Analysis as the starting point for the development of scientific research

B Oroian¹, I Condrea¹, A Hrițuc¹*, C Botezatu¹, M Ețcu¹, and L Slătineanu¹
¹ Technical University of Iași, Romania
E-mail: hrituc.adelina3295@yahoo.com

Abstract. The development of scientific research in a given field requires firstly an analysis of the known aspects found in a certain connection with the problem to solve. There are distinct analysis scientific methods that are able to systematically highlight the current level of the known information in a given field and to offer suggestions for the problem-solving. A short presentation of some such analysis scientific methods was approached in this paper. As proper analysis methods, the systemic analysis, the SWOT analysis, the Ishikawa diagram, the ideas diagram analysis, and the axiomatic design were taken into consideration. A comparison of these analysis methods facilitated the emphasis of some common and distinct aspects specific to these analysis methods.

1. Introduction
The scientific research is an activity aiming to systematically collect, interpret and evaluate data, in a planned manner, and that contributes thus to the accumulation of new information concerning nature, society, and thinking. It is important due to its essential contribution to the economic, cultural and spiritual development of the world. At present, the activities of scientific research could be classified in many ways. Such a classification takes into consideration fundamental research, applicative research, technological development and innovation.

Essentially, the main stages in the scientific research could be the understanding of the problem, identification and ordering of the difficulties, definition of the research theme, elaboration of the research plan, scientific information, development of theoretical and experimental research, processing, analysis, interpreting and validation of the experimental research, valorizing the research results.

Within the theoretical research, the analysis is considered as an effective research tool. The concept of analysis refers to comprehensive and systematic research by which the investigated object is decomposed in its components, and subsequently, these components are ordered, studied and evaluated, taking also into consideration the connections and the interactions among the components.

There are many known methods of scientific analysis and some of them are the systemic analysis, analysis by means of the Ishikawa diagram, of the ideas diagram, value analysis, SWOT analysis, mind-mapping method etc.

Over the years, the researchers expressed various opinions concerning the classification and the contents of the scientific analysis methods [1-5]. In this paper, some analysis methods were considered to highlight their main characteristics before developing experimental research and subsequently develop a short comparison of such characteristics.
2. Systemic analysis
The systemic analysis was promoted in connection with the so-called theory of the general systems. Karl Ludwig von Bertalanffy founded this theory in 1942. By means of the theory of general systems, one takes into consideration the organized complexities, especially the principles, laws, and models of the systems.

The system is the assembly of material or ideal elements that are interdependent, but constituting an organized entire. The systemic analysis aims to better understand the analyzed process, phenomenon, technical solution as a system [1]. When considering a process as a system, the characteristics of the process are appreciated as a result of its components interactions.

| Input factors | Disturbing factors | Output parameters |
|---------------|-------------------|------------------|
| 1. Supply voltage | 1. Uncontrolled variation of the supply voltage | 1. Lifetime of the computing system |
| 2. Environment temperature | 2. Uncontrolled variation of temperature | 2. Instability in operation |
| 3. Components reliability | | 3. Operation errors |

**Process of computer system degradation**

Figure 1. Systemic analysis of computer system degradation considered as a system.

To exemplify the systemic approaching of a system, the process of degradation of components of a computing system will be considered. In this case, as process input factors, one could take into consideration the supply voltage, environment temperature, components reliability, human action characteristics.

The main output parameters of the analyzed process are the lifetime of the computing system, the parameters that characterize the instability in operation, the operation errors etc. Sometimes, the systemic analysis is completed by highlighting the disturbing factors. This means that such factors could not be imposed in the functionality of the system, but they could affect the values of the output parameters. In the case of the computing system degradation process, as disturbing factors, one could consider the uncontrolled variation of the supply voltage and temperature, the dust presence etc.

An example of graphical representation resulted because of considering the process of degradation of a computing system is presented in figure 1.

3. SWOT analysis
The SWOT analysis is a method promoted essentially in the business field to obtain both an assembly image and certain details concerning the considered problem. The concept of SWOT is an acronym that takes into consideration the initial letters of the words that correspond in the English language to the concepts of strengths, weaknesses, opportunities, and threats [2].

As strengths, the internal factors that act to materialize the proposed objectives are considered. The weaknesses define the internal factors able to generate obstacles in obtaining the wanted results. The opportunities include the external factors able to aid the achievement of the assumed objectives, while the threats are those external factors that could generate difficulties in the project development.

Trying to use the SWOT analysis in developing experimental research concerning the process of chemical engraving, one could define such a process as a chemical process that allows the transfer of the texts or designs onto the workpiece surface. Generally, the chemical machining uses the chemical reactions produced on the workpiece surface because of the contact between this surface and certain chemically active substances.
**Strengths**

- The application of the chemical machining method does not need complex equipment
- There is a certain expertise concerning the use of the chemical engraving
- In comparison with other nonconventional processes, chemical engraving could be applied both to electroconductive and insulating materials
- The penetration of the active substances in spaces difficult to be approached by other subtractive machining methods
- The chemical engraving does not generate mechanical stresses in workpieces
- A relatively reduced energy consumption
- Applying in the case of very thin workpieces
- The process could be localized on very small surfaces

**Weaknesses**

- The substances used for chemical engraving could generate polluting processes
- Certain active substances may cause injuries to operators if they are not handled with care
- It is difficult to follow the evolution of the chemical engraving in spaces that could be not directly observed
- If the active substance is not adequately removed, the chemical process could continue in a not controlled way

**Opportunities**

- One could apply the chemical engraving in the case of new metallic and nonmetallic materials
- The extension of using workpieces made of metals and alloys that are easier machined by chemical machining processes
- The chemical engraving could be applied inclusively in the cases of less rigid workpieces

**Threats**

- New processes having more convenient technological characteristics could appear
- A decrease of requests of parts that suppose the use of chemical engraving
- An increase in the active substances costs

---

**Figure 2.** Simplified example of using the SWOT analysis in the case of the chemical engraving.

**Figure 3.** Use of the Ishikawa diagram in the case of necessity to consider the factors able to affect the roughness of the surfaces obtained by flat milling.

4. **Ishikawa diagram**

The Ishikawa diagram is considered as one of the seven tools of the quality; it is known as the diagram cause-effect or diagram in fish bone. Essentially, the Ishikawa diagram is a graphical representation of the connections between a certain result and the factors able to influence it. Professor Kaoru Ishikawa from the University of Tokyo proposed the method in 1986. After the elaboration of an Ishikawa diagram, an analysis of the information offered by the graphical representation could be developed,
followed by the deeper identification of the factors able to exert a major influence and by an action plan, by which the identified solutions could be applied to solve the addressed problem [3].

The main advantage of the Ishikawa diagram is the easiness to observe the assembly of the factors that have determined a certain result. This analysis method could be applied in very distinct activity fields. A disadvantage is a fact that it does not facilitate the investigation of the influences exerted simultaneously by many distinct factors.

In figure 3, an Ishikawa diagram aiming to highlight the factors able to affect the roughness of the surfaces obtained by flat milling is presented. Because of analyzing the diagram, one noticed that the greatest impact on the surface roughness parameters is generated by the operating conditions (feed rate, and cutting speed); on these factors, one could firstly act when the problem of improving the roughness of the flat milled surfaces is formulated. The geometrical parameters of the active zones of the tool could be also taken into consideration, but the change of the cutting tool is more difficult to be applied in comparison with the change of the milling operating conditions.

5. Axiomatic design

The method of axiomatic design is one of the main methods used in the design and manufacture of technical products. It is supposed that this method would greatly contribute to the development of creativity and at the same time to increase the productivity of the design process as it causes the decrease of the number of errors and of the time necessary for the conceptualization of the technical object.

The method was first thought and used by the Professor Nam Pyo Suh during the period when he was professor at Massachusetts Institute of Technology (U.S.A.). It was used in the design of manufacturing processes and equipment. The axiomatic design is based on two axioms, that of independence of the functional requirements and that of the minimum information. These axioms are very important, and their application leads to a considerable simplification of the process of designing the desired technological system. The method is also built as a link between the four essential areas, the customer’s needs, the function of the active zones of the tool could be also taken into consideration, but the change of the cutting tool is more difficult to be applied in comparison with the change of the milling operating conditions.

| Functional requirements | Design parameters | Design parameter of zero order, DP0 | Design parameters of the first order: | Design parameters of second order |
|-------------------------|-------------------|------------------------------------|-------------------------------------|----------------------------------|
| FR0                     | FR of first order | DP1                                | DP2                                | DP3                              |
| FR1                     | FR of second order| X                                  | X                                  | X                                |
|                         | FR1.1             | X                                  | X                                  | X                                |
|                         | FR1.2             | X                                  | X                                  | X                                |
|                         | FR1.3             | X                                  | X                                  | X                                |
|                         | FR1.4             | X                                  | X                                  | X                                |
| FR2                     | FR2.1             | X                                  | X                                  | X                                |
|                         | FR2.2             | X                                  | X                                  | X                                |
|                         | FR2.3             | X                                  | X                                  | X                                |
| FR3                     | FR3.1             | X                                  | X                                  | X                                |
|                         | FR3.2             | X                                  | X                                  | X                                |
|                         | FR3.3             | X                                  | X                                  | X                                |
optimization process that ultimately compares the initial requirements with the selected design parameters to see if the customer's needs were satisfied.

To exemplify the above-mentioned considerations, the use of the axiomatic method for conception and designing equipment used for oxy-hydrogen welding is pursued. The equipment will be used later to develop laboratory research. Oxy-hydrogen welding is the process, which consists in the water electrolysis, resulting in diatomic hydrogen that will be ignited in contact with oxygen in the air. This procedure is used inclusively for deep underwater welding.

The customer's requirement is as follows: CN1: design equipment that can be used in laboratory research concerning oxy-hydrogen welding. The main functional requirement has the form: FR0: Design equipment for oxy-hydrogen welding, using elements easy to be purchased or manufactured. As functional requirements that correspond to the first level, one can consider: FR1: Perform the water electrolysis and obtain diatomic hydrogen; FR2: Ensure the combination of hydrogen and air; FR3: Switch on the gas. If the problem of identifying the functional requirements that correspond to the second level is concerned, it might be about: FR1.1: Ensure of the space for developing the electrolysis process; FR1.2: Ensure the existence of the required electrolysis fluid; FR1.3: Ensure the existence of electrodes; FR1.4: Ensure the power supply; FR2.1: Ensure the transport of hydrogen from the inside to the outside of the space where it was generated; FR2.2: Ensure hydrogen filtration to remove impurities; FR2.3: Avoid gas losses; FR3.1: Drive the hydrogen; FR3.2: Ensure an ignition source; FR3.3: Control the quantity of the gas. The design parameters DPs that correspond to the first level of the functional requirements will be: DP1.1: First container; DP1.2: Water; DP1.3: Copper plates; DP1.4: Plug-in connection; DP2.1: Houses; DP2.2: Second water container; DP2.3: Sealing of the containers; DP3.1: Nozzle; DP3.2: Fire; DP3.3: Tap.

6. Ideas diagram method

The ideas diagram is a graphical representation used to highlight the versions of the distinct subassemblies or components valid for the investigated equipment. A simplified example of ideas diagram elaborated in the case of a device that could be used to investigate the sharp peaks behavior under the action of the electrical discharges is presented in figure 4. Essentially, when using the ideas diagram, the designer has to identify the subassemblies versions and place them along a vertical column that corresponds to a certain subassembly [5]. One could notice also that interrogation signs were used to highlight that other versions of each subassembly or just other subassemblies could be found in the future. In stages that could be addressed after the elaboration of the ideas diagram, the distinct combinations of the considered subassemblies will be analyzed, so that finally an improved solution for the investigated equipment could be identified.

**Figure 4.** Example of simplified ideas diagram valid in the case of a device for investigating the sharp peaks behavior under the action of the electrical discharges.
7. Comparison of some analysis methods applicable in the development of a scientific research

To deeper investigate the research problem, when selecting a certain analysis method, some criteria could be taken into consideration. Such criteria could be the time necessary for the developing and finalizing the analysis, the complexity level that characterizes the analysis method, the ease of application in a proper case, the necessity of using knowledge from distinct scientific fields, the possible generation of an applicative solution. One could notice that the analysis is one of the first stages when a research problem is approached, while distinct methods could be used to develop an adequate solution to the research problem. For the above-mentioned analysis methods, a synthetic comparison based on considering some evaluation criteria is presented in table 2. One took into consideration three levels of evaluation, namely high, medium and low. The examination of this synthetic comparison of some analysis methods showed that the ideas diagram method and the axiomatic design are relatively complex methods, but they could offer a way to immediately develop or at least approach a possible solution for the research problem.

Table 2. Synthetic comparison of some distinct analysis methods.

| Analysis method       | Time necessary for the elaboration of an analysis | Complexity level | Ease of application | Necessity of knowledge from distinct fields | Possible finalizing by generating a solution |
|-----------------------|---------------------------------------------------|------------------|---------------------|---------------------------------------------|---------------------------------------------|
| Systemic analysis     | low                                               | low              | high                | low                                         | low                                         |
| SWOT analysis         | medium                                            | low              | high                | medium                                      | low                                         |
| Ishikawa diagram      | medium                                            | low              | high                | medium                                      | medium                                      |
| Ideas diagram         | high                                              | medium           | medium              | high                                        | high                                        |
| Axiomatic design      | high                                              | high             | high                | high                                        | high                                        |

8. Conclusions

In the solving of a research problem, the analysis is one of the first stages that must be approached. One noticed that there are many analysis methods that could be used in solving the research problem. Some such methods were investigated and applied in proper cases. Thus, the systemic analysis, SWOT analysis, Ishikawa diagram, ideas diagram, and axiomatic design were succinctly presented, subsequently aiming to develop adequate solutions for the research problem. A final succinct comparison of the distinct analysis methods showed that even the ideas diagram and axiomatic design are considered as more time consuming and of higher complexity level, they could ensure the defining of the first solutions for the approached research problem.

References
[1] Băloiu LM, Frăsineanu I 2001 Innovation management (in Romanian) (Bucharest, Romania: Editura Economică)
[2] Střelec J. SWOT analysis 2016 Available at https://www.ownway.eu/methods/swot-analysis/ accessed: 22.01.2018
[3] OpenQAsS Ishikawa Diagram 2016 Available at http://openqass.istudy.hu/en/knowledge-repository/pdca-cycle/ishikawa-diagram Accessed: 12.07.2017
[4] Gonçalves-Coelho AM, Mourão AJF 2007, International Journal of Production Economics 109 81–89
[5] Belous V 1992 Inventions (in Romanian) (Iaşi, Romania: Publishing House Asachi)