

## PROJECT RISK ASSESSMENT REGARDING INDUSTRIAL ROBOTS IMPLEMENTATION IN PRODUCTION SYSTEMS

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*Dezvoltarea unor strategii efective și eficiente pentru aprecierea riscurilor la nivelul unui proiect de implementare necesită o analiză de identificare și evaluare a riscurilor, utilizarea unor tehnici de decizie care încorporează efectiv considerații despre evenimente nedorite, probabilitățile și consecințele producerii evenimentelor și evaluarea punctelor slabe. Lucrarea analizează modul în care riscurile de coliziune identificate la nivelul de funcționare al unui sistem robotizat de sudare afectează obiectivele generale ale proiectului, prin utilizarea metodei de sensibilitate. Rezultatele obținute conduc la adoptarea unei decizii optime pentru atingerea obiectivelor generale și principale ale proiectului.*

*Developing strategies for effective and efficient risk assessment throughout a project implementation requires risk identification and analysis, use of techniques that incorporate effective decision considerations about adverse events, likelihood and consequences of undesirable events and assessment of weaknesses. The paper deals with how the collision risks identified in operation of a welding robotic system affects the overall objectives of the project using sensitivity method.*

*The results lead to adopting an optimum decision for achieving project general and specific objectives.*

**Key words:** risk assessment, simulation, industrial robots.

### 1. Introduction

The market mobility and demands in products quality and quantity impose a growth in production adaptation capacity, fast manufacturing process, diversification of technologies and materials. Partial or total fulfillment of these requirements leads producers to improve their economic index and also to become more competitive [1].

The use of robots in the production process facilitates worker physical activity and automates production for a significant increase in economic efficiency but radically changing the processes design structure.

Industry is the main factor in leading to economic development of each country. Neglecting or ignoring the role of industry in economy has disastrous consequences, with a major impact on environment, social, economic and political structures. That is why a strong and objective project management is needed to

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maintain a competitive industry at the national and international level, leading to the successful achievement of all objectives.

A project consists of general objectives and specific objectives. The general objectives aims at lowering costs, minimizing the duration and improving the processes technical results [2], while the specific objectives relate to the operation benefits of industrial robots implementation.

When using ordinary production equipment, conventionally accumulated errors during the design and production stage were usually corrected after the system purchase and installation. This approach can not be used for robotic systems as it presents a high level of technical complexity.

The objectives pursued by robotic technology is to produce goods of an adequate quality, neither too high nor very low, as cheap as possible and completed on time [3].

The robots implementation in a production system must be analyzed at a project level in which the specific risks will be examined.

Project risk can be defined simply as the possibility of a future event with unexpected consequences, likely negative (undesirable). Risk is a concept containing events, forces and circumstances that represent a danger to people or the things that they manage. Insecurity, related to general and specific objectives, is determined by the lack of knowledge or the events that will be happening in the future.

The decision in taking actions is extremely subjective, the explanation consisting in the personal judgment and risk appetite of each person that must be taken into consideration for a certain process [4]. On the other side, reactivity is caused by external constrains and decisions are made in emergency conditions, having a vision on a very short time. Decisions are often of survival more than of development or perenniarity [5].

Project analysis uses simulation, which follows the way in which risks affect project objectives. In order to be able to use simulation, the project should be shaped as to include all the necessary data to carry out an analysis. However, a project does not consist in reproducing faithfully the model, but uses extrapolated information accumulated in previous activities. Usually it presents a high complexity which involves the use of knowledge and different methods requiring the coordination of various activities, some of them being contradictory [6].

Simulation carries out only a projection of the project in time, in a virtual environment, considering the interdependencies chosen before, without optimizing the project. That is why it is essential that the virtual model correspond as much as possible with its real version.

Risk assessment is carried out in three stages (fig. 1) [7]:

- risk identification: determines which risks might affect the project and registers their characteristics; it is an iterative process because new risks may become known as the project progresses through its life cycle;
- qualitative risk analysis: assesses the priority of identified risks using their probability of occurrence and the corresponding impact on project objectives, if the risks do occur;
- quantitative risk analysis: is performed on risks that have been prioritized by the qualitative risk analysis process as potentially and substantially impacting the project competing demands; it analyzes the effect of those risk events and assigns a numerical rating to those risks.

1. Risk identification	2. Qualitative risk analysis	3. Quantitative risk analysis
<p>1 Inputs</p> <ol style="list-style-type: none"> <li>1 Enterprise environmental factors</li> <li>2 Organizational process assets</li> <li>3 Project scope statement</li> <li>4 Risk management plan</li> <li>5 Project management plan</li> </ol> <p>2 Tools and Techniques</p> <ol style="list-style-type: none"> <li>1 Documentation reviews</li> <li>2 Information gathering techniques</li> <li>3 Checklist analysis</li> <li>4 Assumptions analysis</li> <li>5 Diagramming techniques</li> </ol> <p>3 Outputs</p> <ol style="list-style-type: none"> <li>1 Risk register</li> </ol>	<p>1 Inputs</p> <ol style="list-style-type: none"> <li>1 Organizational process assets</li> <li>2 Project scope statement</li> <li>3 Risk management plan</li> <li>4 Risk register</li> </ol> <p>2 Tools and Techniques</p> <ol style="list-style-type: none"> <li>1 Risk probability and impact assessment</li> <li>2 Probability and impact matrix</li> <li>3 Risk data quality assessment</li> <li>4 Risk categorization</li> <li>5 Risk urgency assessment</li> </ol> <p>3 Outputs</p> <ol style="list-style-type: none"> <li>1 Risk register (updates)</li> </ol>	<p>1 Inputs</p> <ol style="list-style-type: none"> <li>1 Organizational process assets</li> <li>2 Project scope statement</li> <li>3 Risk management plan</li> <li>4 Risk register</li> <li>5 Project management plan</li> </ol> <p>2 Tools and Techniques</p> <ol style="list-style-type: none"> <li>1 Data gathering and representation techniques</li> <li>2 Quantitative risk analysis and modeling techniques</li> </ol> <p>3 Outputs</p> <ol style="list-style-type: none"> <li>1 Risk register (updates)</li> </ol>

Fig. 1: Risk assessment process

Simulations are usually performed with the Monte Carlo method which is capable of analyzing multidimensional situations, better said, the outcome depends on many variables or risk factors.

In project, risks are introduced to the process variables using probability distributions. The advantages of simulation refer to the ability of a large number of concurrent analyses and efficiency in decision making.

A series of software applications, have been developed offering the possibility of risk modelling situations through probability distributions, such as

Palisade @ Risk for Microsoft Project, Risky Project, Pert Master etc. The software complexity consists in the number of probability distributions that are used to introduce uncertainty and diversity of the modelling methods that allow consideration of real events.

The paper deals with the development of effective and efficient strategies for assessing project risk by identifying risk and use of methods and techniques to effectively incorporate considerations about uncertain events.

## **2. Risks regarding specific objectives**

For a project that aims to use industrial robots in production systems, there is a matter of system functionality analysis in order to identify any errors.

For this matter, it is necessary to use simulation software to analyze the way in which industrial robots perform a process.

Thus, we examined a process for welding an exhaust gas part in order to detect errors of collision (fig. 2). For this purpose, the industrial robots programming and off-line simulation software of ABB company, RobotStudio was used [8]. The part is fixed in position (using fixture devices) by means of fastening devices.

In order to identify collisions, two groups were defined, containing the robotic workcell components (fig. 3). In the first group, the welding gun was considered and in the second group, the part and the fixture devices.

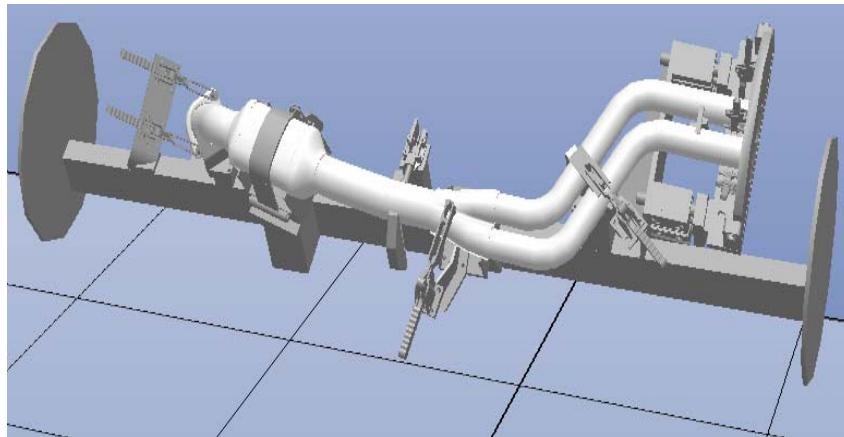


Fig. 2. Exhaust gas part and fixture devices.

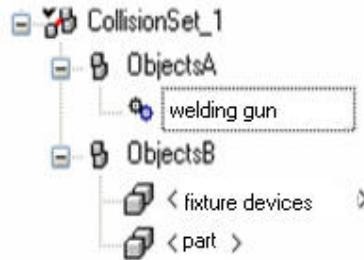


Fig. 3. Collision set.

After the simulation, the following errors were identified:

- collision between the gun and part (fig. 4): in order to make a circular belt welding, the gun must be positioned between the two components of the part. Due to very low angle value, the gun comes into collision with the first component, when it is positioned to continue the weld on the second component. Such collisions are common in welding processes, especially when the welding belt is made at an angle less than 90°.

The consequences are serious consisting in deterioration of the part or the welding gun and the subsequent positioning errors.

- collision between the gun and the fixture devices that holds the part in position (fig. 5): the clamping elements are arranged on the part in order to create a high stiffness at the time of the welding process and their location is usually near the welding belt. Thus, the robot trajectory must be precisely calculated by introducing a safe distance between the welding gun and the clamping elements. Verification of the restriction imposed is served using "near misses" function which allows the introduction of a safety value and warn the user when this value is reached.

The robot or the welding gun collisions with the clamping elements or with other system components are caused by the completion of the necessary trajectory for the welding process.

Risks identification conducted in the simulation environment result in making a safe process, without adverse consequences on the system. The models fidelity of the virtual environment influences decisively the results by analyzing each area that shows the positioning errors or the trajectory errors.

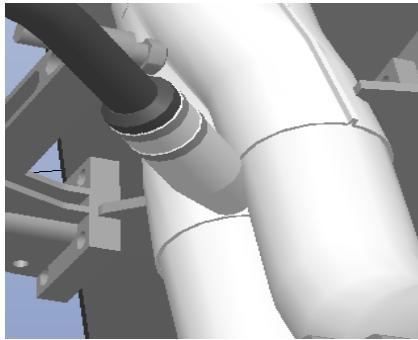


Fig. 4. Positioning error.

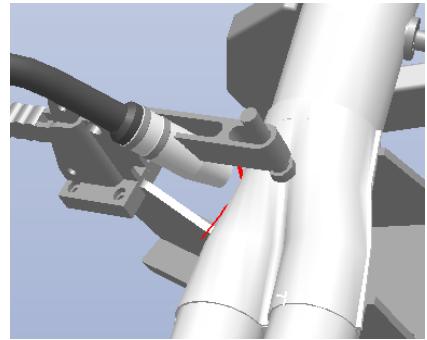


Fig. 5. Trajectory error.

The identified collisions are consequences of positioning the welding gun on the part and the robot trajectory.

The technical risks that arise from operating a robotic system influence directly the project management, reaching the general objectives. The time associated with system optimization or errors elimination, contribute to an extension of the project duration and cost. Therefore it is required to use specific methods for identifying and analyzing risks at the main objectives level, in order to provide information from which strategies can be adopted to continue the project.

Since the duration to obtain a final product is a matter of probabilistic interpretation, it is necessary to define a variation range in which the duration will take certain values.

A range within a minimum of 6 days and a maximum of 18 days was considered for obtaining an error free process:

- 6 days for the shortest period, which excludes modification of the robot trajectory or elimination of the singularities, to avoid collision with the part fixing devices etc.;
- 12 days for the longest period which can include reposition of the robotic workcell components, redesign of the part in the virtual environment for repositioning and rearranging the fixing elements etc.

After reviewing the process, a value of 12 days duration was considered as a medium value, to exclude the risk of collision resulted from welding the piece.

### 3. Risks regarding general objectives

In order to analyze the project, a mathematical model was created in @Risk for Project module (trial mode). The mathematical model consists in assigning probability distributions to project processes duration variables that are considered uncertain.

@ Risk for Project uses the sensitivity method to determine the factors that have a major influence on an expected result.

The duration variable is introduced in the form of a triangle probability distribution:  $Duration=RiskTRIANG(6, 12, 18)$  where the value of 12 days is the distribution average duration.

The results obtained after simulation are displayed as a tornado diagram, which shows the share of each process to project total medium duration. In figure 6, the ratio value of the robotic system simulation duration is the highest. For this matter, it is necessary to analyze how changes of the simulation process duration affect the sensitivity and project total duration.

A descending safe range [-50%, 0] and an increasing safe range, [0, 50%], in which the medium process duration may take values were considered.

In the [-50%, 0] range (fig. 7), the following medium total duration values and sensitivity values were obtained (tab. 1).

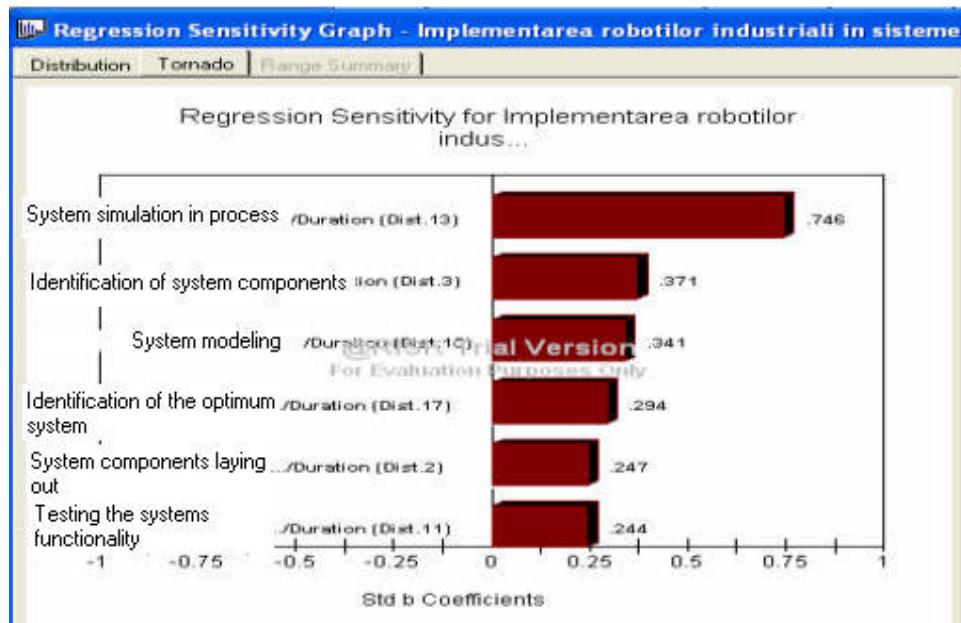


Fig. 6. Sensitivity analysis for project duration.

Table 1

Sensitivity and medium total values

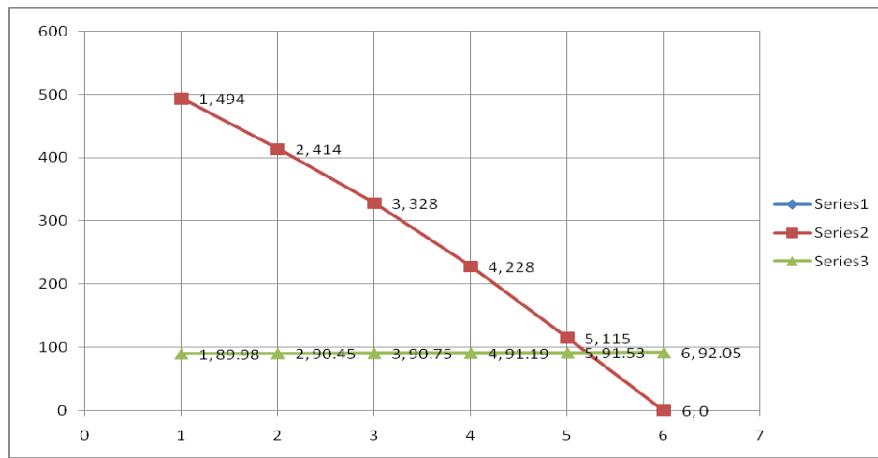
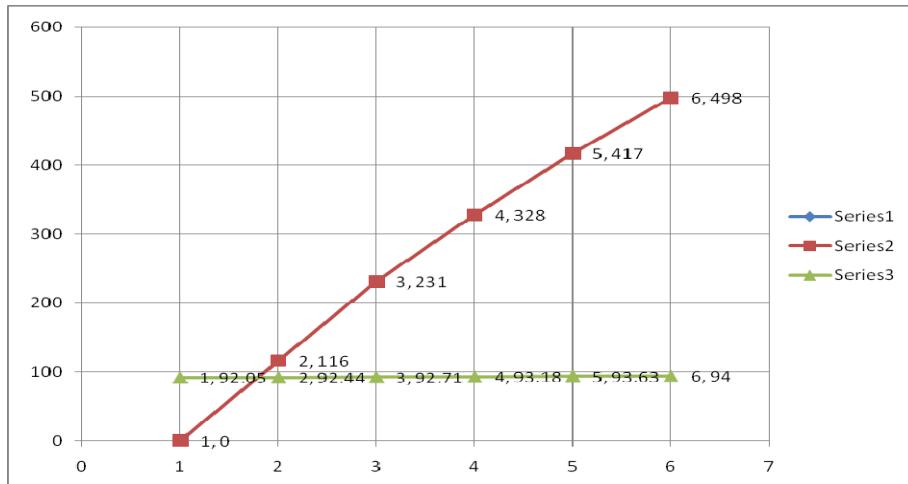
Safe range	[-50%,0]	[-40%,0]	[-30%,0]	[-20%,0]	[-10%,0]	[0,0]
Sensitivity value	494	414	328	228	115	0
Medium total value	89.98	90.45	90.75	91.19	91.53	92.05

In the  $[0, 50\%]$  range (fig. 8), the following medium total duration values and sensitivity values were obtained (tab. 2).

Table 2

**Sensitivity and medium total values**

Safe range	[0,0]	[10%,0]	[20%,0]	[30%,0]	[40%,0]	[50%,0]
Sensitivity value	0	116	231	328	417	498
Medium total value	92.05	92.44	92.71	93.18	93.63	94

Fig. 7. Sensitivity and medium total values variation  $[-50\%, 0]$  range.Fig. 8. Sensitivity and medium total values variation on  $[0, 50\%]$  range.

#### 4. Interpretation of results

1. Sensitivity values do not depend on the increasing or decreasing variation of the medium duration variable but on the variation range. Thus, the sensitivity value is directly influenced by the degree of project risk introduced by the probability distributions.

2. The duration value depends on the variation value. If the variation is negative, meaning the probability reflects a reduction of the medium value, the duration will decrease; as the negative variation increases, the duration decreases. Conversely, if the probability is to increase the medium value, the duration will increase.

3. Sensitivity reaches zero value, when the duration medium value is exactly 12 days, which excludes the occurrence of a risk expressed by a probability distribution;

4. The lower duration value is obtained for a maximum negative variation, the one that takes into account a minimum amount of medium duration value.

The results lead to two decision possibilities for selecting the optimum variant:

- the sensitivity must have the lowest value, in a situation where there is a possibility of a risk with a negative impact. Such risk will reverberate at the objective level, having an impact reflected by the sensitivity value; in this case the total duration will have a medium value (92.44 days);
- the sensitivity value must have the highest value, in a situation where there is an opportunity for the medium duration value to decrease. Such opportunity will be transferred on the objective, leading to a reduction of the total duration. In this case, the total duration will have a minimum value (89.98 days).

The most risky situation, which must be excluded, is characterized in terms of a maximum sensitivity value with the highest positive variation of medium duration. In this case, the risks with negative impact will be found in the project total duration.

#### 5. Conclusions

Risk and uncertainty define all types of projects, including the technical ones. Therefore, it is important to clearly establish the project objectives and to identify sources of risk.

The welding process risks influence not only the specific objectives but also the general objectives, creating a link between project levels and phases. It is very important to use the right tools and techniques in order to conduct the risk assessment.

The results from the risk analysis show how the duration of the simulation process affects the total medium duration and the sensitivity value. The sensitivity depends on the range in which the medium duration take values and not on the medium duration values. Variation of medium duration, with a certain percentage of its value, changes in the same way, the medium total duration.

Knowledge of how the project variables change along with the modification of one or more parameters, lead to the elimination of uncertainty, so the decisions are optimum.

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