteristics in abnormal situations as well as ambiguity in decision results' evaluation. Objective and ontological models of technological process hazard control of food production are presented in this article. The description of hazard assessment ontology with the integrated Bayesian Belief Network is shown hereby. Qualitative and quantitative hazard assessment analysis is made with the usage of risks and hazards identification method as well as Bayesian method of hazards statistic assessment.**

Keywords–hazard analysis, hazard control, ontology, technological process.

I. INTRODUCTION

Political and economical uncertainty, reduce in industry investments, competitiveness increase, social tension as well as inadequate efficiency of control system negatively reflects on factories' operation. Rationally organized technological process of food production shall provide manufacturing of qualitative and competitive products by the factory at economic costs and proper labor management. Efficiency of modern industrial factories functioning is defined mostly with management improvement of hazards peculiar to food production processes.

For the time being, manufacturers are eager to design a technology of quick and low-cost production. In this manner, products manufacturing process has been undergoing multiple changes, new technologies have been used, formulae have been changed (new chemical ingredients, which, on the one hand, serve for increase of organoleptical characteristics, and, on the other hand, can be harmful for people's health). The above-mentioned factors can be the reason of hazards occurrence, which may result in significant financial and social losses. Operative decision-making in these events, as a rule, happen against the backdrop of this or that uncertainty. Therefore, the hazard occurs defined according to GOST R ISO 31010-2011 "Hazard management. Hazard assessment methods" as "a combination an event probability and its consequences [1] related with such consequences as property loss, and in case of an emergency condition – threat to life and health of people [4].

Increase in quality and safety of products considerably defines the factory's ability to survive under a free market economy, scientific and technological process paces, increase of production efficiency, all types of resources economy used in manufacture. The important issue of quality improvement is increase in decision-making efficiency under unfavorable events. Difficulties arising in the course of decision-making are lack of knowledge regarding objects' characteristics in hazardous situations. During hazards management on the phase of decision-making the manufacture encounters the choice of a hazard level acceptable for it as well as the choice of response strategy for negative hazards (hazard avoidance, hazard transfer and share, hazard reduce). Each factory has its own preferences affecting hazard control process.

Hazard management implies usage of different methods of hazard analysis and assessment allowing to forecast to one extent or another unfavorable event (UE) coming and to apply some measures for hazard level decrease. The examples are the below-mentioned methods: inductive method of preliminary hazards analysis (from English Preliminary Hazard Analysis – PHA); method of hazard and operability study (from English Hazard and Operability Study.-HAZOP); method of hazards and critical control points analysis (from English Hazard Analysis and Critical Control Points – HACCP) [3]. The choice of methods for specific hazard management objects is defined with characteristics of the problematic field as well as such features of methods as a type of uncertainty measure (possible, indefinite), dependence on affecting factors (resources and possibilities, uncertainty, complexity), possibility for getting quantitative output data, availability of effective algorithms and means of the discussed methods implementation. Timely and qualitative decision-making on hazard management facilitates efficient functioning and development of the factory.

II. MODELS AND METHODS OF HAZARD ASSESSMENT AND CONTROL

Manufacturing of food products is a complex system consisting of co-dependent elements such as institutional structure, personnel, technical equipment, raw materials, materials, financing and is characterized by process continuity. For manufacturing processes, hazards analysis and assessment has some peculiar nature, as not only financial resources are required in management but also personnel, technical and material resources. An important task during hazards management is classification of

unfavorable events, which may lead to social and economic losses.

Technological process (TP) of manufacturing bread and bakery products can be divided into 2 stages: baking quality test in the laboratory and baking in the main shop. The model of technological process from the moment of raw materials purchase up to products release to the buyer is presented on Figure 1. Products quality control has a special place in the production. Each stage of technological process is controlled by a specialist who provides control and inventory of products condition. The raw materials delivered to the factory undergo strict physical and chemical and organoleptical control. However, main amount of unfavorable events occur due to raw materials quality or personnel mistakes at manufacturing formula designing. In food industry personnel constantly encounter situations of collective decision-making like the following: designing of manufacturing formula, elaboration of products assortment, suppliers selection etc. These decisions are forwarded to prevention of critical situations and massive losses of the factory. This process requires consideration of multiple factors: condition of technical equipment; knowledge and experience of personnel; external factors; quality of applied ingredients and so on. During decision-making information from various sources is used and initial data elaboration shall be made according to specifics of this information characteristics.

For effective hazards management, primarily, unfavorable events and their main characteristics shall be specified, and spot analysis of hazards shall be maintained. Timely and effective delineation of unfavorable events allows to shorten probability of a hazard occurrence and to decrease the factory's losses. Qualitative analysis of hazards will let to define hazard types which mostly affect the factory and are applied as a basis for quantitative analysis.

For defining causes of unfavorable events occurrence in bread and bakery products manufacturing process there is a wide variety of methods worked out in other technical systems by means of complex systems' analysis. According to [РД 03-418-01 (Regulatory Document)] the following methods can help to identify causes and forecast defective products [2]: «What - if?»; «Check List»;«Hazard and Operability Study» - HAZOP; «Failure Mode and Effects Analysis» - FMEA; «Failure Mode, Effects and Critical Analysis» FMECA; «Fault Tree Analysis» - FTA; «Event Tree Analysis» - ETA. The present methods allow to design structured logical diagrams, to use expert evaluations, to consider data regarding the structure of the researched object

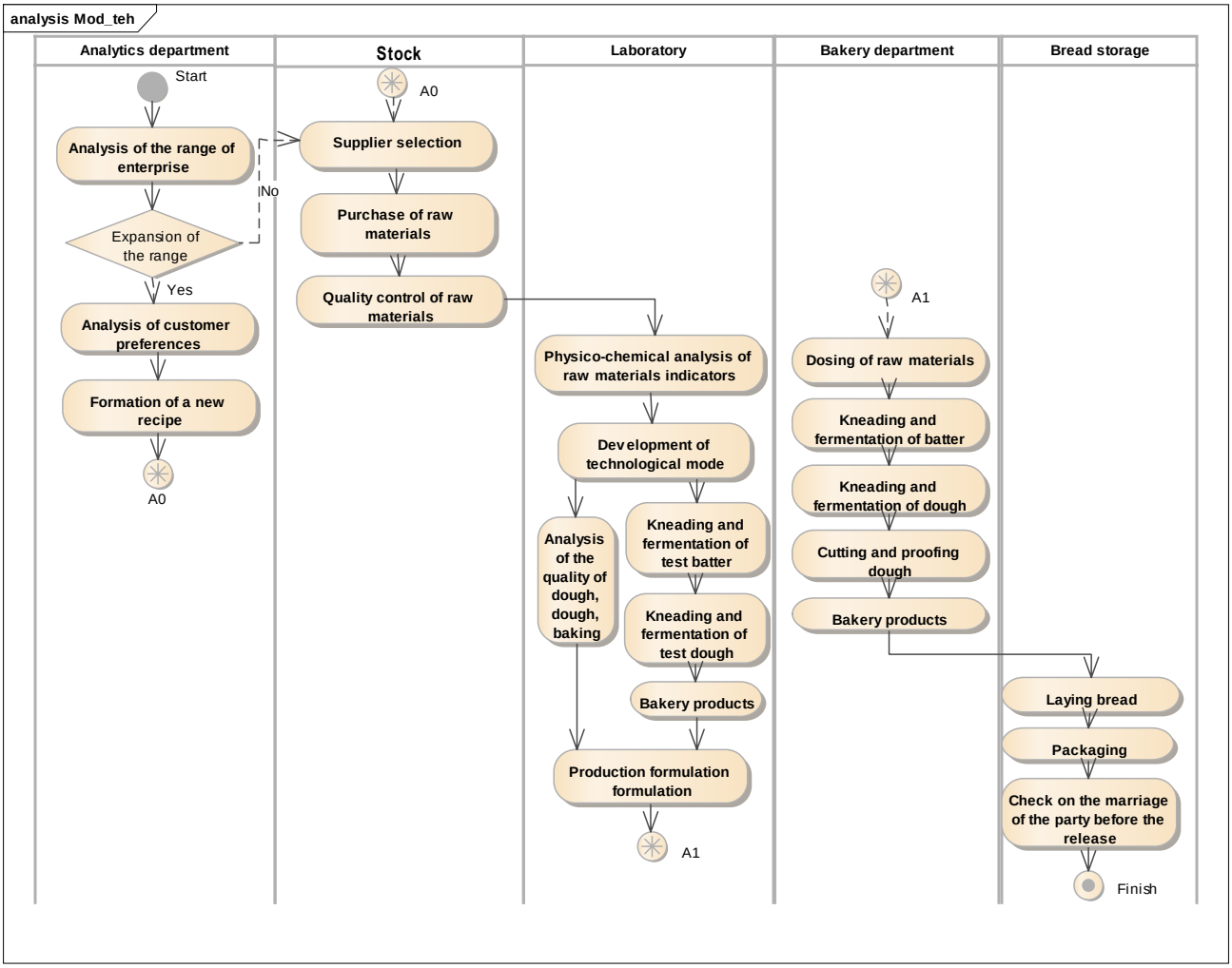

Fig. 1. Diagram of the technological process of production of bread and bakery products

and to provide visual results of the hazard analysis conduct. As experts, qualified personnel is applied, whose qualification corresponds with the analyzed subject matter. An advisory group of experts represented by a production engineer, a foreman, a workshop supervisor and technical laboratory personnel is formed. For detecting of unfavorable events at life-cycle phases of technological process, hazards analysis and critical control points method is applied (Hazard Analysis and Critical Control Points – HACCP).

A regulatory document with requirements to HACCP in the Russian Federation is the national standard GOST R 51705.1–2001 "Quality systems. Food products quality control on the basis of HACCP principles. General requirements". HACCP application starts with analysis and detailed elaboration of technological process and documentation, in which unfavorable events are described, as well as their management methods.

Hazards management process accompanies technological process on each life-cycle stage of food products manufacturing beginning with the moment of assortment compilation and choice of raw materials up to products release. The present research shows the process of critical points analysis at raw materials purchase and storage stage.

Raw materials quality control is dealt by a laboratory making sampling and compilation of manufacturing formula

TABLE I. CRITICAL CONTROL POINTS TECHNOLOGICAL PROCESS

Stage	Critical Control Points		Critical values	Risk assessment	
				Probability	Damage
Raw materials	Physical and chemical indicators of flour	humidity	9 – 14%	high	high
		acidity	2,5 – 3,0 degrees N.	high	low
		fat content	0,8 -1,5	average	average
		squirrels	12-14 %	low	high
		cellulose	0,1-0,3 %	high	low
	Qualitative characteristic of pressed yeast	humidity	% no more 75	high	low
		ascensional power	no more 76 min.	average	average
		acidity	no more 120 mg.	high	high

The technological process of bread and bakery products

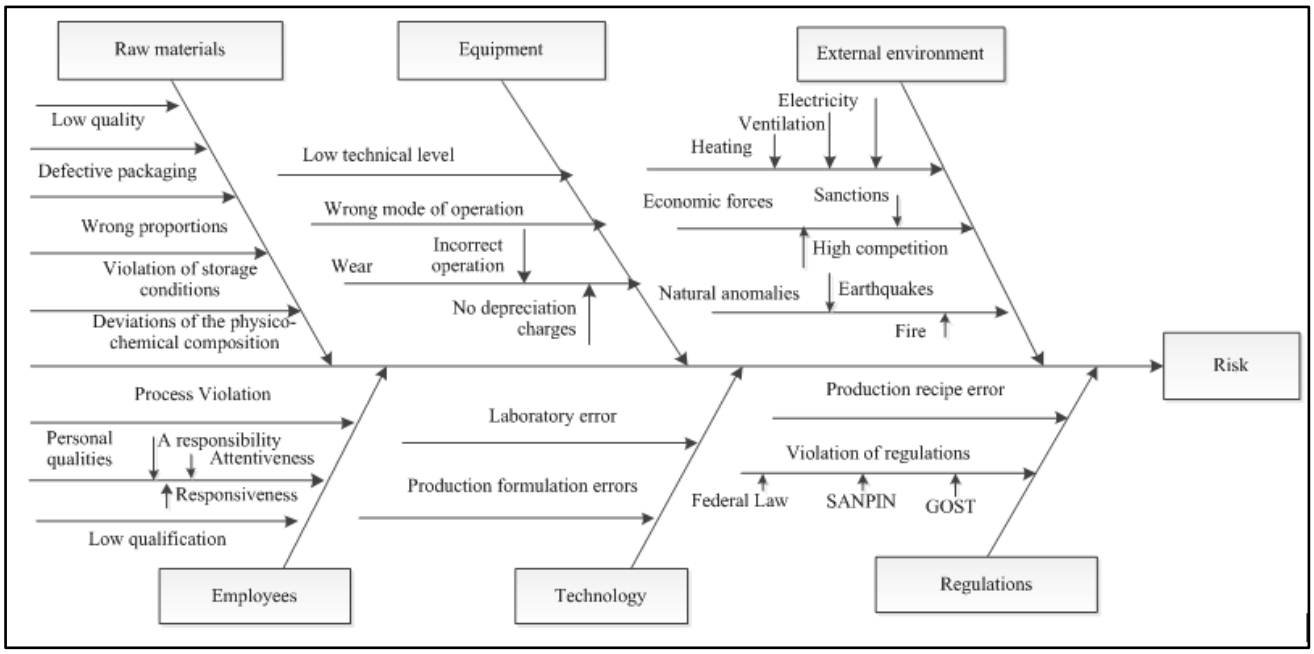

Fig. 2. The causal diagram of factors influencing the process, on the occurrence of risk

manufacturing is governed with the Federal Regulations (№ 52-FZ, 184-FZ, 29-FZ), National standards (GOST 31805-2012, GOST 26987-86, GOST 27842-88), sanitary norms and regulations (SanPiN 2.3.4.545-96, SanPiN 2.3.2.1324-03, SanPiN 2.3.6.1079-01.), technical regulation of the Customs Union, Industry-specific process engineering standards 02-92, norms of technological design of bread and bakery products manufacturing factories as well as internal factory documentation (instructions, process charts, manufacturing and process formulas).

(proportional distribution) on the basis of recommendations and requirements of GOST. Table 1 demonstrates main critical points and parameters for flour and yeasts as these

ingredients are affected by external factors. Figure 2 shows the causal diagram of the confluence of factors characterizing the technological process, the occurrence of risk.

During qualitative analysis and hazard assessment of technological process, models “Use Case Diagram”, “Class Diagram”, “Statechart Giagram”, “Activity Diagram”, “Component Diagram” are constructed on the basis of Object-Oriented Analysis and Design. During analysis of subject field and construction of object-oriented models, huge amount of information is gathered. The glossary of subject field is made for all models, in which all key terms are specified facilitating understanding of the subject field and eliminating risk of disagreements during its discussion. Abstractions from the glossary as a rule have co-dependence between objects resulting in associations and generations formation. Detecting of such co-dependencies is the basis the subject field glossary creation. Designed object-oriented models are foundation of ontology elaboration process automation.[Decision support for a strategic enterprise based on knowledge engineering / ed. L.R. Chernyakhovskaya. – Ufa: Gil, 2010. - 128 p.].] Ontology of a factory hazard management is a model of unified semantic description of knowledge for elaboration of complex processes’ participants cooperation during agreed management decisions formation. Ontology is applied for formal description of notions belonging to the discussed subject field of technological process hazards management and relations between them.

As a result of the conducted ontological analysis, peculiarities of business interrelationship processes management are revealed for decision-making regarding hazards management as well as for solving the problem of trustworthy and up-to-date information for decision-making within uncertainty conditions [11]. Description of ontology is made in OWL DL OWL DL (Ontology Web Language based on Description Logic) programming language. OWL elaborated based on Semantic Web theory and technology and in compliance with abilities of descriptive logic, allows describing various characteristics of classes and their features as well as relations between classes defining the structure of relations between class instances. [OWL Web Ontology Language Gaide. URL: http://www.w3.org/TR/2004/ REC-owl-guide-20040210/ (date of the application: 20.08.2018)].

The present research specifies hazard management ontological analysis with implementation of Bayesian Belief Networks as method of analysis and assessment of technological process hazard, which allows applying of results of events observations with possible parameters of unfavorable events occurrence. Bayesian rules specify initial uncertainties depending on other events and evidences.

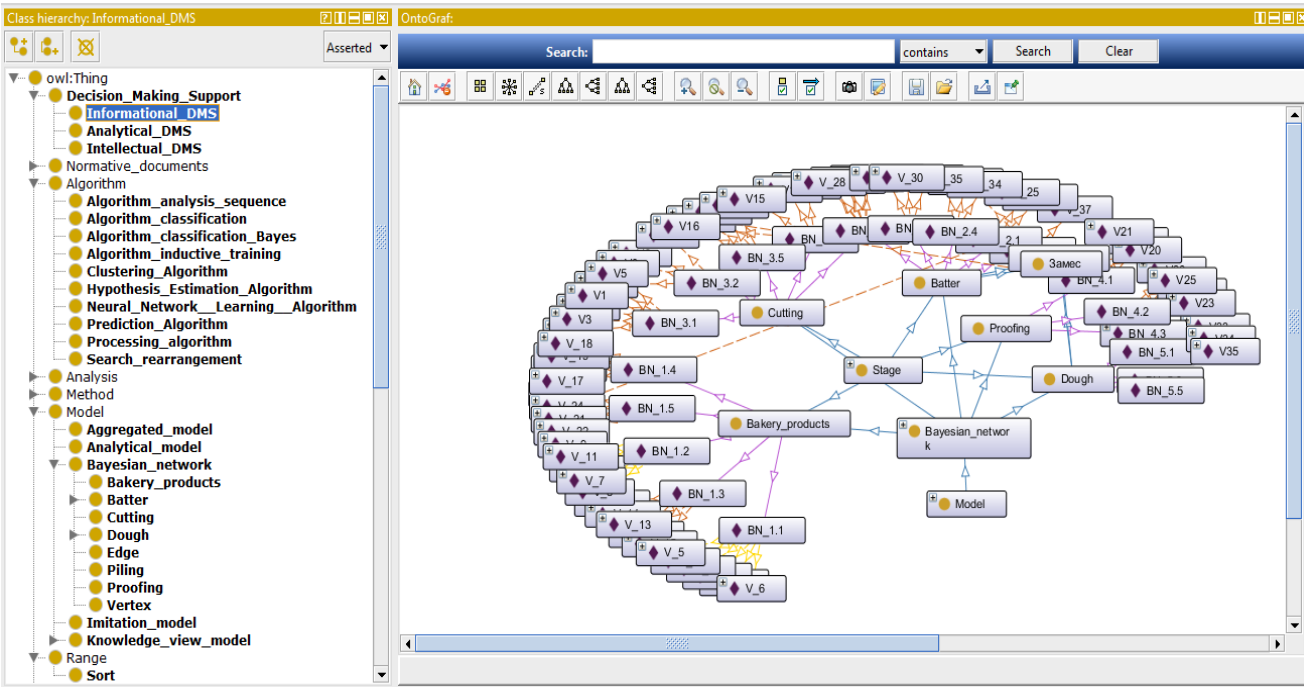

Fig. 3. Fragment of the ontological risk management model

This research applies ontological analysis of hazards management with implementation of Bayesian belie networks – this is an oriented graph, where each node is marked by quantitative probability information [6]. The network’s nodes are events with specified probability (certainty) characteristics. Nodes are connected pair-wise oriented edges; edges form set of edges. If the arrow is pointed from node x to node y, node x is called ancestor node of node y. Each node x is characterized by distribution of possible certainties P(Xi /Parents(Xi)), which quantitatively evaluates ancestor nodes effect on this node [7].

Bayesian method of hazards assessment and analysis is specified with huge amount of conditional and posterior probabilities. Ontology is used for responding users’ inquiries regarding Bayesian networks structure for specific unfavorable situations as well as a tool for storage of huge volume of information for posterior probabilities calculation. Critical control points designed and revealed earlier with usage of HACCP method act as nodes during Bayesian

Belief networks construction. Technological process is strictly regulated, which allows to design Bayesian belief networks in ontology as typical frameworks for each stage of technological process and to make calculation of possible probabilities in the network nodes. Figure 3 shows the fragment of search and designing of a typical Bayesian belief network. So, possibility for decision-support system in the field of hazard management with application of Bayesian method is provided.

The designed decision-support system is designated for implementation in manufacturing and accompanying it on all stages of technological process. However, prior to that, imitation modeling shall be done, which enables to assess efficiency of implementation and operation of the system. Agent-oriented modeling (AOM) helps to analyze complicated, continuous, dynamic systems within uncertainty conditions. AnyLogic framework was chosen as a modern software tools. Experts, people participating in decision making, decision-support system and the technological process act as agents. Interrelation of these agents happens according to designed regulations. For each agent, basic variables are specified such as for agent "Human being" specified parameters are age, qualification, skills set. The technological process is presented with usage of internal library of manufacturing flows and looks like continuous process of material resources transfer along all stages of technological process.

Results of imitation model are presented in data of decisions amount taken due to decision-support system and time spent for the whole process of decision-making. Imitation modeling defines parameters for decision-support system efficiency assessment.

III. Results

The results of the research described in the present article are the designed models of technological process on the basis of object-oriented approach in consequence of critical control points of unfavorable events occurrence are created as well as ontology of hazard control with the integrated Bayesian Belief Networks. The revealed unfavorable events are the basis for formation of nodes in the Bayesian Belief Networks and further hazards assessment. Therefore, decision-making is supported for analysis and hazards assessment in the technological process.

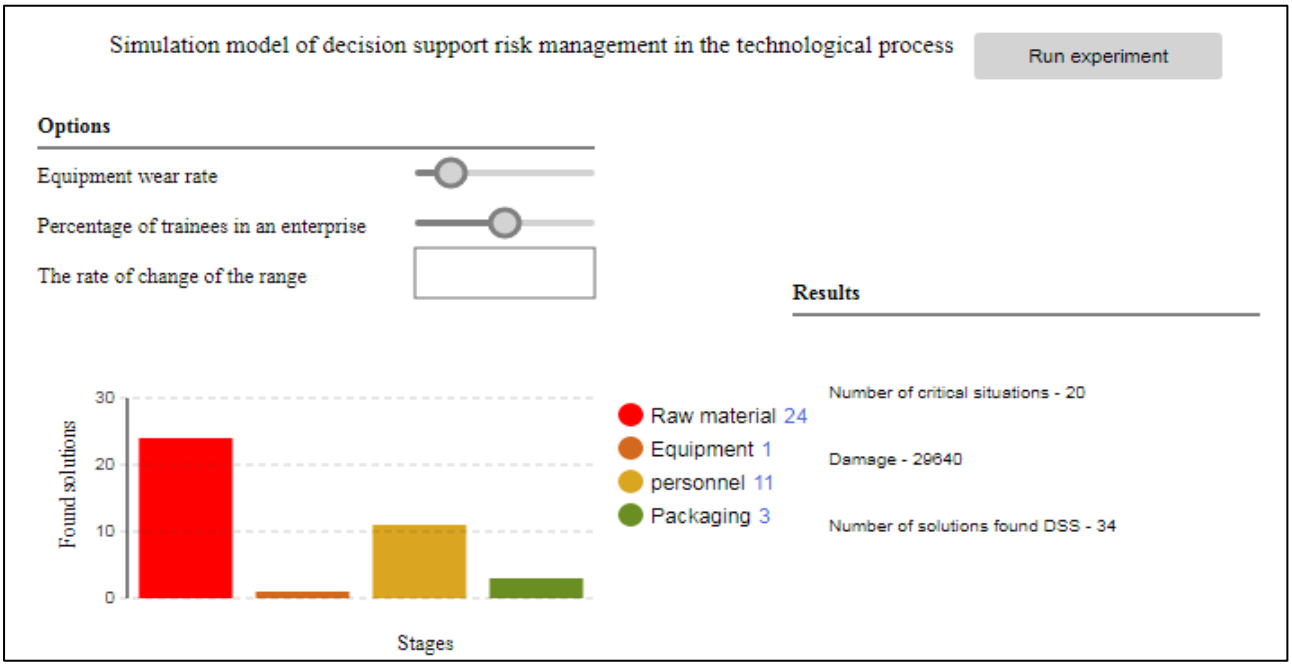

Fig. 4. Scenario Analysis Interface

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