Hierarchical modeling of professional skills in the field of castings manufacture engineering

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Abstract. The paper presents a method of hierarchizing professional skills in the manufacturing of molded parts (castings) by using and adapting the FAHP algorithm (Fuzzy Analitical Hierarchy Process). Assessments are made regarding the peculiarities of the professional training process, specifying the activities to be carried out and the competences necessary for their development. The contribution of the design of the method extends to the design of the hierarchy system architecture, the linguistic determination of the importance of each characteristic, the construction of the fuzzy ordering matrices for each stage of the process, the determination of the share of the characteristics for each hierarchy step and establishing the hierarchy of the characteristics taking into account the influences of the others, grouped at the level of the steps and within the global matrix. The research carried out represents the support for generating an instrument of hierarchy of professional competencies that can be used in various professional and institutional contexts. Case study on the hierarchy of professional skills in the manufacturing of molded parts engineering.

Keywords: Materials engineering, castings manufacture professional skills, hierarchy, AHP method, standard occupational curriculum.

1 Introduction

The paper is determined by the fact that the manufacturing processes of the molded parts (castings) are particularly complex and in permanent consolidation due to the mutations favored by the dynamics of the fields of use, the diversification of the casting alloys, the innovations to the technological process and the appearance of the new restrictions related to the required quality of the products and the existence of the necessary conditions to ensure ecoresponsibility. In this context, it is appreciated the need to adapt the educational and training forms to the new realities and evolution trends.

The objective of the paper is to structure, from the point of view of the interdisciplinary scientific research, a tool for modeling and hierarchizing of the competences that must be included at the
educational level for the specialization related to the manufacturing of castings within the specific training in the field of materials engineering.

The problem to be solved consists in the structuring of the professional competencies in terms of the correlation of the educational plan with the requirements of the profession in the field of engineering regarding casting manufacturing.

From the methodological point of view, the form of structure analysis consists of the following steps: establishment of the hierarchy tool and elements necessary for its use; structuring the data characterizing the professional activities specific to the field; conceptualizing and implementing the hierarchy tool; formalizing input data within it; processing input data through the proposed algorithm; use of results in the curriculum structure.

In the paper are presented some contributions in the process of substantiation of the professional competences in the manufacturing of castings: the adaptation of the FAHP method for its use as a ranking tool of professional skills; analyzing and determining by institutional means, the data characterizing specific professional activities; the construction and algorithmization of the hierarchy specific to the FAHP method; establishing on a statistical basis the linguistic assessments to be introduced at the level of the hierarchy; establishing under various conditions the hierarchy of professional competences required in exercising of the profession; the use of the data obtained at the level of the occupational standard and the construction of the training plan of the specialization “castings manufacture engineering”.

The results of the research activity provide the basis for a methodology for determining the professional competency hierarchy in order to structure the occupational standards and the support for the construction of the educational plan, with an example in the manufacturing of the molded parts. At the level of the specialized literature we notice the classification of the specific notions, related mainly to the traceability and knowledge management in order to use them. The construction of competency references was done mainly by using empirical methods, specific to public authorities, having inherent responsibilities in this field [1]. An analysis of the possibilities of using the FAHP algorithm in the modeling of work situations in competency characterization is presented by Farouk, Bonjour and Dulmet [2]. An important support in structuring the research theme was determined by the experience gained in the PhD thesis elaborated by Potra Florina Liliana [3] and Pop Alin Lenut [4], the discussions and lectures of Professor Potra Teodor [5] and the writing of a synthesis on the need to professionalize the environmental engineer [6]. The paper included the principles of hierarchy presented at the level of juridical-engineering convergence. [7]

At the same time, the activities carried out at the level of casting manufacturing were taken from the analysis of the domain from the perspective of the circular economy. [8]

The qualitative and quantitative assessments used were based on the report 50th Census of world casting production. [9]

In determining the characteristics, the assessments made in the portrait of the engineer at "L’Institut Mines-Telecom" were taken into account. [10]

2 Considerations on the particularities of the professional training process in the manufacture of castings

Considering the institutional validation methodology of professional training, it is appreciated that the process of professional training takes place by following several stages: establishing the activities; establishing competencies; developing the occupational standard; validation of the occupational standard; institutionalization of the educational plan; authorization of training activities; carrying out training activities, according to the established institutional framework; individual certification of training. In the context of this paper, by taking into consideration the regulatory framework, it is appreciated that the establishment of the activities carried out in the casting industry must consider the following elements: technological establishment and conditioning; technical and technological specificity of the fields served by the production of castings; technological specificity of the participants in the process.
Based on these considerations, in the first stage of the procedure, a questionnaire asked the specialists in the field of analysis to specify the activities currently carried out by engineers in this field for the different phases of the entire manufacturing process. Using the answers given in a narrow context, that of the representatives of the professional association and of the specialists in the field of the university professional training, the ones considered as being essential in the engineering praxis were retained.

In assessing the competencies required to carry out an engineering activity, these are organized according to the following groups: the group of transversal competences (CT); the group of general professional competence (CPG) and the specific professional skills group (CPS).

The following types of questionnaires were used for determining and assessing the importance of competencies: a questionnaire for determining the importance of transversal skills in castings manufacturing; a questionnaire to determine the importance of general professional skills at the manufacturing stage of castings; a questionnaire to determine the importance of specific professional skills at the manufacturing stage of castings. The interrogated specialists were recruited from the following categories: specialists working in the field of castings manufacturing in a technical position; specialists working in the castings manufacturing in a managerial or administrative or commercial position; specialists working in the field of education and training; specialists working at the research and design level; specialists working in other areas, specifying the area. The results of the investigation were the basis for structuring the features to be used in the design of the architecture of the competency system.

3 Applying the FAHP method in the analysis of the influences on the engineering training system in the casting industry

The stages of the hierarchy method refer to the following aspects: designing the architecture of the process hierarchy system; linguistic determination of the importance of each feature in the hierarchy process; constructing fuzzy ordering matrices for each stage of hierarchy; determining the share of the characteristics for each hierarchy; determining the share of the characteristics taking into account the influences of each level of hierarchy; establishing the hierarchy of the influence of the characteristics in the process analyzed according to the calculated weight, taking into account the influence of each hierarchical stage; observations and discussions regarding the results obtained.

3.1 Designing the architecture of the skills system in castings manufacturing

The design of the architecture of the system of competencies in the manufacturing engineering of castings includes the following stages: establishment of the characteristic elements of the competencies; the establishment of levels of competence characteristics and grouping criteria for each level; assigning the characteristic elements for the first stage of hierarchy and establishing the groups of the first ranking hierarchy; grouping the structures of the first stage of hierarchy at the second stage of hierarchy; the establishment of the global hierarchy structure.

For the present case, the system to be architecturally structured comprises 81 characteristic features \((ECC)_i, i \in \{1 \ldots 81\}\), the first stage of hierarchy comprises 25 groups of detailed competences \((1GCD)_j, j \in \{1 \ldots 25\}\), and the second stage of hierarchy contains 3 skill groups \((2GC)_k, k \in \{1,2,3\}\), which constitute components of the global hierarchy group. The overall global hierarchy structure will be composed of the groups determined on the second level of hierarchy, i.e., the representation of transversal skills, general professional skills and specific professional skills.

Therefore, the architecture resulting in the analysis is shown in Figure 1.

3.2 Determining the importance of each feature within the hierarchy of professional skills specific to the manufacture of castings

Determining the importance of each characteristic within the hierarchy of professional skills specific to the manufacture of castings includes the following steps: specifying the objective and the criteria according to which the hierarchy is made. The objective of the analysis is to determine a multi-step hierarchy of characteristics, in view of establishing a hierarchy of “characteristic features of
Figure 1. The architecture scheme of the system of professional competencies through FAHP
motivation corresponds to the one presented tailored competence groups (1GCD) established as ranking and 3 groups on the second constitute they need at least two components. The analyzed structure co

In the AHP algorithm, the fuzzy ordering matrices attached to each level are created, which in order to quantify of importance and a scoring correlation through fuzzy numbers were established as follows: 11 - very important, 9 - important, 7 - medium, 5 - low and 3 - very low; the assignment of fuzzy numbers for each parameter in the analysis according to the specified criteria. For the case analyzed the attribution of characteristic fuzzy numbers (ECC), detailed competence groups (1GCD), and competence grouping (2GC), are presented in Table 1.

Table 1 Fuzzy numbers assigned to the components of the analyzed architecture

| Architecture component | Fuzzy number assigned | Architecture component | Fuzzy number assigned | Architecture component | Fuzzy number assigned | Architecture component | Fuzzy number assigned | Architecture component | Fuzzy number assigned |
|------------------------|-----------------------|------------------------|-----------------------|------------------------|-----------------------|------------------------|-----------------------|------------------------|-----------------------|
| (ECC)$_1$              | 9$_a$                 | (ECC)$_{23}$          | 11$_a$               | (ECC)$_{45}$          | 9$_a$                 | (ECC)$_{67}$          | 11$_a$               | (1GCD)$_8$             | 11$_a$                |
| (ECC)$_2$              | 7$_a$                 | (ECC)$_{24}$          | 11$_a$               | (ECC)$_{46}$          | 9$_a$                 | (ECC)$_{68}$          | 11$_a$               | (1GCD)$_9$             | 11$_a$                |
| (ECC)$_3$              | 7$_a$                 | (ECC)$_{25}$          | 9$_a$                | (ECC)$_{47}$          | 9$_a$                 | (ECC)$_{69}$          | 9$_a$                | (1GCD)$_10$            | 9$_a$                 |
| (ECC)$_4$              | 11$_a$                | (ECC)$_{26}$          | 11$_a$               | (ECC)$_{48}$          | 9$_a$                 | (ECC)$_{70}$          | 9$_a$                | (1GCD)$_11$            | 11$_a$                |
| (ECC)$_5$              | 11$_a$                | (ECC)$_{27}$          | 9$_a$                | (ECC)$_{49}$          | 9$_a$                 | (ECC)$_{71}$          | 9$_a$                | (1GCD)$_12$            | 7$_a$                 |
| (ECC)$_6$              | 7$_a$                 | (ECC)$_{28}$          | 9$_a$                | (ECC)$_{50}$          | 11$_a$               | (ECC)$_{72}$          | 9$_a$                | (1GCD)$_13$            | 7$_a$                 |
| (ECC)$_7$              | 11$_a$                | (ECC)$_{29}$          | 9$_a$                | (ECC)$_{51}$          | 9$_a$                 | (ECC)$_{73}$          | 9$_a$                | (1GCD)$_14$            | 9$_a$                 |
| (ECC)$_8$              | 11$_a$                | (ECC)$_{30}$          | 11$_a$               | (ECC)$_{52}$          | 9$_a$                 | (ECC)$_{74}$          | 9$_a$                | (1GCD)$_15$            | 11$_a$                |
| (ECC)$_9$              | 11$_a$                | (ECC)$_{31}$          | 9$_a$                | (ECC)$_{53}$          | 9$_a$                 | (ECC)$_{75}$          | 9$_a$                | (1GCD)$_16$            | 5$_a$                 |
| (ECC)$_{10}$           | 9$_a$                 | (ECC)$_{32}$          | 9$_a$                | (ECC)$_{54}$          | 7$_a$                 | (ECC)$_{76}$          | 11$_a$               | (1GCD)$_17$            | 11$_a$                |
| (ECC)$_{11}$           | 11$_a$                | (ECC)$_{33}$          | 11$_a$               | (ECC)$_{55}$          | 11$_a$               | (ECC)$_{77}$          | 11$_a$               | (1GCD)$_18$            | 9$_a$                 |
| (ECC)$_{12}$           | 7$_a$                 | (ECC)$_{34}$          | 9$_a$                | (ECC)$_{56}$          | 9$_a$                 | (ECC)$_{78}$          | 9$_a$                | (1GCD)$_19$            | 11$_a$                |
| (ECC)$_{13}$           | 9$_a$                 | (ECC)$_{35}$          | 9$_a$                | (ECC)$_{57}$          | 11$_a$               | (ECC)$_{79}$          | 9$_a$                | (1GCD)$_20$            | 9$_a$                 |
| (ECC)$_{14}$           | 11$_a$                | (ECC)$_{36}$          | 9$_a$                | (ECC)$_{58}$          | 9$_a$                 | (ECC)$_{80}$          | 9$_a$                | (1GCD)$_21$            | 9$_a$                 |
| (ECC)$_{15}$           | 11$_a$                | (ECC)$_{37}$          | 9$_a$                | (ECC)$_{59}$          | 11$_a$               | (ECC)$_{81}$          | 7$_a$                | (1GCD)$_22$            | 11$_a$                |
| (ECC)$_{16}$           | 11$_a$                | (ECC)$_{38}$          | 9$_a$                | (ECC)$_{60}$          | 9$_a$                 | (1GCD)$_1$            | 9$_a$                | (1GCD)$_23$            | 7$_a$                 |
| (ECC)$_{17}$           | 11$_a$                | (ECC)$_{39}$          | 9$_a$                | (ECC)$_{61}$          | 9$_a$                 | (1GCD)$_2$            | 7$_a$                | (1GCD)$_24$            | 9$_a$                 |
| (ECC)$_{18}$           | 9$_a$                 | (ECC)$_{40}$          | 11$_a$               | (ECC)$_{62}$          | 11$_a$               | (1GCD)$_3$            | 11$_a$               | (2GC)$_1$              | 5$_a$                 |
| (ECC)$_{19}$           | 11$_a$                | (ECC)$_{41}$          | 11$_a$               | (ECC)$_{63}$          | 11$_a$               | (1GCD)$_4$            | 11$_a$               | (2GCD)$_2$             | 7$_a$                 |
| (ECC)$_{20}$           | 9$_a$                 | (ECC)$_{42}$          | 9$_a$                | (ECC)$_{64}$          | 9$_a$                 | (1GCD)$_5$            | 11$_a$               | (2GCD)$_3$             | 7$_a$                 |
| (ECC)$_{21}$           | 9$_a$                 | (ECC)$_{43}$          | 9$_a$                | (ECC)$_{65}$          | 9$_a$                 | (1GCD)$_6$            | 7$_a$                | (2GCD)$_4$             | 11$_a$                |
| (ECC)$_{22}$           | 9$_a$                 | (ECC)$_{44}$          | 9$_a$                | (ECC)$_{66}$          | 9$_a$                 | (1GCD)$_7$            | 11$_a$               |                        |                       |

3.3 Construction of fuzzy ordination matrices for each stage of the hierarchy

In the AHP algorithm, the fuzzy ordination matrices attached to each level are created, which in order to constitute they need at least two components. The analyzed structure corresponds to the one presented in Figure 1, where 81 characteristic features of competences appear, 25 groups on the first level of ranking and 3 groups on the second level of ranking.

Expressing the ordering matrices is done by means of triangular cut fuzzy numbers.
\( \tilde{\alpha}, \tilde{\beta}, \tilde{\gamma}, \tilde{\delta}, \) and \( \tilde{\Pi}_\alpha, \) corresponding to the assessments of the importance of the feature or structure analyzed, as follows: \( \tilde{\alpha} \) – very low importance; \( \tilde{\beta} \) – low importance; \( \tilde{\gamma} \) – medium importance; \( \tilde{\delta} \) – big importance and \( \tilde{\Pi}_\alpha \) – very big importance. The use of this structure, that of the triangular cut fuzzy numbers, is motivated by the fact that this typology is considered as generating reasonable results. Therefore, they are:

\[
\begin{align*}
3\tilde{\alpha} &= (1-\beta)(1+2\alpha)+\beta(5-2\alpha); \\
5\tilde{\alpha} &= (1-\beta)(3+2\alpha)+\beta(7-2\alpha); \\
7\tilde{\alpha} &= (1-\beta)(5+2\alpha)+\beta(9-2\alpha); \\
9\tilde{\alpha} &= (1-\beta)(7+2\alpha)+\beta(11-2\alpha); \\
11\tilde{\alpha} &= (1-\beta)(9+2\alpha)+\beta(9-2\alpha)
\end{align*}
\]

and their inverses are given by:

\[
\begin{align*}
3\tilde{\alpha}^{-1} &= \frac{1-\beta}{5-2\alpha} + \frac{\beta}{1+2\alpha}; \\
5\tilde{\alpha}^{-1} &= \frac{1-\beta}{7-2\alpha} + \frac{\beta}{3+2\alpha}; \\
7\tilde{\alpha}^{-1} &= \frac{1-\beta}{9-2\alpha} + \frac{\beta}{5+2\alpha}; \\
9\tilde{\alpha}^{-1} &= \frac{1-\beta}{11-2\alpha} + \frac{\beta}{7+2\alpha}
\end{align*}
\]

The problem is solved with moderate appreciation in the situation of \( \alpha = 0.5 \) and \( \beta = 0.75 \); the fuzzy number and their inverse have the following values: \( 3\tilde{\alpha} = 3.5000; \ 5\tilde{\alpha}=5.5000; \ 7\tilde{\alpha} = 7.5000; \ 9\tilde{\alpha} = 9.000; \ 11\tilde{\alpha} = 11.5000; \ 3\tilde{\alpha}^{-1} = 0.4375; \ 5\tilde{\alpha}^{-1} = 0.2292; \ 7\tilde{\alpha}^{-1} = 0.1563; \ 9\tilde{\alpha}^{-1} = 0.1188; \ 11\tilde{\alpha}^{-1} = 0.0958. \)

For example, some fuzzy ordination matrices determined in the procedure used are presented:

\[
\begin{array}{c|cccc}
\text{(MOF)}_{15} &= \text{(1GCD)}_{15} & = \tilde{\alpha} & = \tilde{\beta} & = \tilde{\gamma} & = \tilde{\delta} \\
\hline
\text{(ECC)}_{21} & = \tilde{\alpha} & = \tilde{\alpha} & = \tilde{\Pi}_\alpha & = \tilde{\Pi}_\alpha & = \tilde{\alpha} \\
\text{(ECC)}_{22} & = \tilde{\alpha} & = \tilde{\alpha} & = \tilde{\Pi}_\alpha & = \tilde{\Pi}_\alpha & = \tilde{\alpha} \\
\text{(ECC)}_{23} & = \tilde{\Pi}_\alpha & = \tilde{\Pi}_\alpha & = 1 & = \tilde{\Pi}_\alpha & = \tilde{\Pi}_\alpha \\
\text{(ECC)}_{24} & = \tilde{\Pi}_\alpha & = \tilde{\Pi}_\alpha & = 1 & = \tilde{\Pi}_\alpha & = \tilde{\Pi}_\alpha \\
\text{(ECC)}_{25} & = \tilde{\alpha} & = \tilde{\alpha} & = \tilde{\Pi}_\alpha & = \tilde{\Pi}_\alpha & = \tilde{\alpha}
\end{array}
\]
\[(\text{MOF1})_{18} = (1\text{GCD})_{18} = \]

\[
\begin{array}{cccccccc}
(\text{ECC})_{37} & (\text{ECC})_{38} & (\text{ECC})_{39} & (\text{ECC})_{40} & (\text{ECC})_{41} & (\text{ECC})_{42} & (\text{ECC})_{43} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} & \frac{9}{a} \\
\frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} \\
\frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} \\
\frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} \\
\frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} \\
\frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} \\
\frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} \\
\frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} \\
\frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} & \frac{1}{a} \\
\end{array}
\]

\[(\text{MOF2})_{1} = (2\text{GC})_{1} = \]

\[
\begin{array}{cccccccc}
(1\text{GCD})_{1} & (1\text{GCD})_{2} & (1\text{GCD})_{3} & (1\text{GCD})_{4} & (1\text{GCD})_{5} & (1\text{GCD})_{6} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\frac{9}{a} & \frac{9}{a} & \frac{9}{a} & \frac{1}{a} & \frac{1}{a} & \frac{9}{a} \\
\end{array}
\]

The global fuzzy ordering matrix has the following form:
\[ G = \begin{pmatrix}
(2GC)_1 & (2GC)_2 & (2GC)_3 \\
5_\alpha & 7_\alpha^{-1} & 11_\alpha^{-1} \\
7_\alpha^{-1} & 1 & 11_\alpha^{-1} \\
11_\alpha^{-1} & 11_\alpha & 1
\end{pmatrix} \]

3.4 Determination of shares for each stage of hierarchy
After fully loading the fuzzy ordering matrices, the fuzzy FAHP algorithm continues with steps that are strictly dependent on the problem being considered. Consequently, the own value theory and the vectors corresponding to the fuzzy ordination matrices, (MOF1)_i and (MOF2)_j, will be used. Thus, for each characteristic its share will be determined, expressed by a number between 0 and 1, which shows its importance in all the characteristics that occur in the analyzed situation. These shares are no longer independent, they are consequences of the interactions between the features. Therefore, the contribution of fuzzy theory to solving problems, such as the one analyzed, in which linguistic input data is used, and several interdependent inputs lead to a single conclusion is evident.

3.5 Determining the shares of the characteristics considering the influences of each stage of the hierarchy
The calculation of the share of a characteristic at the level of the influences of the two stages of the hierarchy and of the global one is done with the formula:

\[
\text{Share (ECC)}_i = \text{Share (ECC)}_{i, \text{stage 1}} \times \text{Share (ECC)}_{i, \text{stage 2}} \times \text{Share (ECC)}_{i, \text{global matrix}}
\]

Table 2 presents the shares of the 81 characteristics by taking into account the influences of each stage of the hierarchy.

Table 2. Selected values of the shares of the characteristics by taking into account the influences of the hierarchical stages

| Name of the characteristic | Symbol | Share  | Position in the hierarchy | Importance/group |
|---------------------------|--------|--------|---------------------------|------------------|
| CT04: The ability to work in an international context | (ECC)_4 | 0.016146171 | 13 | CFI – Group I |
| CT05: The ability to self-evaluate, to make professional choices. | (ECC)_5 | 0.016146171 | 14 | CFI – Group I |
| CPG1: Knowledge and understanding of a broad field of knowledge in the field of fundamental sciences as well as the ability to analyze and synthesize what is associated with them from the perspective of casting production. | (ECC)_7 | 0.033747852 | 8 | CFI – Group I |
| CPG2: The ability to mobilize resources from a scientific and technical field related to the given specialty. | (ECC)_8 | 0.033747852 | 9 | CFI – Group I |
| CPG3: Using engineer-specific methods and tools: identifying and solving problems, collecting and | (ECC)_9 | 0.033747852 | 10 | CFI – Group I |
interpreting data, using computer tools.

CPG5: Ability to take into account the environmental protection objectives. (ECC)\textsubscript{11} 0.033747852 11 CFI – Group I

CPS02.02: Performing a comparative study (quality, cost, availability, ...) of compatible processes. (ECC)\textsubscript{10} 0.025032609 12 CFI – Group I

CPS03.03: Writing technological sheets. (ECC)\textsubscript{12} 0.070178487 2 CFI – Group I

CPS03.04: Standardization of operations. (ECC)\textsubscript{14} 0.070178487 3 CFI – Group I

CPS04.01: Validation of the production system and verification tests. (ECC)\textsubscript{16} 0.004100396 44 CIM – Group I

CPS05.01: Analyzing the real load of the production sector (ECC)\textsubscript{16} 0.064971121 6 CFI – Group I

CPS07.07: Identification of faults and installations anomalies and coordination of preventive maintenance actions of the sector. (ECC)\textsubscript{19} 0.103192165 1 CFI – Group I

CPS05.04: Sorting the tasks of different production sectors by optimizing all criteria and taking into account different constraints. (ECC)\textsubscript{13} 0.064971121 7 CFI – Group I

CPS10.03: Identifying and implementing prevention and protection means and procedures for personal and collective safety. (ECC)\textsubscript{17} 0.070178487 4 CFI – Group I

CPS10.04: Ensuring and implementing measures related to safety and environmental protection. (ECC)\textsubscript{18} 0.070178487 5 CFI – Group I

CPS07.01: Team appointment and organization of the service. (ECC)\textsubscript{14} 0.009409941 21 CI – Group II

CPS07.02: Adjusting the distribution of staff according to the tasks to be performed, their skills, qualifications and availability. (ECC)\textsubscript{15} 0.009409941 22 CI – Group II

CPS07.03: Decipher the existing operation indicators. (ECC)\textsubscript{16} 0.009409941 23 CI – Group II

CPG4: Using experimental methods in a context of research and innovation. (ECC)\textsubscript{10} 0.005884519 42 CIM – Group III

CT01: Developing the spirit of entrepreneurship and the ability to take into account economic objectives. (ECC)\textsubscript{1} 0.004564520 43 CIM – Group III

CPS08.01: Performing control of problems with deadlines, quality, safety and environmental protection. (ECC)\textsubscript{11} 0.001349475 57 CIS – Group IV

CPS08.02: Performing periodic inspection of machinery. (ECC)\textsubscript{12} 0.001349475 58 CIS – Group IV

CT02: Ability to take into account social and ethical objectives. (ECC)\textsubscript{2} 0.000893768 71 CIFS – Group V

CTAC Competence other than those previously mentioned in the transversal skills (ECC)\textsubscript{6} 0.000893768 73 CIFS – Group V

The influence of characteristics on the skills required for the “casting engineer” profession is shown in Figure 2. The influence of characteristics on the skills required for the “casting engineer” profession is shown in Figure 2. Another analysis that can be done by evaluating the global shares is the one related to mentioning the order of importance of the groups formed on the first stage of hierarchy. The overall share of the group is determined by summing the global shares of the features present within it. Using this procedure, Figure 3 shows the global shares of the groups present on the first stage of hierarchy.
Figure 2. Global shares values and characteristic elements of competencies

Figure 3. Shares of the groups on the first stage of hierarchization

4 Interpretation of the results obtained
Considering the results presented in Table 2, we find that from the point of view of the value of the global share, determined mathematically, we have to deal with five groups of importance (by returning to the linguistic appreciation):
- The group of very important characteristics (CFI) – Group I;
- The group of important characteristics (CI) – Group II;
- The group of medium importance characteristics (CIM) – Group III;
- The group of low importance characteristics (CIS) – Group IV;
- The group of very low importance characteristics (CIFS) – Group V.

In the group of very important features, of which 14 characteristics are part, the following are ranked according to the hierarchy criteria of the second step:
- 2 characteristics of the transversal competences (CT4 and CT5) of the 6 present in the analysis, with a share of 14.28% of the total of the very important characteristics;
- 4 characteristics of the general professional competences class (CPG1, CPG2, CPG3 and CPG5) of the 6 present in the analysis, with a share of 28.56% of the very important characteristics;
- 8 characteristics of the specific professional competences class (CPS03.03, CPS03.04, CPS02.02, CPS05.01, CPS05.04, CPS07.07, CPS10.03, CPS10.04) of the 69 present in the analysis, with a share of 57.12% of all the very important features.

From the previous presentation, it is noted that within the very important features, the essential role belongs to the transversal competences (CT) and general professional ones (GPs) their share exceeds 42.84%. Therefore, it is appreciated that in the curriculum the disciplines that support the mentioned competencies must be properly represented.

In an expression of linguistic assessment, the priority competences to be insisted on, in the educational processes resulting from the analysis, have the following expression: CT04: The ability to work in an international context; CT05: The ability to self-evaluate, to make professional choices; CPG1: Knowledge and understanding of a broad field of knowledge in the field of fundamental sciences, as well as the ability to analyze and synthesize what is associated with them from the perspective of manufacturing molded parts; CPG3: Using engineer-specific methods and tools: identifying and solving problems, collecting and interpreting data, using computer tools; CPG5: Ability to consider environmental objectives; CPS03.03: Writing technological sheets; CPS03.04: Standardization of operations; CPS02.02: Performing a comparative study (quality, cost, availability, ...) of compatible processes; CPS05.01: Analyzing the real load of the production sector; CPS05.04: Sorting the tasks of different production sectors by optimizing all criteria and taking into account different constraints; CPS07.07: Identification of installation faults and anomalies and coordination of preventive maintenance actions of the sector; CPS10.03: Identifying and implementing means and procedures for prevention and protection of personal and collective security; CPS10.04: Ensuring and implementing measures related to safety and the protection of the environment.

From the point of view of the specific professional competencies, their order of priority, determined according to the methodology developed in the research, shows as follows: 1. CPS07.07: Identification of defects and anomalies of the installations and coordination of preventive maintenance actions of the sector; 2. CPS03.03: Writing technological sheets; 3. CPS03.04: Normalization of operations; 4. CPS10.03: Identification and implementation of prevention and protection means and procedures for personal and collective safety; 5. CPS10.04: Ensuring and implementing measures related to safety and environmental protection; 6. CPS05.01: Analyzing the real load of the production sector; 7. CPS05.04: Sorting the tasks of the different production sectors by optimizing all criteria and taking into account different constraints; 8. CPS02.02: Performing a comparative study (quality, cost, availability, ...) of compatible processes.

5 Conclusions
In conclusion of the presentation, which reflects the researches undertaken, it is appreciated that starting from the determination the hierarchy of professional skills in the manufacturing engineering of castings it is possible to structure a tool that puts into operation the following methodological steps: 1. Establishing the activities that are carried out in the field to be analyzed; 2. Determining the professional competencies that are necessary for carrying out the analyzed activities by means of specialized questionnaires addressed to the specialists present on the different levels of action of the field; 3. Studying and analyzing the institutional documents regulating the vocational training in the analyzed field (global documents, European documents, national documents); 4. Experiences of good practice in
the field of training of the analyzed domain (global situation, European situation, national situation); 5. Determining the characteristics of the competencies that will be subjected to the hierarchy process; 6. Establishing the general criteria for assessing the characteristics; 7. Establishment of the linguistic assessment scale or levels; 8. Linguistic assessment of the characteristics according to the general criterion or the established criteria; 9. Establishing and justifying criteria for the allocation of attributes within the hierarchical stages and the formalization of classes through the characteristics; 10. Linguistic appreciation of classes established according to the general criterion; 11. Establishment and justification of criteria for the allocation of classes established on the higher ranking hierarchy; 12. The linguistic appreciation of the structures built on the upper levels according to the established general criterion; 13. Continuing the allocation process up to the level of the last hierarchy; 14. Linguistic assessment of the last formations grouped according to the general criterion or established criteria; 15. Allocation of fuzzy numbers according to linguistic assessments at the level of architectural features and classes. 16. Formation of the fuzzy ordering matrices at the level of the classes constituted by comparing the fuzzy numbers assigned to the characteristics; 17. Calculation of local shares on established hierarchy levels; 18. Calculation of the global shares for each component characteristic; 19. Determination of the importance groups of the characteristics analyzed according to the decreasing values of the global shares: the group of very important characteristics; the group of important characteristics; the group of medium importance characteristics; the group of low importance characteristics; the group of very low importance characteristics; 20. Interpretation of results through the hierarchy of competences required to conduct a profession.

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