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RISK ASSESSMENT OF THE INNOVATIVE PROJECTS IMPLEMENTATION

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Abstract
The article presents the issue of risk assessment of innovations. Specificity of technological innovation realized in manufacturing companies has been particularly well described here. An original method of assessing the innovative projects risk has been presented. The elaborated method has been implemented in three enterprises, the business activity of which is not typical for electrical engineering, metal and mechanical engineering and companies which are going to carry out the innovative project simultaneously with already started innovative projects. Moreover, an example of the risk assessment of a chosen technological innovation has been presented.

Keywords
innovation, product and process innovation, technical innovation, risk, risk assessment, manufacturing enterprise.

Introduction

The issue of innovation is not new. It is rather a kind of challenge of everyday life to which entrepreneurs had to adjust. One of most important problems which has to be faced at the moment of making a decision on implementing innovation is the efficacy issue. An issue of appropriate innovation assessment, mainly in the context of risk of its implementation appears.

Risk can be understood as a deviation from the desired state both in case of negative and positive effects. It is generally presented as a product of the danger occurrence probability and its effects. In case of innovation, risk identification is connected with specification of dangers that can be encountered by an enterprise during the process of a given solution implementation (the negative concept of risk). The process of potential dangers identification is a key point in the context of assessment result. On the basis of appropriately identified dangers, the company is able to make a real assessment of an innovative idea. The assessment is one of elements of the risk management process which (when simplified) includes [1–18]:

- identification of dangers,
- risk measurement and assessment,
- monitoring and control.

In view of the above, it is possible to state that the sheer risk analysis includes identification, measurement and assessment of dangers. The monitoring and control area is a risk management element in which results of former analyses are used. Generally speaking, it is possible to come across a parallel treatment of the terms of risk analysis and management. The complete risk management process has been presented in Fig. 1.

There are many classifications of innovation, resulting from an individual author's approach to the examined issue. It seems that the most frequently used division is the one presented in the Oslo manual [19], which divides innovation into four basic groups, from the point of view of product, process, organisation and marketing (see [19–25]).

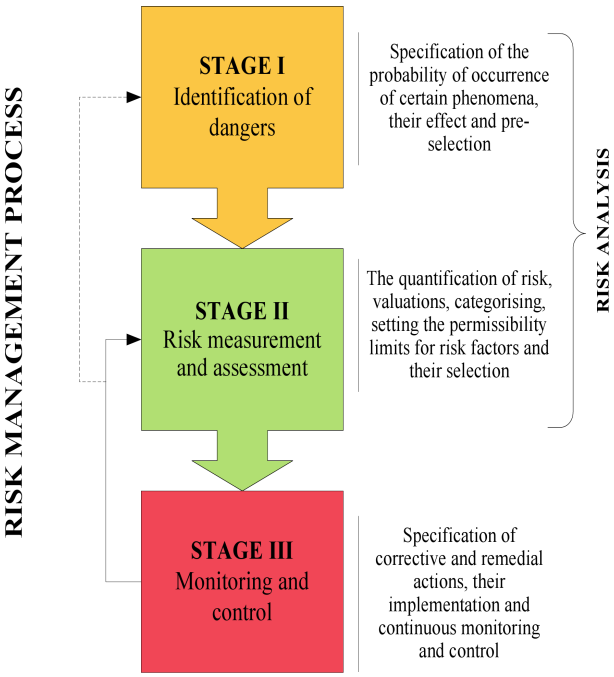

Fig. 1. Risk management stages (see [1–18]).

The category of technological innovation concerning technical and technological changes in the organisation is important in manufacturing companies. In this domain it is important to differentiate innovation related to the effect of realisation of a particular technological idea, where we have to do with an improved or new product or an improved or new manufacturing process. The second approach treats innovation as a process in which a specific technological concept is transformed into a material one, the effect of which is a manufacturing method or a product [26]. Technological innovations concern technical and technological changes. Most frequently they are related to product innovations, resulting from the implementation of new products or improvement of already existing ones and the process that is resulting from the implementation of new ways of producing or using the existing goods. Characteristics related to organisational innovations, connected with the improvement of the effectiveness of action e.g. in the scope of management and systemic innovations such as for example new technological and organisational solutions, mainly in the scope of the so-called information and communication technology leading to the improvement of information flow in the logistic and management processes as well as traditional processing are also frequent [27, 28].

The risk connected with innovation activity of enterprises is divided into [29]:

- project risk – connected with technological conditions of the project realisation,
- owners' risk – connected with the lack of diversification of the enterprise development directions,
- company risk – connected with the difficulty of gaining financial resources for the project realisation.

These components present basic innovation features which include among others: big costs of the undertaking realisation, a long time horizon and technology which has not been verified yet. The project risk is defined in the article as risk connected with technological conditions of the project realisation, whereas the owners' risk results from the lack of diversification of the enterprise development directions. The company risk is connected with the widely understood financial risk [30].

The aim of the article is to present the original method of an assessment of technological innovation risk designed for the electrical engineering. A practical example of the technological innovation risk assessment has also been presented.

Problem statement

Many models of investment risk analysis based mainly on internal (chosen) dangers of a given project can be found in the literature [2, 10–18, 31–36]. However, there are too few models considering the problem of risk comprehensively.

A comprehensive approach to the innovation risk assessment is a gap in the research concerning innovation. This area became an indicator of the risk assessment method development for the authors, which joins many aspects of analyses, mainly in the scope of technological and economic character as well as social, political and legal [37]. So, research problem is elaboration method of assessment risk, way of choice experts and criteria assessment in particular. Method should meet expectations of entrepreneurs implementing innovations in area where detailed analysis of dangers is necessary.

Although there are opinions that in case of innovation, there is no possibility of risk verification, it is possible to come across arguments that even if the project is characterised by uniqueness it is necessary to focus on the possibility of applying existing solutions in order to find a reference point and elaborate alternative possibilities of the project modification. According to its definition, innovation is unpredictable and completely uncertain. However, the issue of its realisation possibilities remains in the scope of determining probability of such an eventuality. This is why, it is possible to look for its effects and specify the probability of certain dangers occur-

rence influencing the innovation realisation. In this way, we define a certain reference point. Determination of such point makes the assessment to be relative, among others by means of an analysis of risk dangers of technological nature in relation to their economic effects and vice versa. This is why, the risk analysis of such an undertaking seems to be a rational step in the decision-making process of enterprises [26, 38, 39].

The academic literature focuses mainly on economic aspects of innovation, however technological issues will be the centre of gravity of analyses in the suggested assessment.

In the elaborated method, innovation risk will be regarded from the point of view of the project risk, owners' risk and (company) financial risk [30].

The article presents an original method of technological innovation risk assessment implemented in manufacturing enterprises in electrical engineering. This method makes it possible to make an assessment in three alternative cases:

1. Enterprises, the business activity of which is not typical for the electrical engineering.
2. Metal and mechanical engineering companies.
3. Companies which are going to carry out an innovative project parallel with the projects of innovative character which have already been started.

The elaborated method takes into consideration the three above cases which result from the needs of analysed enterprises.

Method of technological innovation risk assessment

General characteristics

The assessment of risk will be conducted in two steps. In the first step, an indicator determining a general predisposition of an enterprise for the realisation of innovative projects will be calculated. It is a synthetic piece of information which is required in case of an application for the innovation financing and shows the readiness of an enterprise to carry out the project. At this stage, only the so-called general guidelines (hereinafter called general criteria) concerning the entity implementing a given innovative solution are analysed. This score-based assessment takes into consideration the importance of criteria. At this stage of assessment, an enterprise can obtain maximum 17 points. A weighted partial rating is calculated as regards particular criteria, which in this case fulfil the role of dangers and then a total assessment. A general assessment is conducted on the basis of the following criteria [40]:

1. The company size.
2. The scale of innovations.
3. The period of applying the technology in the world.
4. The period of the project realisation.
5. The relations of external sources of financing to the size of the entire project.

The problem complexity causes that in this case a multi-criteria analysis has to be used. The method of pair comparision according to the following formula [41] was used in the elaboration of the weight of criteria:

$$w_j = \sum_{i=1}^{m} u_{ji}, \qquad j, i = 1, \ldots, m, \tag{1}$$

where w_j – c_i criterion weight, u_{ji} – assessment of weight of a given pair of criteria.

If the c_1 criterion is more important than c_2 criterion, then values from the range $0.5 < u_{12} \leq 1.0$ are entered in the row c_1 under c_2, whilst the value $u_{21} = 1 - u_{12}$ in the row c_2 under c_1. In an equivalent case, the value $u_{15} = u_{51} = 0.5$ is entered. Zeros occur on the matrix diagonal as a criterion cannot be weighted against itself. Then, the obtained weights are subject to normalisation [41]. The example has also been presented in the paper [42].

Weights have been determined by specially chosen experts with taking into consideration their individual psychological features. Experts have been chosen according to assumptions presented in papers [43, 44]. The assessment result as regards general criteria is given and divided into low, medium and high risk. The indicator is calculated according to the following formula [37]:

$$RI_{GC} = \sum_{j=1}^{n} w_j \cdot p_j, \tag{2}$$

where RI_{GC} – the risk indicator for general criteria, w_j – importance of a given criterion, $p_j = 1, \ldots, 4$ – the score-based assessment, $j = 1, \ldots, 5$ – the criterion number.

The range scale is estimated according to the following formula [37]:

$$d = \left[\left(\sum_{j=1}^{n} w_j \cdot \max p_j \right) - 1 \right] \Big/ 3, \tag{3}$$

where d – range, and

$$Dg_q = 0.001 + Gg_{q-1}, \qquad q = 2, 3, \qquad Dg_{q=1} = 1, \tag{4}$$

$$Gg_q = d + Dg_q, \tag{5}$$

where Dg_q – the lower limit of the range, Gg_q – the upper limit of the range, q – the range number.

The second step of an assessment is not connected with the first one, this is why the criteria weights determined in this range are considered separately.

The following detailed criteria form the basis of assessment [40]:

1. Minimization of the negative impact on the environment.
2. Minimization of procedural errors which can result in the lack of permission to start production.
3. The innovative solution's competitiveness.
4. The state of readiness for the realisation of innovations.
5. Minimization of solutions on the short market life of the product.
6. Minimization of disturbances connected with the use of the product.
7. Minimization of disturbances connected with the effective transfer of materials/subcomponents, etc.
8. Minimization of disturbances in the process of the product acceptance and complaint management.
9. Minimization of technologically non-developmental solutions.
10. Minimization of mistakes connected with submitting erroneous construction documents of the product.
11. Minimization of dangers in the scope of creating technological data sheets, as well as processing, mounting, control and cost calculation
12. Minimization of disturbances in the process of changing shapes, dimensions, the surface quality or physical-chemical conversions of the product.
13. Minimization of dangers in the scope of mistakes formed as a result of joining parts and components forming the whole product.
14. Minimization of projects which do not meet customer's technical and economical requirements.

The weights of particular detailed criteria can be used several times as each criterion includes a proposed set of dangers which is not limited by anything. For example, criterion number 3: the innovative solution competitiveness can be related to such dangers as: the necessity of the main change of the overall manufacturing process, elongation of the production chain, higher product price, lower product quality than it was expected, higher production costs.

The risk indicator for detailed criteria, being an overall assessment, is calculated on the basis of the following formula [37]:

$$\forall_{j=1,\ldots,14} \quad RI_{DC} = \sum_{i=1}^{m} w_j \cdot P_{ij} \cdot W_{ij} \cdot S_{ij}, \qquad (6)$$

where RI_{DC} – risk indicator for detailed criteria, w_j – weight of a given criterion, P_{ij} – subjective probability of i danger occurrence as regards the j criterion, W_{ij} – i danger detection as regards the j criterion, S_{ij} – the result of the occurrence of i danger occurrence as regards the j criterion, $j = 1, \ldots, 14$ – the number of criterion, $i = 1, \ldots, m$ – the number of danger.

In the second stage, a detailed innovation risk is determined and it is calculated as a product of three weighted parameters: P_{ij}, W_{ij} and S_{ij}. The value from 1 to 10 is assigned to parameters. Each danger has its own weight corresponding with the assessment criterion in the area of which it was identified. The calculations are thus based on the summing up products of three adopted parameters with weights of particular criteria for all identified dangers. In this way partial assessments are calculated and they are subject to aggregation assessments an overall grade as a result. The result for detailed criteria is given and divided into very low, low, medium, high and very high risk. The range scale was agreed on the basis of the following formulas [37]:

$$H = \sum_{i=1}^{m} w_j \cdot \max P_{ij} \cdot \max W_{ij} \cdot \max S_{ij}, \qquad (7)$$

where H – the maximum value for all dangers, and

$$d = \frac{0.2 \cdot H}{5}, \qquad (8)$$

and

$$\begin{gathered} Dg_q = 0.001 + Gg_{q-1}, \quad q = 2, 3, 4, 5, \\ Dg_{q=1} = 0, \end{gathered} \qquad (9)$$

$$Gg_q = d + Dg_q. \qquad (10)$$

Having determined risk ranges, the calculated RI_{DC} is joined to an appropriate risk area.

The set range depends on the number of specific dangers. In order to prevent the anxiety which can accompany the determination of a large number of dangers, one of the most well-known assumptions in economy and management, that is the Pareto rule, was used. According to this rule, 20% of the value of all dangers was taken into consideration in order to analyse the result. This action was very well received by entrepreneurs and encouraged them to determine as wide list of dangers as possible so that it was possible to choose those which could cause the worst impact. This is why a sum for all dangers is calculated out of the maximum value of the product of the weight of criterion and parameters P_{ij}, W_{ij} and S_{ij}. Then, 20% of the value is calculated and it is divided by 5, in accordance with the division into 5 scopes of

risk. The value obtained in this way is the range for each of risk areas.

The method was used for three cases, what can be seen in Fig. 2.

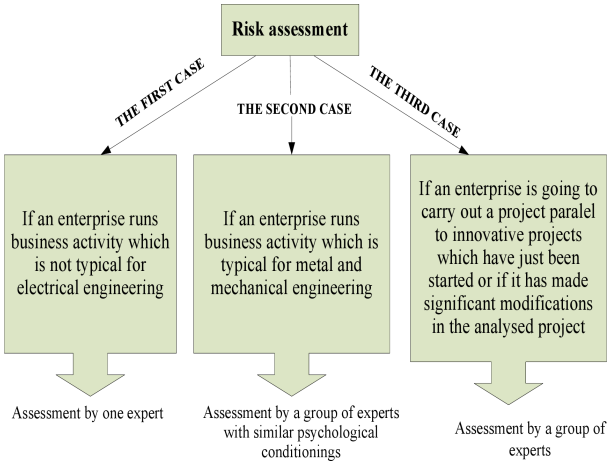

Fig. 2. Cases of the risk assessment model. Source: [37].

In addition, a risk map elaboration is a key element of this method, on the vertical axis of which an important product P_{ij} and W_{ij}, is presented and on the horizontal axis of which there is the value of the result S_{ij} of a given danger. Such a division was made due to the fact that it reflects a given danger as regards its result in a better way. Conclusions from this map analysis are included in those obtained from the interpretation of values of particular dangers.

The model of process risk assessment is presented in Fig. 3.

An unquestionable advantage of the elaborated method is its application without the necessity of determining one's own weights and criteria. It assumes that the company has a possibility to compare the obtained result with an assessment made according to its own agreed importance of criteria. Constant elements of an assessment are criteria which determine the innovation assessment direction. At the same time, dangers, specified in the area of particular criteria, are of changeable character (depending on the analysed innovation) and are not limited by anything as it is possible to enter one's own danger in the field entitled *others*. In addition, the suggested dangers make it easier to determine one's own, individual dangers connected with a given innovation. A company has thus a possibility to compare its own view on innovation with the one which results from the assessment as regards the importance of criteria specified by independent experts. It is necessary to highlight the fact that from the point of view of a practical assessment of projects, it is possible that some dangers will occur several times as they are specified in the area of particular criteria.

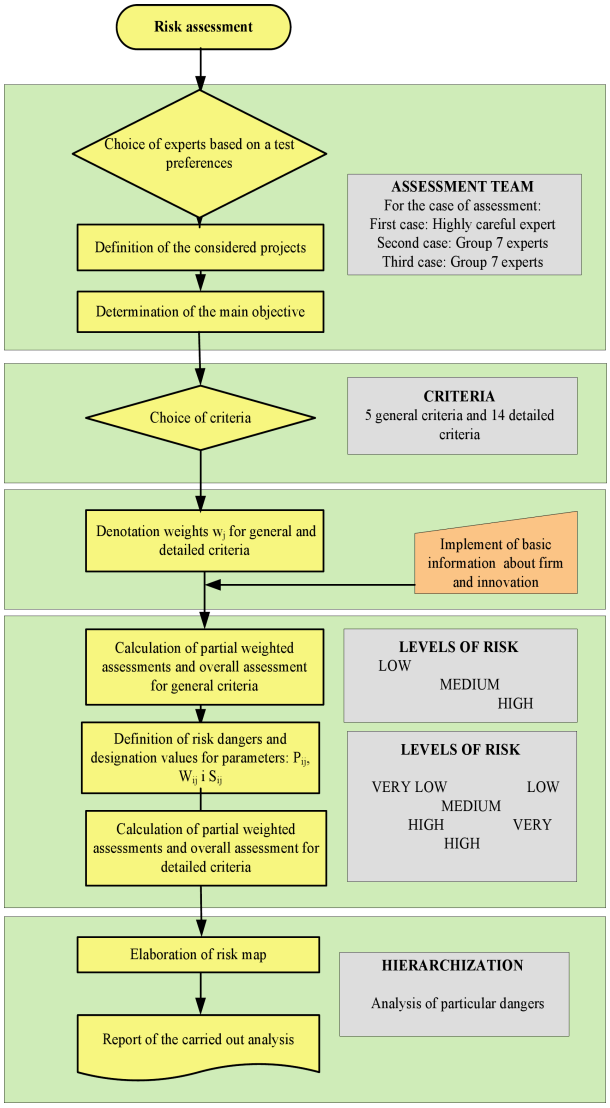

Fig. 3. Model of process risk assessment.

The first case

The first case of assessment is recommended for the situation in which the business activity is not typical so it is possible that it can be anxiety that the chosen experts' knowledge is not adjusted to the reality of a given unit. The assessment method based on the use of one expert's weights was elaborated for the companies which think that only experts in a given branch are able to well assess the risk of a given innovation. For such solutions, a case of assessment by one expert, the assessment of whom is very careful, was elaborated. Also in this case it is suggested

that the company sets its own weight of criteria and then compares the obtained assessment results elaborated on the basis of both criteria weight. It is also possible to compare the obtained results as regards the weight of criteria determined by other experts, the individual features of whom were characterised and analysed as regards the impact on the final assessment result.

The assessment version with one expert has some advantages as it makes it possible for the company to adjust weights, according to its own consideration, to the company's specificity. The application algorithm is presented in Fig. 4.

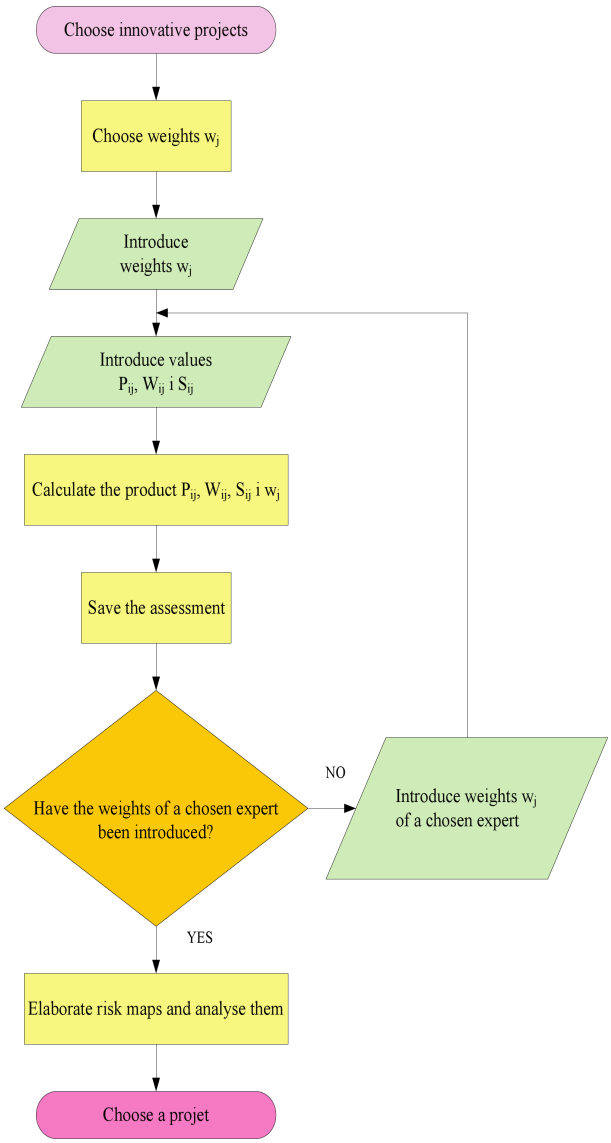

Fig. 4. Flow chart for the first case.

Ordered weights are given in Table 1.

Table 1
Weights of criteria determined by a highly careful expert.

Hierarchy of criteria			
Weight	Detailed criteria	Weights	General criteria
0.0339	2	0.0500	3
0.0449	1	0.1750	4
0.0595	5	0.2167	5
0.0595	6	0.2583	2
0.0595	7	0.3000	1
0.0723	3		
0.0723	8		
0.0723	9		
0.0852	4		
0.0852	10		
0.0852	11		
0.0852	12		
0.0852	13		
0.0998	14		

A suggested expert was chosen on the basis of an analysis of weights agreed by all considered experts. In the overall results, the number of the highest weights assigned to him was 6 (what is a maximum value when compared to all experts) and the lowest 3. In addition, when assessing chosen innovation with the application of his weights, we get the highest assessment value in comparison to the other experts. It is obviously as a result of using particular criteria weights. This expert was characterised by the most extreme assessments in the scope of the mentioned criteria.

The second case

The second case is recommended for typical metal and mechanical engineering. It can also be used to make repeated analyses of innovative projects, which were postponed due to the possibility of implementing only one solution in a given period. It is a so-called assessment with taking into consideration similar psychological features of decision-makers. It is made by a specially chosen team which was divided into three groups, so it includes opinions of appropriately selected people who from the point of view of psychological aspects are ideal experts in the scope of assessment of innovation (see [43]). This is why each group has weight determining the degree of impact on the overall risk assessment assigned.

Weights for this case are presented in Table 2.

Table 2
Weights of criteria in the second case.

Detailed criteria	Weight	General criteria	Weight
1	0.058	1	0.201
2	0.082	2	0.249
3	0.081	3	0.216
4	0.074	4	0.151
5	0.068	5	0.182
6	0.073		
7	0.063		
8	0.061		
9	0.083		
10	0.07		
11	0.069		
12	0.065		
13	0.063		
14	0.09		

The assessment application algorithm has been presented in Fig. 5.

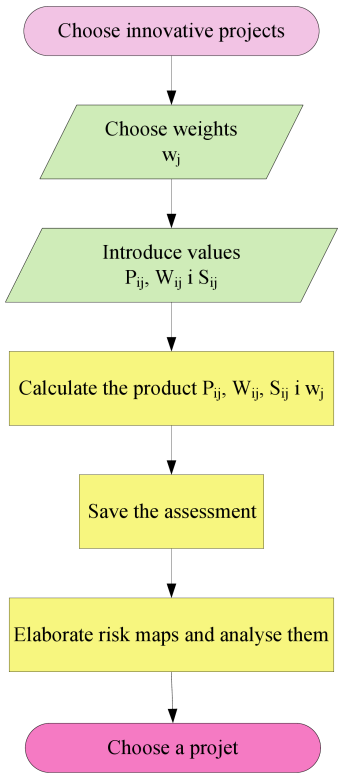

Fig. 5. Flow chart for the second case.

The third case

The third case is recommended for projects which are to be carried out parallel with already started innovative projects or which have been subject to major modifications due to the critical approach of constructors/employees. The procedure has been shown in Fig. 6.

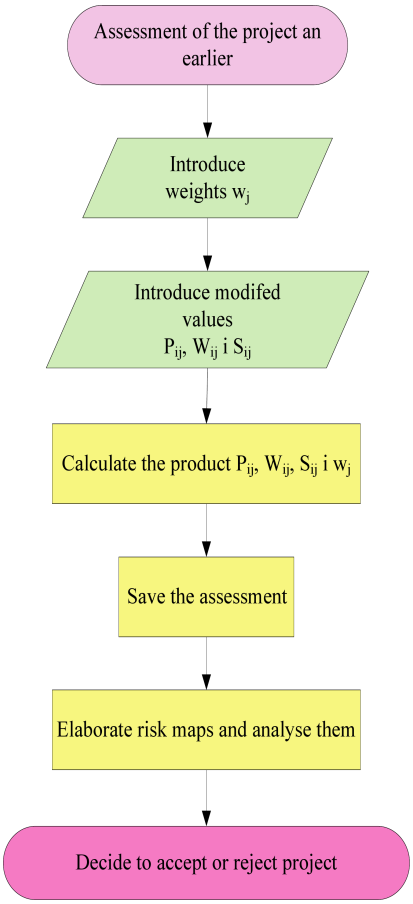

Fig. 6. Flow chart for the third case.

Due to the fact that the project analysed in this way is carried out as the second one, it can potentially come across numerous obstacles connected with possible difficulties which appeared during the implementation of the first innovation (e.g. on the financial state of an enterprise or other aspects of business activity). This is why it is assumed that an additional security margin should be applied by means of multiplying the obtained result at the level of detailed criteria by the result obtained at the level of general criteria. For example, if the risk value at the general level amounts to 2.0039 and 363.6 at the detailed level, then the result 728.618 is the basis to interpret the project risk.

Earlier cases did not profit directly from the result obtained at the general assessment level as it was only an approximate assessment. Here it is a key analysis element which significantly determines the possibility of carrying out an undertaking. Such modification is justified in the context of difficulties dur-

ing the realisation of two innovative undertakings at the same time. In the assessment process, the same weights of criteria are used as in the second case. An application of this kind of assessment method is also recommended in case of projects which cause doubts and contradictory opinions in the scope of the discussion of experts in the company.

Case study

The analysed example was the construction of an innovative technological line of welded constructions elements prefabrication. Assumptions described in the second case were used in this assessment.

An innovation which was characterised by a low scale of innovation in the enterprise area and foreign financing exceeding 30% was subject to risk assessment. The project was carried out by a small enterprise. The realisation took one year. The applied technology was used all over the world for the period shorter than one year. The project risk was assessed as high on the basis of presented data at the first stage of assessment.

Innovation specificity

The implementation of innovation made it possible to manufacture elements of silos, dryers, transport machines out of galvanised steel, etc. more effectively, in a more automated way and of better quality. The realisation of innovation influenced on the improvement of company products quality as e.g. grain silos are in 60% built out of galvanised steel. Load-bearing elements of the silo are welded. Until now their cutting, welding, cleaning and painting was handmade. Little precision of works, long time of realisation of handmade operations, a lot of impurities and thus harmfulness of works causes that these construction elements were of the poorest quality. A prefabrication line of welded construction elements guarantees appropriate strength and quality parameters. Having implemented the innovation a company became the only enterprise in the branch having such innovative machinery. There are only few companies in Poland which have similar technological lines. The innovation is of process type. A detailed analysis of the project in the version accepted for realisation was included in the article.

Risk assessment

Innovation was assessed as highly risky at the level of general criteria. It resulted mainly from a low innovation scale of the project and high percentage of financing innovation by means of foreign capital. The risk value amounted to 2.88. The risk rating scale for general criteria was presented in Table 3.

Table 3
The rating scale for general criteria.

Low		Medium		High	
1	1.794	1.795	2.589	2.59	3.386

48 dangers were found as a result of identification. The risk indicator value resulting from specific innovation features amounted to 292.5, which means that the risk is medium. The risk rating scale for detailed criteria was presented in Table 4.

Table 4
The rating scale for detailed criteria.

Very low		Low		Medium		High		Very high	
0	139.368	139.369	278.736	278.737	418.104	418.105	557.472	557.473	696.84

The following dangers were identified as major on the basis of data analysis:

- 8. Very large dependence of innovation on the mounting process: 9.76;
- 46. Too excessive client's demands regarding the product quality: 10.08;
- 33. Omission of changes annotation found during the mounting process 10.6344;
- 25. Incorrectly determined way, place and frequency of control: 17.388;
- 34. Incorrectly elaborated service program and aftersales services: 18.21;
- 16. Incorrectly made figure (the product outline and dimensions): 18.981;
- 15. Lack of research regarding the product purchase repeatability: 24.408;
- 10. Financial situation of the company – the business activity profitability: 25.4506.

The critical point of the report analysis (above which it is necessary to lead a detailed monitoring of dangers) is an outcome calculated on the basis of the highest weight of a detailed criterion which amounts to 0.09 and the maximum value for the product P_{ij} and W_{ij}. For the presented example it amounts to 9.

In addition, the risk map analysis, showed in Fig. 7, makes it possible to widen the area of reinforced surveillance by such dangers as:

- 47. Too excessive client's demands in the scope of product manufacturing costs: 7.2;
- 24. Incorrectly elaborated list of technological operations: 2.208;
- 23. Incorrectly elaborated list of working (processing) positions: 3.864;
- 42. New formula of logistics: 4.5576;

- 43. Innovation realisation generates the increase of warehousing costs: 5.3172;
- 44. No diversification of suppliers: 5.3172;
- 35. Incorrectly made empirical analysis of the prototype: 5.2488;
- 45. Others: 3.798.
- 39. No own solutions in the scope of know-how: 3.96;
- 26. Incorrect choice of material, component supplier, etc. (material quality and price, etc.): 2.484.

The presented risk map shows dangers connected with the analysed innovation. As it is possible to notice in Fig. 7, the major dangers with the effect of value 6 are the following: 16, 25, 26, 35, 39, 42, 43, 44, 45. Only the names of important dangers were included in the paper. As it can be seen, the major danger is connected with the lack of capacity of satisfying the client as regards costs of product manufacturing (47). This danger is crucially connected with the aim of the realised innovation which assumes the increase in the quality of manufactured goods. This is why the company focused on performing and monitoring all actions connected with the quality of manufactured goods and proper determination of clients' needs in this scope. Moreover the analysis showed that dangers connected with: incorrectly elaborated list of technological operations (24), company profitability (10), too excessive client's demands in the scope of product quality (46), incorrectly elaborated list of working (processing) positions (23) and the lack of research regarding the product purchase repeatability (15) are also important aspects. At the same time, it is possible to highlight that the sheer risk map analysis did not show that there is a need of monitoring such dangers as: very large dependence of innovation on the mounting process (8), omission of changes annotation found during the mounting process (33) as well as incorrectly elaborated service program and aftersales services (34). This is why, conclusions from the risk map analysis and report should be treated as complementary.

The assessment conducted in accordance with assumptions in *the second case*, makes it possible to look at risk of an analysed innovation objectively. An application of weights for three groups of experts made it possible to take into consideration their psychological conditions, what makes the assessment more reliable. The interpretation of results obtained from the report and risk maps, makes possible to take a broader look at innovation risk. Both tools should be treated as complementary.

The obtained result, that is 292.5 signifies a medium innovation risk, which was confirmed during the undertaking realisation.

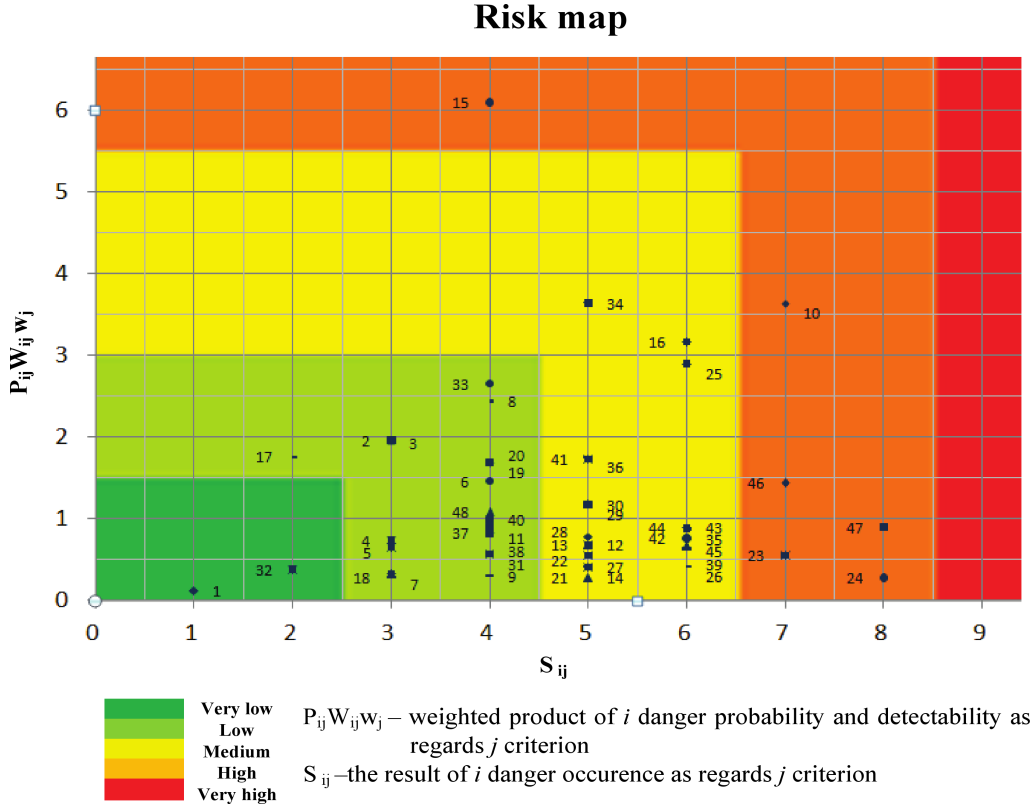

Fig. 7. An element of a risk map.

Conclusions

The innovation risk assessment is an important stage in the decision making process concerning the realisation of an undertaking. It is a complicated action which is difficult to carry out. The suggested method connects technological and economical aspects at the same time taking into consideration social, political and legal issues. It makes possible to characterise innovation in the scope of its specific features. It supplies us with analyses of relative character, among others by means of an analysis of risk dangers of technological character regarding their economical results and vice versa. It also makes it possible to verify one's own views with the expert's approach to the problem analysis.

The risk assessment method uses the weights of experts who were purposefully chosen. The method has multi-criteria character, thus it makes possible to notice many dangers which are not taken into consideration in one-aspect techniques.

The presented assessment combines results obtained on the basis of the assessment report analysis that is a list of particular values of dangers in the ascending or descending order with conclusions from the risk maps interpretation. Advantages of individual analyses of particular dangers and widening the monitoring scope of the most risky dangers in the context of an analysis of their possible result (conclusions from risk maps) were indicated.

The developed method has a wider practical application, thus it contains many simplifications making it easy to use by the company employees and at the same time, it is correct from the point of view of methodology.

The research and verification of the method was conducted in electrical engineering industry. Criteria applied in the proposed model are so general that they can be treated as universal with the possibility of applying them in different projects of technological character. However, an application of this method in other branches will require to include other dangers specific for a given branch.

The unquestionable advantage of this method is its "open" character, which makes it possible to introduce undefined dangers dynamically.

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