RISK IN PROJECT MANAGEMENT IN THE AUTOMOTIVE INDUSTRY ON THE EXAMPLE OF A SELECTED COMPANY

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Introduction/background: Despite the existence of many standards, guidelines and methods for risk management in manufacturing companies, it is still an issue that is often overlooked in management practice. This is due to the natural reluctance of managers to deal with risks related to ongoing projects and processes, which additionally require additional organisational effort and the use of various inputs. This paper presents the problem of risk management in projects implemented in a selected automotive company.

Aim of the paper: The main aim of the paper was to develop and implement a risk management model for the project management process, which includes stages such as: identification of risk factors in ongoing projects, risk analysis and evaluation, and development of risk response methods.

Materials and methods: In the research part, heuristic and statistical methods (group, ocean of experts) were used to identify key project risks. In addition, a qualitative method such as a risk matrix was used to analyse and evaluate risks. An element of the risk management model of options in response to risk was also identified.

Results and conclusions: This paper presents how to determine the key risk factors in projects and how to use them in a risk management model for projects in the selected company. The model can be used for risk management in projects in other companies.

Keywords: project management, risk, risk management, risk factors, identification of risk factors, risk quantification, risk assessment.

1. Introduction

In a rapidly changing environment, increasing competition and growing customer demands, risk management is one of the most important tasks facing a manufacturing company. Product design and development processes are taking place under increasing pressure of time, cost reduction and higher quality. For these reasons, these processes are subject to the risk of disruption caused by various risk factors. With the increasing specialisation and complexity of production processes, risk management is increasingly being considered on an industry-specific basis. This also applies to the automotive industry and the projects carried out there. Using an automotive company from the SME sector in the Silesian Voivodeship as an example, the paper presents a practical solution to risk management as one of the basic activities in project management. Despite its importance, the issue is not dealt with holistically and there is no comprehensive and universal approach to the issue of risk, especially in the area of its identification and quantification.

Practice shows that almost all projects run differently than planned and that many projects fail due to inadequate risk management. And it is precisely the purpose and essence of risk management to rationally maximise benefit or rationally minimise loss (Kulińska, 2009, p. 31).

It should be pointed out that risk management is a structured process and can be divided into a number of successive stages (Figure 1). The number of stages varies depending on the approach. For example, the PMBoK methodics (A Guide to the Project Management…, 2013, pp. 319-321) distinguishes six risk management processes: risk management planning, risk identification, qualitative risk assessment (quantitative and qualitative), quantitative risk assessment, response planning, risk handling, monitoring and controlling risks.

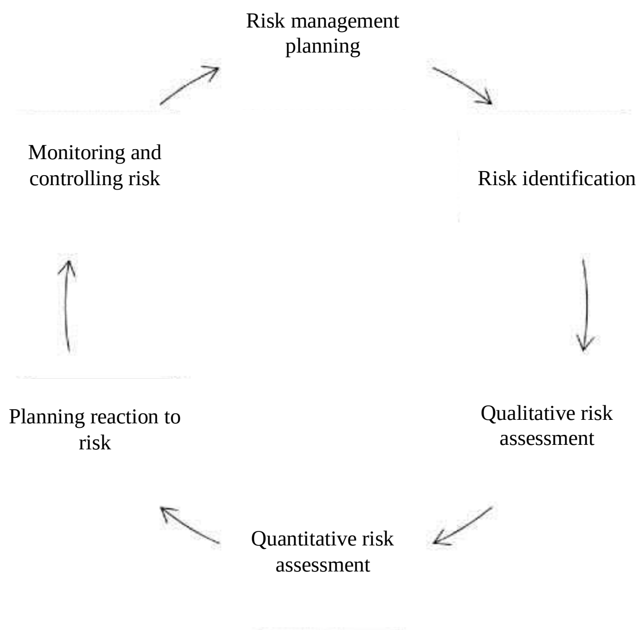

Figure 1. Stages of project risk management.

Source: own study based on PMBoK.

Similarly, the risk management process is presented in PN-ISO 31000 (PN-ISO 31000:2018, 2018) (Figure 2), which points to its basic elements, such as the risk ocean, which includes risk identification, risk analysis and evaluation, and risk handling.

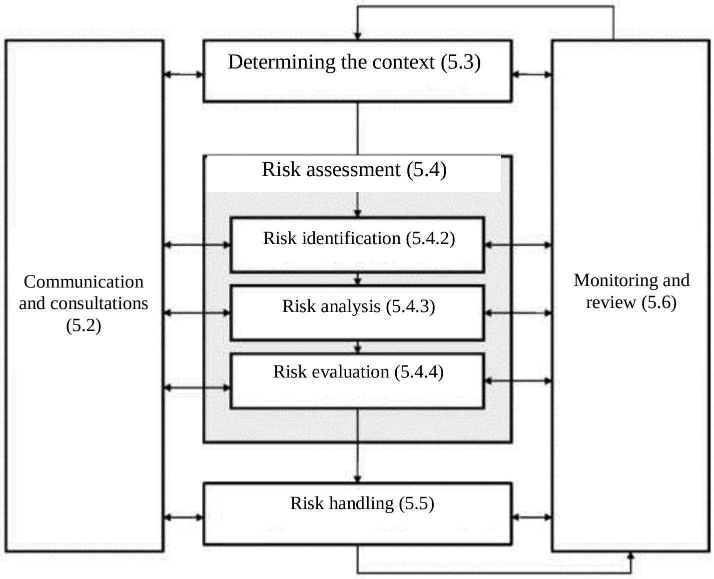

Figure 2. Steps in the risk management process.

Source: PN-ISO 31000.

Risk identification involves looking for sources of risk, so-called risk factors, i.e. areas of influence, events (including changes in circumstances) and their causes and potential consequences. The aim of this step is to create an exhaustive list of risks based on those events that can create, stimulate, prevent, hinder, accelerate or delay the achievement of objectives. The exhaustive identification of risks is important because risks not identified at this stage will not be included in future analyses (Pritchard, 2001, p. 24). Risk identification is, according to K. Czajkowska, a fundamental stage without which it is not possible to carry out the risk management process effectively (Czajkowska, 2017, p. 44). The crucial importance of this stage of risk management for the successful completion of a project is also emphasised by M. Trocki (Trocki, 2012, p. 299).

Risk analysis provides a more detailed understanding of risk. It provides input for evaluating risks and deciding how to deal with risks, together with the most appropriate strategies and methods for dealing with risks. Risk analysis includes consideration of the causes and sources of risk, their positive and negative consequences and the likelihood of those consequences occurring. So, risks are analysed by determining the consequences and their probability and other risk attributes. For this to be possible, it becomes necessary to define the criteria that will be used to assess the materiality of the risk. When defining risk criteria, factors such as, but not limited to, the types of causes and consequences (effects) that may occur and how they are measured, defining the probability of occurrence with a timeframe for the occurrence of the probability and/or consequence, how the level of risk is determined, the level of risk that is acceptable or tolerable and the views of stakeholders should be taken into account.

The purpose of risk evaluation, on the other hand, is to facilitate decisions, based on the results of the risk analysis, about which risks require the implementation of a course of action and what the priorities for implementing that course of action should be. The evaluation compares the established risk levels with the risk criteria values defined for the risk factors.

Based on this comparison, the need to proceed or not with the risk is considered. This decision will depend on the organisation's attitude towards risk and the risk criteria established. Dealing with risk refers to the selection of one or more options to affect risk and how these options are implemented. There are a number of options for dealing with risk. These may include avoiding the risk by deciding not to start or continue with the activity causing the risk, taking or increasing the risk to exploit the opportunity, removing the source of the risk, changing the probability and/or consequences (results), sharing the risk and retaining (retention) the risk based on a conscious decision (Karbownik, Wodarski, 2014; Bijańska, Wodarski, Aleksander, 2022, p. 15).

Of course, ISO 31000 also points to other elements of the risk management process, such as communication and consultation, monitoring and review, and context setting. This is to develop the so-called organisational infrastructure for risk management. It is worth noting here that also C.L. Pritchard points out that risk management planning should include the preparation of a risk management process, but also the development of an organisational infrastructure to support the project manager in activities concerning the mitigation of potential risks, the elimination of risks, the preparation of alternative actions or the definition of tolerances (temporal and monetary) to protect against its occurrence (Pritchard, 2001, p. 24).

2. Subject of study

The organisation under examination is a selected SME company based in Zabrze (Poland). The company specialises in medium- and large-scale production of metal products using the following methods: stamping of steel and aluminium strips and sheets, tube cutting and forming, and wire bending and forming. The main area of activity is the automotive sector (over 95% of volume), but also the white goods, gas and metallurgy industries. In June 2022, the company employed 60 people with an employment growth rate of 4 FTEs per quarter. The company has an implemented and maintained quality management system based on the requirements of the ISO 9001:2015 standard and the IATF 16949:2016 specification. Product design is excluded from the scope of certification of the referenced standards, as the company implements customer product designs based on the technical documentation provided. The implementation of new projects therefore consists of designing the production process based on the product design provided by the customer, including finding material suppliers and designing and manufacturing or purchasing the necessary tools.

Each year, the company carries out around twenty projects. Due to the small size of the organisation, the project teams consist entirely of employees who carry out non-project-related tasks on a daily basis. The main constraint on each of the projects undertaken is time. Most often, 24 to 30 weeks elapse between the start of work on a project and its completion.

Due to the specific nature of the industry, the quality of the product, i.e. meeting all the requirements that the customer has set out in the product technical documentation, also plays an extremely important role. These include dimensional requirements, material requirements, packaging or additional tests to confirm product properties.

The company operates in an environment of fierce competition, a rapidly changing materials market and stringent quality and logistical requirements set by customers. From this point of view, in the implemented projects, the development and implementation of a risk management model, including risk identification and assessment, becomes essential for their success. It was assumed that the risk management model for the project management process, in the selected company, would include the following elements:

a) Identification of risk factors in ongoing projects.
b) Risk analysis
c) Risk evaluation
d) Developing methods of responding to risks.

3. Development of risk management model

The development and implementation of a risk management model for the project management process in a selected company requires:

- identification of risk factors in ongoing projects,
- risk analysis and evaluation,
- developing methods for responding to risks.

3.1. Identification of risks

In order to identify potential risk factors, a two-stage brainstorming session was conducted with members of the project teams. In an ingenuity session, participants gave a maximum number of potential risk factors, which were later reviewed by a panel of experts. This resulted in a number of potential risk factors. These factors were categorised according to the quality management system processes involved in the implementation of new projects, i.e.: quoting and purchasing, process design (including tool design), logistics, quality control, common/general. This resulted in a list of thirty-three potential risk factors, categorised according to the processes of the quality management system. The list of factors is presented in Table 1.

Table 1.
List of risk factors identified in brainstorming

No.	Offering and procurement
1.1	Incorrect calculation - underestimation of bid.
1.2	Incorrectly selected manufacturing technology at the bidding stage.
1.3	Failure to recognise legal/regulatory requirements
1.4	Failure to recognise customer requirements
1.5	New, untested supplier - risk of discontinuity of supply/poor quality
1.6	Unstable supply due to the length of the supply chain.
1.7	Linguistic/cultural barrier in dealing with supplier
1.8	Linguistic/cultural barrier in customer relations
1.9	No material available for the project
	Process design (including tool design)
2.1	Poorly designed tool
2.2	Poorly designed process
2.3	Ineffective performance analysis
2.4	Inadequate machinery
2.5	Poor supervision of tools (lack of spare parts)
2.6	Lack of oversight of tool design change
2.7	Lack of human resources to produce the pre-series
	Logistics
3.1	Overloading the own fleet
3.2	Risk of late delivery of production material
3.3	Damage to the material during transport
3.4	Damage to products during transport
3.5	Unsuitable storage conditions
3.6	Excessive freight risk
3.7	Increase in transport costs
3.8	Packaging inadequate for transport conditions
	Quality control
4.1	Unaccounted for suitable method of measurement - increase in cost of measurement
4.2	Inadequate measuring method - insufficient measuring capacity
4.3	Failure to meet product quality requirements (incorrect dimensions)
4.4	Lack of availability of measurement equipment.
	Common/general risks
5.1	Loss of data confidentiality
5.2	Threat of cyber attack
5.3	Lack of financial liquidity
5.4	Insufficient experience of the project coordinator
5.5	Insufficient experience of the project team.

Source: own study.

Group expert assessment was used to determine the materiality of the identified risk factors. It belongs to the heuristic methods that are increasingly being used to analyse management processes. The essence of the group expert appraisal method is to determine the relative importance of the assessments given by the individual experts. Hence, the team of experts making the assessment should be competent and comprised of individuals with compatible views in the field under study. Experience can be an indicator for the selection of experts.

It appears that an expert's self-assessment of his or her relative competence is relatively well correlated with his or her actual knowledge of the field. For this reason, experience can be an objective indicator to assist in the selection of individual experts. Thus, as an indicator of the degree of competence of the expert obtained from the self-assessment, the competence coefficient - Kk calculated according to the formula can be adopted:

$$Kk = (kz + ka)/2 \tag{1}$$

where:

Kk - expert competence coefficient,

kz - coefficient of the expert's degree of familiarity with the problem,

ka - argumentation factor.

The coefficients kz and ka are obtained from the expert's self-assessment and take values in the range <0.1>; thus, the coefficient Kk also takes values in the range <0.1>. In order to determine the value of the coefficient for the expert's degree of familiarity with the problem in question kz, the experts were asked to self-assess their familiarity with the problem using a rating from a five-point scale (Table 2).

The number of points obtained by the expert is multiplied by 0.1 and this number is taken as the value of the coefficient for the expert's degree of familiarity with the problem kz. The argumentation coefficient ka, in turn, takes into account the structure and sources of arguments used by the expert in expressing his or her opinion. In order to determine the value of the argumentation coefficient, the experts determined their familiarity with the problem, taking into account the source of the arguments that formed the basis of their ratings (Table 3).

Table 2.

Assessment of the expert's familiarity with the problem in question

No.	Evaluation by the expert	points
1	Expert does not know the problem	0
2	Expert knows little about the problem	1, 2, 3
3	Expert knows the problem, theoretically but is not involved in solving it	4, 5, 6
4	Expert knows the problem, and participates in solving it	7, 8 ,9
5	Expert knows the problem, very well - it belongs to the expert's specialisation	10

Source: Own study based on: Męczyńska, A. (2007). Grupowa ocena ekspertów w procesach decyzyjnych zarządzania. Zeszyty naukowe. Organizacja i Zarządzanie, z. 40. Silesian University of Technology.

Table 3.

Assessment of knowledge of the issue in question, taking into account the source of the arguments

Source of argumentation	Argumentation		
	high	average	low
Expert's theoretical analysis	0.3	0.2	0.1
Practical experience of the expert	0.5	0.4	0.3
Generalisation of the work of indigenous authors	0.05	0.035	0.02
Generalisation of the work of foreign authors	0.05	0.035	0.02
Expert intuition	0.1	0.08	0.06

Source: Own study based on: Męczyńska, A. (2007). Grupowa ocena ekspertów w procesach decyzyjnych zarządzania. Zeszyty naukowe. Organizacja i Zarządzanie, z. 40. Silesian University of Technology.

The coefficients for the expert's degree of familiarity with risk in projects (kz), argumentation (ka) and competence (Kk) were determined on the basis of the experts' self-assessment. The results are presented in Table 4.

Table 4.
Summary of coefficients for the expert's degree of familiarity with the problem, argumentation and competence

Expert	kz	ka	Kk
E1	0.7	0.85	0.775
E2	1	0.75	0.875
E3	0.7	0.45	0.575
E4	0.7	0.7	0.7
E5	1	0.85	0.925
E6	0.1	0.25	0.175
E7	0.3	0.6	0.45
E8	0.5	0.6	0.55
E9	0.5	0.45	0.475

Source: own study.

Experts for whom the competence coefficient (Kk) reached a value greater than or equal to the threshold value s = 0.5 were qualified for the next part of the study. This group consisted of 6 people (experts E6, E7 and E9 were not qualified).

The identified experts were asked to rate the potential risk factors. The study was conducted using a questionnaire in an MS Excel spreadsheet, in which the experts were asked to rate the importance of the potential factors on a scale from 0 to 100 points. The results of the assessment are shown in Table 5.

Table 5.
Summary of expert assessments for risk factors

No.	Risk factors	El	E2	E3	E4	E5	E8
1.1	Incorrect calculation - underestimation of the offer.	75	70	60	65	60	55
1.2	Incorrectly selected manufacturing technology at the bidding stage.	55	50	40	45	45	40
1.3	Failure to recognize legal/regulatory requirements.	85	75	55	60	65	50
1.4	Misunderstanding of customer requirements	80	85	65	70	75	70
1.5	New, untested supplier - risk of not maintaining continuity of supply/insufficient quality.	85	85	80	80	90	75
1.6	Unstable supply due to length of supply chain.	80	70	90	75	70	75
1.7	Language/cultural barrier in dealing with supplier	30	20	40	45	50	35
1.8	Language/culture barrier in dealing with client	30	25	25	25	20	30
1.9	Lack of material availability for the project	80	65	45	55	30	45
2.1	Poorly designed tool	55	50	65	50	55	50
2.2	Poorly designed process	45	40	55	50	55	65
2.3	Ineffective performance analysis	50	40	50	50	45	50
2.4	Inadequate machinery	75	80	70	55	60	50
2.5	Poor supervision of tooling (lack of spare parts)	60	60	50	55	60	65
2.6	Lack of supervision of tool design change	90	70	40	35	45	50
2.7	Lack of human resources to produce pre-series	65	60	40	45	30	45
3.1	Excessive workload on own fleet	30	25	20	15	30	40
3.2	Risk of late delivery of material for production	55	55	70	65	60	65
3.3	Damage to material during transport	30	30	35	40	35	30

Cont. table 5.

3.4	Damage to products during transport	60	55	60	65	60	60
3.5	Inadequate storage conditions	60	65	65	55	60	60
3.6	Excessive freight risk	20	20	35	40	20	35
3.7	Increase in transport costs	20	30	45	35	40	20
3.8	Packaging inadequate for transport conditions	50	45	20	40	30	35
4.1	Inadequate measurement method - increase in measurement cost	60	65	45	60	55	65
4.2	Inadequate measurement method - insufficient measurement capacity	50	55	45	75	70	45
4.3	Failure to meet product quality requirements (incorrect dimensions)	85	85	50	60	75	75
4.4	Non-availability of measuring equipment.	70	75	60	70	40	70
5.1	Loss of data confidentiality	40	40	40	45	40	45
5.2	Threat of cyber attack	55	50	50	50	55	45
5.3	Lack of liquidity	60	65	65	60	65	55
5.4	Insufficient experience of project coordinator	20	20	35	40	20	25
5.5	Insufficient experience of the project team.	40	20	45	50	35	35

Source: own study.

Kendall's concordance coefficient ω (Cieslak, 2001, p. 21) was used to characterise the degree of agreement between experts' opinions.

In the next stage of the research, the relative importance of objects method was used to identify the risk factors to be taken into account in the projects implemented by the organisation. The relative importance of objects method uses designations as follows:

M - number of experts participating in the group evaluation,

N - number of sites assessed,

m_j - number of experts evaluating the site,

m* - number of experts evaluating at least one site,

m_{maxj} - the number of experts who gave the maximum number of points when evaluating the *j*-th object,

c_{ji} - score awarded to the *j*-th site by the *i*-th expert,

n* - number of objects assessed by at least one expert.

In the method of relative importance of objects, the experts first assessed the potential risk factors and then the generalised opinion of the experts and the degree of agreement of their opinions were determined. The basic indicator of the generalised opinion of the experts is the mean evaluation value M_j determined for each *j*-th object, calculated according to the formula:

$$M_j = \frac{\sum_{i=1}^{mi} c_{ji}}{m_j} \tag{2}$$

The greater the value of Mj, the greater the importance of the factor in question. A complementary indicator of generalised expert opinion and the relative importance of objects is the frequency of awarding the highest possible rating that an object can receive K_{max} calculated according to the formula:

$$\mathrm{K_{maxj}} = \frac{\mathrm{m_{maxj}}}{\mathrm{m_j}} \tag{3}$$

where j = 1, ..., n.

Of great importance for the opinion on the significance of an object (factor) is the sum of the ranks received by this object S_j . When determining the sum of the ranks, only those objects that have been assessed by a minimum of one expert and only those experts who have assessed a minimum of one object are taken into account. The determination of the sum of the ranks is carried out in the following steps:

1. A completed matrix $[c'_{ji}]$ is created. If the *i*-th expert is considered insufficiently competent then c'_{ji} is assumed to be the mean value of the evaluation of the factor in question. Otherwise $c'_{ji} = c_{ji}$.
2. For each expert, the sequence of their evaluations is ordered in descending order, resulting in a sequence c''_{ji0}, where: j = 1, 2, ..., n.
3. Each grade in the above sequence is assigned a rank of $r'(c''_{ji0})$ according to the rule:

- if the string is strongly decreasing then $r'(c''_{ji0}) = j$,
- if there are words in the sequence that are the same, they are given the same rank equal to the arithmetic mean of the ranks they would have if they were different.

4. The rank of object *j*, with the evaluation i_0-th expert, is equal to the rank of the evaluation that this object has received and of expert i_0.
5. The sum of the ranks awarded by the group of m experts to the *j*-th object is calculated according to the formula:

$$S_j = \sum_{i=1}^{m} r_{ji} \tag{4}$$

The following risk factors had the highest average score (above 60 points):

1.5 New, unproven supplier - risk of failure to maintain continuity of supply/inadequate quality (82.50 points).
1.6 Unstable supply due to length of supply chain (76.67 points).
1.4 Failure to recognise customer requirements (74.17 points).
4.3 Failure to meet product quality requirements (due to incorrect dimensions) (71.67 points).
4.4 Failure to recognise legal/regulatory requirements (65.00 points).
4.5 Inadequate machinery (65.00 points).
1.1 Incorrect calculation - underestimation of bid (64.17 points).
4.4 Lack of availability of measurement equipment (64.17 points).
3.2 Risk of untimely delivery of production material (61.67 points).
3.3 Lack of liquidity (61.67 points).
3.5 Inadequate storage conditions (60.83 points).
3.4 Damage to products during transport (60.00 points).

For all risk factors, the kmax index was 0. This means that in no case did the experts give the highest rating. To characterise the concordance of the experts' opinions, the Kendall concordance coefficient was calculated, the value of which was ω = 0.72 and, with the scale proposed by A. Stabaryła, is assessed as good (Stabryła, 2005, p. 106).

The average values of the scores assigned to the individual risk factors Mj are shown in Figure 2.

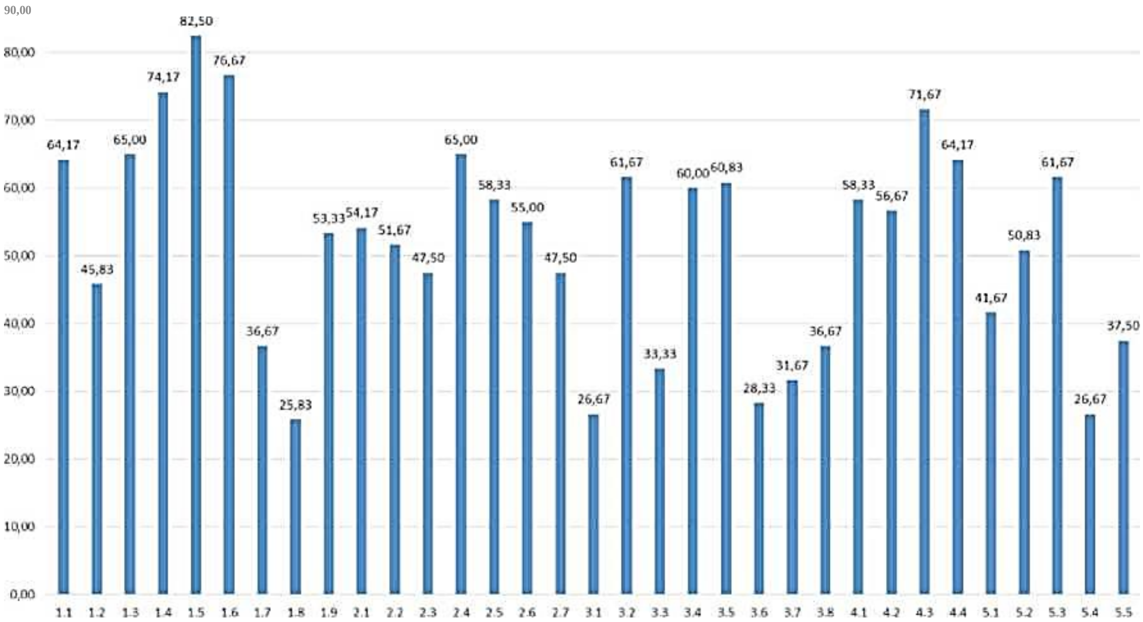

Figure 2. Average Mj scores for potential risk factors.

Source: own study.

It should be noted that the identified risk factors revolve around three main thematic areas. The first is suppliers and supply logistics in the broadest sense, including but not limited to supply chain disruptions or transport risks. The second area is made up of risk factors that can be called technical related to production and support infrastructure. The last group contains elements that are related to the business as such and concern, for example, incorrect calculation, failure to recognise or misrecognise various types of requirements or lack of financial liquidity.

It was assumed that all of the aforementioned risk factors (with an average score of more than 60 points) are critical and must always be assessed in the risk assessment model for projects in the company under review.

3.2. Risk analysis and evaluation in projects

The projects carried out by the company under study follow an established project management model. This has allowed risk analysis to be incorporated into the relevant stages - at project initiation (when the project information sheet is created) and during the stages called 'project progress review', carried out after each project milestone. A minimum of three reviews must occur during the life of each project, so that a minimum of four risk analyses will be carried out throughout the project.

The risk assessment matrix (Wroblewski, 2015), adopting a three-stage scale for assessing the probability and a three-stage scale for the effects of events considered as risk factors, was used for the risk assessment. This is a graphical method of assessing the level of risk using a two-dimensional matrix in which one variable is the probability of a hazard occurring and the other is the effects of that hazard. The assessment of the probability and consequences of events can be carried out on different scales. In the present case, a scale of 1 to 3 was adopted for both the probability of events and their consequences of occurrence. A value of 1 means low probability and low impact, a value of 2 means medium probability and medium impact and a value of 3 means high probability and high impact.

Risk probability levels have been adopted for specific events that are specific to individual risk factors (Table 6).

Table 6.
Description of the likelihood of risk factors

No.	Risk factor	P	Description
1.6	Unstable supply due to the length of the supply chain.	small	Domestic supplier
		medium	EU supply
		large	Supplier from, outside the EU
1.5	New, untested supplier (risk of discontinuity of supply/poor quality)	small	Supplier audited with no major discrepancies
		medium	No audit has been carried out but the supplier is certified to a minimum of ISO 9001:2015
		large	Audit not carried out, supplier not certified
1.4	Failure to recognise customer requirements	small	Known customer (previously identified requirements)
		medium	New customer, quality contract signed
		large	New customer, no quality requirements presented
4.3	Failure to meet product quality requirements (incorrect dimensions)	small	Low-complexity product
		medium	Medium to high complexity product similar to those already produced
		large	Medium to high complexity product different from those previously produced
1.3	Failure to recognise legal/regulatory requirements	small	Known country of destination of the product, previously identified requirements
		medium	Known country of destination of the product, previously unrecognised requirements
		large	Country of destination unknown
2.4	Inadequate machinery	small	A product similar to those previously produced
		medium	Product different from, those previously produced with indication of manufacturing technology
		large	Product from, a different (from, existing) product group
1.1	Incorrect calculation - underestimation of the offer	small	Low-complexity product offered
		medium	Offered product of medium to high complexity similar to those previously produced
		large	The product on offer is of medium to high complexity different from what has been produced so far
4.4	Lack of availability of measurement equipment	small	Requires the use of manual means of measurement
		medium	Requires the use of a measuring machine
		large	Requires the use of means of measurement that are not in the measuring laboratory's equipment
3.2	Risk of late delivery of production material	small	Local supplier, standard material
		medium	Local supplier, dedicated material
		large	Foreign supplier

Cont. table 6.

5.3	Lack of financial liquidity	small	Determined batch sizes, date of commencement of batch production and conditions for release of tool payments
		medium	Known production start date, unknown series sizes
		large	Tentative date for start of series production, unknown volume
3.5	Unsuitable storage conditions	small	Material/product insensitive to conditions storage
		medium	Material/product that can be provided appropriate storage conditions
		large	Material/product particularly sensitive to storage conditions such as temperature, humidity, soiling
3.4	Damage to products during transport	small	Product not prone to deformation
		medium	Product susceptible to deformation, similar to previously produced (proven method packaging)
		large	Product susceptible to deformation, different than previously produced product (no proven packaging method)

Source: own study.

Risk results levels have been adopted for specific events that are specific to individual risk factors (Table 7).

Table 7.
Description of the effects of the risk factors

No.	Risk factor	S	Description
1.6	Unstable supply due to the length of the supply chain	small	There may be slight delays in delivery without affecting the timing of activities.
		medium	There will certainly be slight delays in delivery. Required changes in deadlines implementation of activities and monitoring of supply status
		large	Long delays in delivery may occur. Required monitoring of supply status and maintenance of safety stock
1.5	New, untested supplier (risk of discontinuity of supply/poor quality)	small	Delay/insufficient quality will not affect the project deadline. Minor adjustments to the timing of individual project activities will be required.
		medium	Delay/inadequate quality may affect the project deadline. Significant adjustments to the timelines of individual project activities will be needed to keep the project on track.
		large	Delay/insufficient quality will certainly affect the timing of the project.
1.4	Failure to recognise customer requirements	small	Unrecognised requirements do not affect the product
		medium	Unrecognised requirements affect the product. Changes in the manufacturing process are necessary
		large	Unrecognised requirements preclude use of the product by the customer

Cont. table 7.

4.3	Failure to meet product quality requirements (incorrect dimensions)	small	Failure to meet the requirements does not affect the functionality of the product
		medium	Failure to meet the requirements slightly affects the functionality of the product. Possible deviation from, customer
		large	Failure to meet the requirements affects the functionality of the product, preventing its use by the customer
1.3	Failure to recognise legal/regulatory requirements	small	Unrecognised requirements do not affect the use of the product
		medium	Unrecognised requirements affect product use. Adaptive changes are necessary
		large	Unrecognised requirements affect product use. Adaptive changes are necessary
2.4	Inadequate machinery	small	Slight decreases in productivity/quality or increased operating expenditure with no major impact on project profitability
		medium	Declines in productivity/quality reducing project profitability
		large	Declines in productivity/quality reducing project profitability
1.1	Incorrect calculation - underestimation of the offer	small	Little impact on project viability
		medium	Project on the brink of viability
		large	Unprofitable project
4.4	Lack of availability of measurement equipment	small	The need to purchase measurement means
		medium	Increase in quality control costs
		large	Necessary measurements in an external laboratory. Significant increase in quality control costs
3.2	Risk of late delivery of production material	small	Slight delay without impact on the delivery date of the product to the customer
		medium	Delay that will affect the delivery date. Acceptable by the customer
		large	Delay not acceptable to the customer
5.3	Lack of financial liquidity	small	Slight increase in budget at the expense of other activities
		medium	Temporary stoppage of work on the project without affecting the completion date
		large	Stopping activities in the project. Delaying the implementation date
3.5	Unsuitable storage conditions	small	Slight deterioration in visual aspects
		medium	Deterioration of visual aspects without affecting functionality, additional operations required
		large	Property deterioration affecting functionality
3.4	Damage to products during transport	small	Damage to packaging without damaging the products
		medium	Minor damage to products. Customer dissatisfaction, need to replace/repair parts of products
		large	Damage to the bulk of the delivery so that it cannot be used

Source: own study.

Once the values of the probability and effect scales for a given risk factor have been estimated, a determination of the level of risk (on a three-stage scale, as low, medium and high) is made. Risk in this method is calculated as the product of the probability of a risk factor and its effect:

$$R = P * S \quad (5)$$

where:

P – value on the probability scale,

S – result scale value.

With the assumed size of the risk assessment matrix (3x3), presented in Fig. 3, it can take values from 1 to 9. Three levels of risk are possible as a result of the analysis:

- **small** (marked in green on the risk map - Figure 3), for which the product of results and probability takes the values 1 and 2, indicates an acceptable risk to be monitored for the risk factor being assessed,
- **medium** (highlighted in yellow on the risk map), for which the risk indicator value is between 3 and 4, represents an acceptable risk, which, however, is highly likely to affect the achievement of the full project objectives and for which countermeasures should be introduced to reduce its level,
- **high** (highlighted in red on the risk map), for which the product of results and probability takes values of 6 and 9, represents an unacceptable risk that poses a very serious threat to the achievement of the project objectives and for which decisive countermeasures must be taken to reduce the level to medium or low.

It should be noted that categorising risk factors into different levels of risk involves evaluating them, which means enforcing the necessary response (countermeasures) on the part of the risk manager.

			Probability		
			Small	**Medium**	**Large**
			1	**2**	**3**
Result	**Large**	**3**	3	6	9
	Medium	**2**	2	4	6
	Small	**1**	1	2	3

Figure 3. Risk assessment matrix.

Source: own study.

3.3. Risk response

Appropriate risk response actions were developed for all risk factors at all risk levels. The developed actions were proposed based on expert knowledge and experience from previous projects. They are presented in Table 8.

Table 8.
Description of risk response

No.	Risk factor	R	Description
1.6	Unstable supply due to the length of the supply chain.	small	Confirmation of delivery date in agreed moments in the course of the project
		medium	Ongoing, frequent monitoring of supply status
		large	Ongoing, frequent monitoring of supply status, maintenance of safety stock
1.5	New, untested supplier (risk of discontinuity of supply/poor quality)	small	Ongoing monitoring of supply status
		medium	Ongoing monitoring of supply status. Ordering part of the material from an alternative supplier
		large	Due to the high cost of material in the price of the product, consideration should be given to choosing another supplier
1.4	Failure to recognise customer requirements	small	Completion of knowledge of customer requirements
		medium	Unrecognised requirements affect the product
		large	Unrecognised requirements preclude use of the product by the customer. Scrapping of products
4.3	Failure to meet product quality requirements (incorrect dimensions)	small	Process improvement to achieve 100% compliance or customer acceptance of current status
		medium	Process improvement to achieve 100% compliance
		large	Product scrapping
1.3	Failure to recognise legal/regulatory requirements	small	Action not required
		medium	Identification of requirements, adaptation of the process/product
		large	Identification of requirements, adjustment of process/scrapping of non-compliant product
2.4	Inadequate machinery	small	Refining the production process
		medium	Refinement of the production process, changes to the tool design
		large	Considering the purchase of another/more efficient machine
1.1	Incorrect calculation - underestimation of the offer	small	No additional action
		medium	Conduct a process performance analysis. Develop a plan to improve profitability
		large	Enter into negotiations with the customer
4.4	Lack of availability of measurement equipment	small	Purchase of additional measurement equipment
		medium	Carrying out measurements on measuring machines, involvement of measuring laboratory
		large	Obtaining tenders and carrying out measurements in an external laboratory

Cont. table 8.

3.2	Risk of late delivery of production material	small	Confirmation of delivery date in agreed moments in the course of the project
		medium	Ongoing, frequent monitoring of supply status
		large	Ongoing, frequent monitoring of supply status, maintenance of security stocks
5.3	Lack of financial liquidity	small	Revision of the project budget
		medium	Obtaining funds from the budgets of other projects or operational activities
		large	Obtaining an additional source of funding for the project
3.5	Unsuitable storage conditions	small	Carry out root cause analysis, improve storage conditions.
		medium	Repairing products, conducting root cause analysis, improving storage conditions.
		large	Scrap products, conduct root cause analysis, improve storage conditions
3.4	Damage to products during transport	small	Root cause analysis
		medium	Repair of products; root cause analysis of damage, improvement of packaging
		large	Delivery scrapping, root cause analysis, change in packaging method

Source: own study.

4 Summary

The paper addresses the issue of risk management in projects implemented in a selected automotive company. The risk management process is presented as consecutive stages of risk identification, risk analysis and evaluation, and selection of adequate and effective methods of risk response.

The identification of potential risk factors for the company under study was done using brainstorming. This was followed by a selection of key project risks based on a group expert assessment method. Employees who are involved in project implementation on a daily basis took part in the research. The research resulted in a group of twelve key risk factors. In their analysis, the experts identified essentially four groups of key risks: technical, logistical, supplier-related and business wide.

The consideration of the determinants of the risk factors that went into the risk management model for projects also leads to the conclusion that the identification of factors should be carried out on a cyclical basis. Once the situation in our neighbours has normalised and the supply chain has been rebuilt, the experts will certainly identify other risks as key, perhaps risks that were not included in this research.

Based on the key risk factors, a model for the analysis and evaluation of risks in projects was developed. A qualitative method of risk analysis and evaluation based on a risk assessment matrix was used here. Three levels of risk were distinguished in the model due to the assumed scales of probability and effect of risk factors. The advantage of this method is the graphical depiction of the risk level with a clear division into low risk (green), medium risk (yellow) and high risk (red). This allows a quick presentation of the magnitude of the risk and the colours analogous to traffic lights make it easy to understand the result at a glance. It also allows appropriate and effective ways of responding to risks.

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