

Manufacturing workforce assessment using AHP and TOPSIS logic

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Abstract—To perform a given activity by two individuals having the same qualification, the performance of achievement varies, which introduces the concept of individual competence level. This article presents an assessment method of multi-skilled workforce. In this paper we will discuss how to consider the differences and similarities between acquired level and required level. For a compound competence, the objective of our method is to present a quantified assessment method using AHP technique and TOPSIS logic which allows calculating the degree of excellence in the use of all individual competencies in execution of all activities.

Keywords-Assessment, Individual competence, Performance, AHP, TOPSIS.

I. INTRODUCTION

Nowadays, the concept of individual competence takes an important place in manufacturing industry. Management methods of production resources have focused mainly on the management of material resources. [4] consider the company as: A system of production of goods and services whose performance resides in the control of the process of creating added value. And as a system of production of knowledge and competences which its competitiveness is based on the control of the process of capitalization of knowledge and competences development.

Thus, the competence management is integrated as a fundamental lever for the improvement of the enterprise performances. Competences management involves a set of practices that aim to use and develop the competences of the individuals and teams in an optimal way, in order to achieve the mission of the enterprise and improve employee performance [1]. In addition, it aims to enhance the competitiveness of an enterprise as well as the mobilization and the employability of its employees [17]. According to [6], the general approach of competences management follows mainly three steps: firstly, to specify the required competences and identify the competences acquired; secondly, to evaluate individual and collective competences and finally, to elaborate strategies for the development of individual and collective competences. In this paper, we have focused on the problem of individual competence assessment. The assessment method must be based on operational tools for its effective implementation by users. In addition, it must be based on an analysis of not only the individual characteristics but also on the characteristics of the work situation [7].

The paper is structured as follows. In the next section, the problem description is given. Section 3 discusses the principle of the proposed assessment method. Section 4 discusses the characterization and prioritization of activities. Section 5 contains details of the characterization of actors and weighting of each assessment criterion. Section 6 discusses the proposed model for assessment of multi-skilled workforce using TOPSIS logic. In section 7 we present our conclusions.

II. RESEARCH CONTEXT AND PROBLEM DESCRIPTION

In this article, we will discuss the problem of assessing the individual performance level which is the manifestation of his/her competency. Thus, to measure the competence level we have chosen the use of tangible results revealing aspects of competence level. An individual is efficient when he/she performs activities with desired performance. The question is: are we talking about his/her performance or his/her competence? According to [19]: "Capable operators who have a good or a very good performance are considered very competent". According to [16], competence is virtual whereas performance is observable. According to the same author "performance becomes competence (i.e. the individual is a subject of a social judgment, an inference of competence from the observation of a performance) when it respects the conditions of efficiency, reproducibility and regularity". Therefore, we can say that the individual competence assessment is a judgment of the performance of the obtained results performed by the worker. In [5], the authors have defined five elements that can be affected by the individual performance: the labor costs, the working speed, the efficiency, the quality of work and the tasks that the worker can perform.

Some of the various techniques used to assess the individual competence are : descriptive assessment, conventional assessment scale; critical incident technique (CIT); repertory grid (RG); behaviorally anchored rating scales (BARS), management by objectives (MBO), etc. There are others models that use the linguistic assessments such as: The problem of evaluating the performance of intellectual capital [23], the problem of assessing knowledge management capacity [8]; problem of assignment under constraints of competences and preferences [10], etc. According to [3] and [22], the process of assessment is based on the difference between both the desired results and the achieved results. According to [18], the assessment by objectives is based on observable facts, which gives credibility and objectivity of the method. Our proposed method is based on the use of tangible results which allow us to provide a quantitative evaluation method.

Let us consider, for example, a production program to be carried out by an operator with medium level. After execution of the quantity demanded, we notice that the completion time exceeds the standard time (Fig. 1). Among the produced units there are non-compliant products and during production there were amounts of components which were handled improperly (Fig. 2). This additional time, non-compliant products and damaged components contribute to losses for companies, these losses are directly related to the worker's performance.

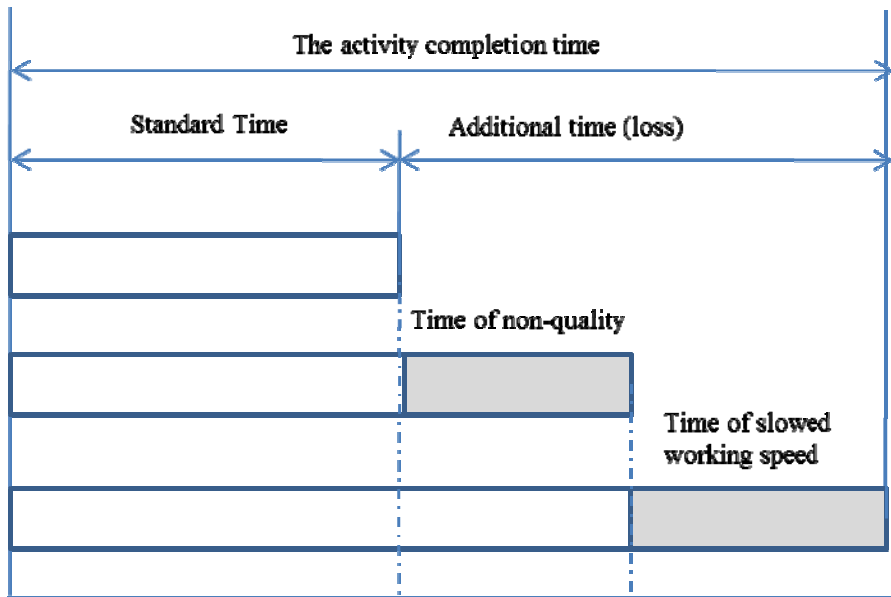


Fig. 1. Completion time compared to the standard time

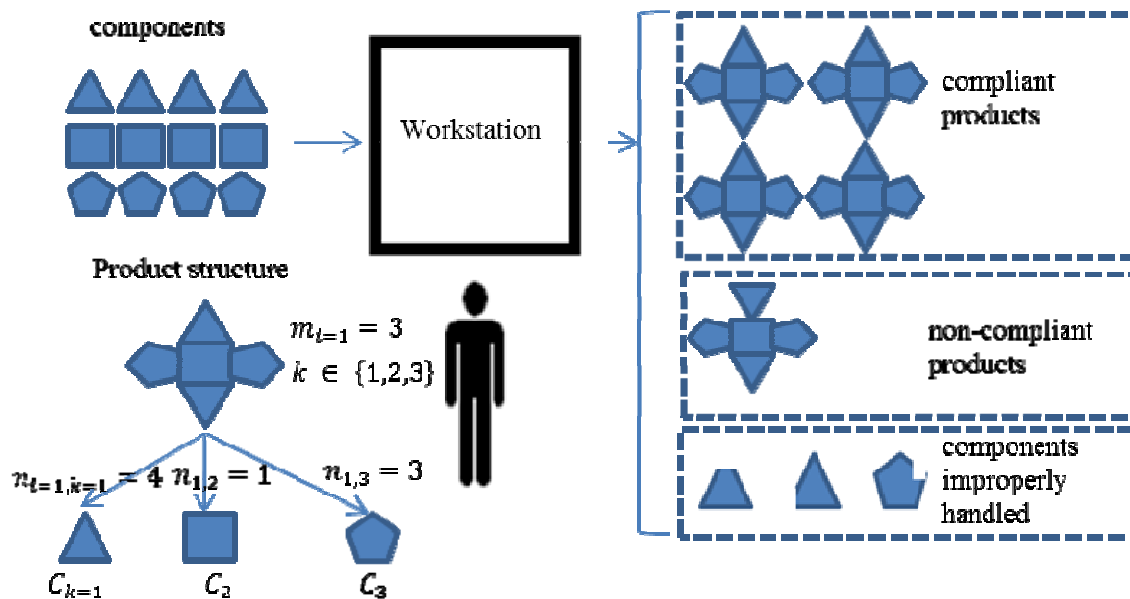


Fig. 2. The losses incurred

In this article, we will define the problem of quantification of an individual’s performance level of multi-skilled workforces with high added value in a manufacturing sector. To properly assess the competence level of the workforces, the most critical step is to determine the relative importance between activities to be performed and the same thing between assessment criteria. According to [9] criteria must be weighted because not all criteria have the same importance. This paper presents an aggregated evaluation indicator allowing the decision-maker to rank the production operators in an objective way.

III. PRINCIPLE OF THE ASSESSMENT METHOD

An activity is performed efficiently when it is performed within the allotted time, with good quality and with the respected number components or the quantity of the raw material used. To properly measure the individual competence level, it is important to have several evaluation criteria. The interest of this method is to help the decision maker to classify individuals. The classification may be carried by the use of advanced decision methods as that AHP (Analytical hierarchy process) and/or TOPSIS (Technique for order performance by similarity to ideal solution). In this paper, we propose an approach based on an evaluation process including AHP technique and TOPSIS logic, to assess the individual performance using the observed differences between required level and acquired level. The following figure (Fig. 3) shows the different steps which are detailed below:

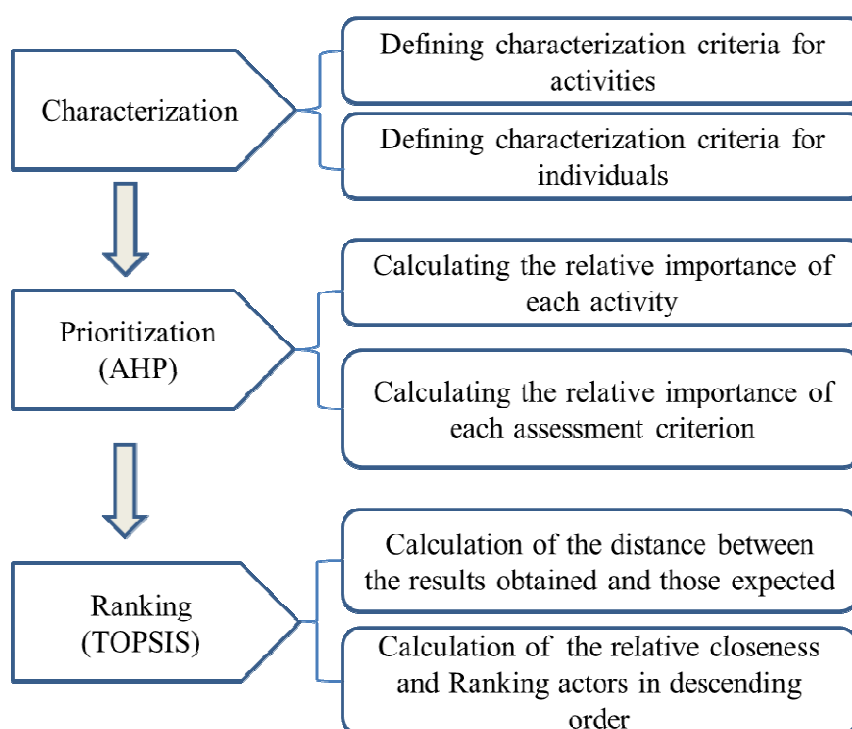


Fig.3. The steps of the assessment method

IV. CHARACTERIZATION AND PRIORITIZATION OF ACTIVITIES

A. Characterization of activities

The characterization and the prioritization of activities depend on their importance and the context of the company. In this article we proposed to characterize the activities by their complexity of realization. We assumed that the complexity of carrying out an activity is based on four contextual factors as shown in Fig. 4.

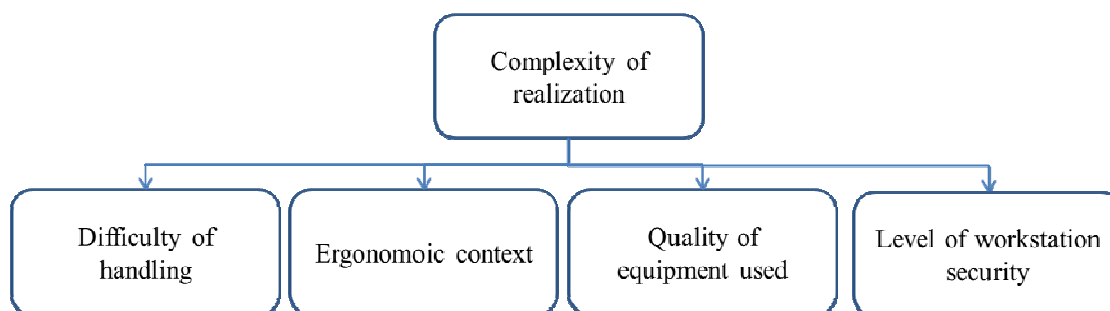


Fig.4. Characterization of activities

Where,

-“Difficulty of handling”is related to the nature of the procedure followed (number of steps, number of parts to be assembled) and the quality of the raw material used (easy or difficult to process);

-“Ergonomic context”reflects the ergonomic working conditions (force exerted, posture, etc...);“Quality of equipment used”reflects the influence of the material used in performing an activity;

-“Level of workstation security”is related to the vigilance required to perform the requested activity.

In order to quantify the complexity of realization (C) in an objective manner, we have considered the value of (Ts : standard time) which indicates the theoretical time needed to perform a given activity taking into consideration the four contextual factors. So the value of (Ts) can reflect the degree of complexity of a given activity in a quantitative manner.

B. Prioritization of activities

To prioritize a given activity, we suggest using AHP method with a matrix that involves three criteria: Raw material cost, profit margin reflecting the importance of the activity and the complexity which reflects the degree of difficulty in performing the activity. Several methods have been proposed in the literature to describe the importance of alternatives. We choose the AHP method which can provide the decision maker with relevant information to assist him/her in choosing the best alternative or to rank a set of alternatives [21]. In this paper, the AHP method is used to rank activities in order to prioritize them. AHP method is based on four steps : The first step is the identification of criteria as shown in Fig. 5. Second step consists in pair-wise comparison for all criteria. The third step contains the determination of activities’ weight and the last step is the ranking of activities. In this paper, to prioritize a given activity, we have adopted three criteria: raw material cost (Cmp), profit margin (Pm) and complexity (C).

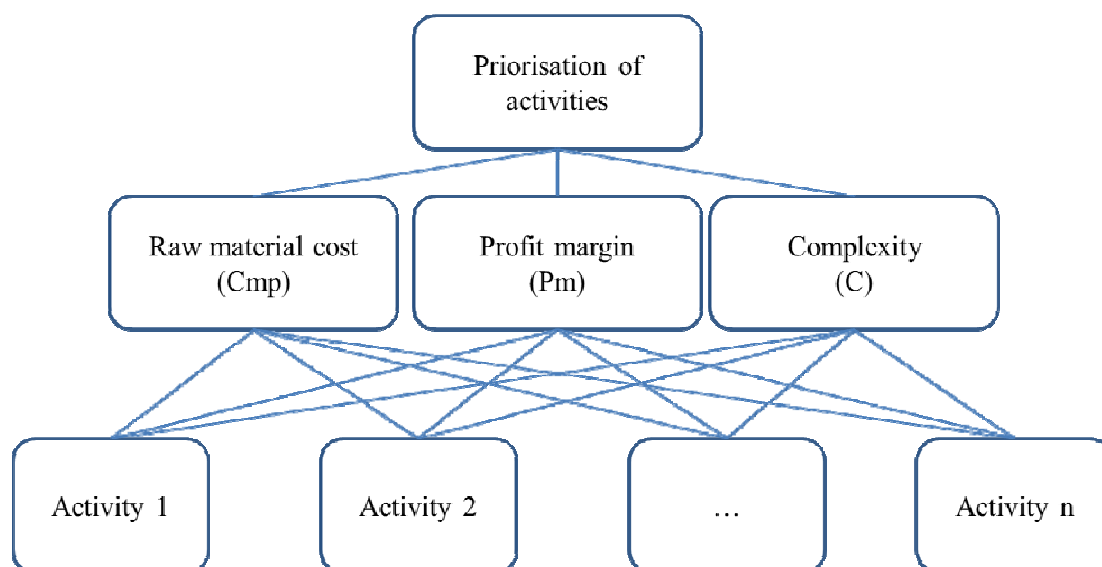


Fig. 5. Hierarchy of criteria

1) Calculation of criteria weight:

In this phase we will define the relative importance of each criterion. The relative importance varies from a criterion to another by reference to each activity. But, in our case we have three non-homogenous quantitative criteria (Cmp and Pm are both a cost criterion; C is not a cost criterion), we will first express the value of (C) as a cost.

As we have seen previously the complexity is expressed in term of (Ts), if we consider that the manufacturing cost (Cf) to produce one unit of a given activity (i) is equal to the multiplication of the average hourly rate (AHR) (expressed in money unit per hour) and the standard time (Ts) (expressed in hour) needed to produce one unit of the same activity, we get: $Cf_{i(1unit)} = AHR \cdot Ts_{i(1unit)}$ with, (AHR) corresponds to the overall charges to be covered divided by the number of invoiced hours. We can deduce that the complexity (C) is directly related to (Cf) : when the complexity (C) increases, the value of (Ts) increases. Consequently, the manufacturing cost (Cf) increases. And we can also rapidly deduce that the combination of those three costs allows calculating the selling price (SP) as follows:

$$SP_{i(1unit)} = Cmp_{i(1unit)} + Cf_{i(1unit)} + Pm_{i(1unit)}$$

Therefore, to determine the relative importance (α_p) of each criterion (p), we propose the following logic:

$$\alpha_1 = \frac{\sum_{i=1}^{i=n} Cmp_i (1 \text{ unit})}{\sum_{i=1}^{i=n} SP_i (1 \text{ unit})}$$

$$\alpha_2 = \frac{\sum_{i=1}^{i=n} Pm_i (1 \text{ unit})}{\sum_{i=1}^{i=n} SP_i (1 \text{ unit})} \tag{1}$$

$$\alpha_3 = \frac{\sum_{i=1}^{i=n} AHR.TS_i (1 \text{ unit})}{\sum_{i=1}^{i=n} SP_i (1 \text{ unit})}$$

As an illustrative example, we consider four alternatives A1, A2, A3 and A4; the three proposed criteria (raw material cost (Cmp), Profit margin (Pm) and Complexity (C)). We suppose the following input data shown in Table 1.

TABLE I. An example of input data concerning activities

	Cmp (\$)	Pm (\$)	C (h)	AHR (\$/h)	Cf (\$)	SP (\$)
A 1	30	40	0,50	40	20,0	90,0
A 2	25	30	0,42	40	16,7	71,7
A 3	40	30	0,17	40	6,7	76,7
A 4	25	20	0,75	40	30,0	75,0
Total	120	120	-	-	73,3	313,3

Thus, the criteria weight value is calculated as follow:

TABLE II. The criteria weight value

	Cmp	Pm	C
α_p	0,383	0,383	0,234

2) Calculation of activities' weight

In this segment, we proposed to use a pair-wise comparison based on ratios calculated from quantitative input data. We assume the input data shown in Table 1.

For instance, when we should express judgment when activity A2 is compared to activity A1 in terms of raw material cost. The corresponding comparison assumes the value of $\frac{Cmp_2}{Cmp_1} = 1.2$. And, when activity A1 is compared to activity A2, the corresponding comparison assumes the value of $\frac{Cmp_1}{Cmp_2} = 0.83$. A similar interpretation is true for the rest. The next step consists in calculating the relative importance for each activity relative to each criterion as shown in Tables 3(a), 3(b) and 3(c).

For the first criterion "raw material cost (Cmp)", the judgment matrix with the pair-wise comparisons is calculated as follow (2):

$$[a_{ij}] = \begin{bmatrix} 1 & Cmp_1/Cmp_2 & \dots & Cmp_1/Cmp_n \\ Cmp_2/Cmp_1 & \cdot & \cdot & Cmp_2/Cmp_n \\ \vdots & \cdot & \ddots & \vdots \\ Cmp_n/Cmp_1 & Cmp_n/Cmp_2 & \dots & 1 \end{bmatrix} \tag{2}$$

TABLE III (a). Criteria pair-wise comparison matrix for raw material cost (Cmp)

	a_{ij}				r_{ij}				w_{ip}
	A1	A2	A3	A4	A1	A2	A3	A4	
A1	1,00	1,20	0,75	1,20	0,25	0,25	0,25	0,25	0,25
A2	0,83	1,00	0,63	1,00	0,21	0,21	0,21	0,21	0,21
A3	1,33	1,60	1,00	1,60	0,33	0,33	0,33	0,33	0,33
A4	0,83	1,00	0,63	1,00	0,21	0,21	0,21	0,21	0,21
Sum	4,00	4,80	3,00	4,80	1,00	1,00	1,00	1,00	1,00

Where,

$$r_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} \quad \forall j \in N \quad (2)$$

$$w_{ip} = \frac{\sum_{i=1}^n r_{ij}}{n} \quad \forall p \in O \quad (3)$$

For the second criterion “Profit margin (Pm)”, the judgment matrix with the pair-wise comparisons is calculated as follow (4):

$$[a_{ij}] = \begin{bmatrix} 1 & Pm_1/Pm_2 & \dots & Pm_1/Pm_n \\ Pm_2/Pm_1 & \cdot & \cdot & Pm_2/Pm_n \\ \vdots & \cdot & \ddots & \vdots \\ Pm_n/Pm_1 & Pm_n/Pm_2 & \dots & 1 \end{bmatrix} \quad (4)$$

TABLE III (b). Criteria pair-wise comparison matrix for profit margin (Pm)

	a_{ij}				r_{ij}				w_{ip}
	A1	A2	A3	A4	A1	A2	A3	A4	
A1	1,00	1,33	1,33	2,00	0,33	0,33	0,33	0,33	0,33
A2	0,75	1,00	1,00	1,50	0,25	0,25	0,25	0,25	0,25
A3	0,75	1,00	1,00	1,50	0,25	0,25	0,25	0,25	0,25
A4	0,50	0,67	0,67	1,00	0,17	0,17	0,17	0,17	0,17
Sum	3,00	4,00	4,00	6,00	1,00	1,00	1,00	1,00	1,00

For the third criterion “complexity (C)”, the judgment matrix with the pair-wise comparisons is calculated as follow (5):

$$[a_{ij}] = \begin{bmatrix} 1 & TS_1/TS_2 & \dots & TS_1/TS_n \\ TS_2/TS_1 & \cdot & \cdot & TS_2/TS_n \\ \vdots & \cdot & \ddots & \vdots \\ TS_n/TS_1 & TS_n/TS_2 & \dots & 1 \end{bmatrix} \quad (5)$$

TABLE III (c). Criteria pair-wise comparison matrix for complexity (C)

	a_{ij}				r_{ij}				w_{ip}
	A1	A2	A3	A4	A1	A2	A3	A4	
A1	1,00	1,20	3,00	0,67	0,27	0,27	0,27	0,27	0,27
A2	0,83	1,00	2,50	0,56	0,23	0,23	0,23	0,23	0,23
A3	0,33	0,40	1,00	0,22	0,09	0,09	0,09	0,09	0,09
A4	1,50	1,80	4,50	1,00	0,41	0,41	0,41	0,41	0,41
Sum	3,67	4,40	11,00	2,44	1,00	1,00	1,00	1,00	1,00

3) Ranking of activities

The relative importance of each criterion is determined previously using pair-wise comparisons. And the activities are compared with each other in terms of each criterion. The final priorities denoted by φ_i are determined according to the following formula (6):

$$\varphi_i = \sum_{l=1}^{l=p} w_{ip} \alpha_p, \quad \forall i \in N \quad (6)$$

The previous priority vectors resulting from the previous pair-wise matrixes are used to form the entries of the decision matrix. The final priorities are calculated according to formula (8). Table 4 illustrates the global weights of activities.

TABLE IV. The global weights of activities

	Cmp	Pm	C	φ_i
	$\alpha_1 = 0,383$	$\alpha_2 = 0,383$	$\alpha_3 = 0,234$	
A1	$w_{11} = 0,25$	0,33	$w_{13} = 0,27$	0,287
A2	0,21	0,25	0,23	0,229
A3	0,33	0,25	0,09	0,245
A4	$w_{41} = 0,21$	0,17	$w_{43} = 0,41$	0,239

V. CHARACTERIZATION OF ACTORS AND WEIGHTING OF EACH ASSESSMENT CRITERION

A. Characterization of actors

The performing of a given activity by an individual requires mobilizing individual competencies which reflect the techniques used to solve problems; processing, reasoning and behaviors related to the characteristics of the worker. The description and the assessment of these elements are difficult. To overcome this difficulty, we have proposed to characterize them in terms of tangible results. Thus, we can say that a task is performed efficiently when it is done within the allotted time, with good quality and the respected theoretical number of components or the theoretical quantity of raw material needed to be used. In this paper, we have adopted the three evaluation criteria proposed by [26] as illustrated in Fig. 6. with a modification of the third criterion.

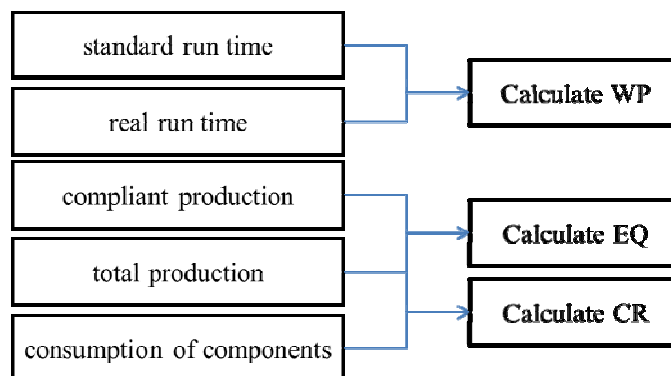


Fig. 6. The three evaluation criteria

In the manufacturing industry, each operator masters one or more activities. We can say that a given activity is performed efficiently when it is done within the allotted time, with good quality and with respect of the number of components set by the bill material file. In this work, we adopted the actors' characterizations discussed by [26]. Therefore, we express a worker's efficiency through three indicators: The first indicator (WP_{ij}) is the work performance of the operator (j) demonstrated when performing the activity (i).

$$WP_{ij} = \frac{Ts(Qp_{ij})}{Tr(Qp_{ij})} \tag{7}$$

With,

Qp_{ij} : The planned quantity of activity (i) assigned to be done by the operator (j);

$Ts(Qp_{ij})$: The standard time required to execute Qp_{ij} ;

$Tr(Qp_{ij})$: The run time spent in executing Qp_{ij} .

The second indicator (EQ_{ij}) is the execution quality of the operator (j) demonstrated when performing the activity (i).

$$EQ_{ij} = \frac{Qd_{ij}}{Qp_{ij}} \tag{8}$$

With,

Qd_{ij} : Compliant production of activity (i) produced by operator (j);

Qp_{ij} : Total production of activity (i) produced by operator (j) (The planned quantity).

The third evaluation indicator (CR_{ij}) is defined as the ratio between the total production carried out by the worker and the quantity of raw material used (Fig. 1.):

$$CR_{ij} = \left[\prod_{k=1}^{k=m_i} CR_{kj} \right]^{1/m_i} = Qp_{ij} \cdot \left[\prod_{k=1}^{k=m_i} \frac{n_{ik}}{Qc_{ijk}} \right]^{1/m_i} \quad (9)$$

With,

m_i : Number of components required to produce one unit of the activity (i);

k : Index of component;

n_{ik} : Number of the component (k) required to produce one unit of the activity (i);

Qc_{ijk} : The amount of component (k) consumed by the operator (j) to produce(Qp_i).

B. Calculation of the degree of importance of each assessment criterion

For the weighting of the three adopted sub-criteria (WP, EQ and CR), which reflect the individual performance, we have used the AHP technique. In the same manner as weighting activities, we proposed to use a pair-wise comparison based on ratios calculated from quantitative. To avoid subjectivity and in order to compare the different criteria in a quantitative way, we will determine the relationships between the three criteria and the different production costs (manufacturing cost, cost of non-quality and cost of waste). In this section, we will formulate the extra cost resulting from the assignment of a given activity (i) to a given operator (j) whose initial performance is not optimal. The demonstration presents three costs: the first one contains the extra cost due to additional time related to the working speed; the second one discusses the extra cost due to non-compliant products, the third one is the extra cost due to the loss of components which are improperly handled.

1) First cost due to the additional time

If the work performance (WP) is less than 1, this means there is an extra time in addition to the standard time. The extra time (Ta) is defined as the difference between the standard time (Ts) required achieving a given activity and the real time (Tr) spent on its achievement. So, there is an extra cost resulting from the assignment of a given activity (i) to a given operator (j) whose work performance is (WP). The extra time (Ta) to produce the quantity demanded (Qd_i) is defined as:

$$Ta(Qd_i) = (1 - WP_i) \cdot Tr(Qd_i) \quad (10)$$

Let,

$$Ts(Qd_i) = Ts_{i(1 \text{ unit})} \cdot Qp_i = Ts_{i(1 \text{ unit})} \cdot \frac{Qd_i}{EQ_i} \quad (11)$$

Replacing (11) in (7), we get:

$$Tr(Qd_i) = \frac{Ts_{i(1 \text{ unit})}}{WP_i \cdot EQ_i} * Qd_i \quad (12)$$

Substituting (12) in (10), the extra time due to the additional time is:

$$Ta(Qd_i) = \frac{1 - WP_i}{WP_i \cdot EQ_i} \cdot Ts_{i(1 \text{ unit})} \cdot Qd_i \quad (13)$$

The extra cost (Cat) due to the additional time (Ta) to produce (Qd) is equal to:

$$Cat(Qd_i) = Ta(Qd_i) \cdot AHR = \frac{1 - WP_i}{WP_i \cdot EQ_i} \cdot Ts_{i(1 \text{ unit})} \cdot Qd_i \cdot AHR \quad (14)$$

Therefore,

$$Cat_{i(1 \text{ unit})} = \frac{1 - WP_i}{WP_i * EQ_i} \cdot Ts_{i(1 \text{ unit})} \cdot AHR \quad (15)$$

We can deduce that (Cat) is related to (WP), when (WP) decreases the value of (Cat) increases. As a result, the value of (Cat) is inversely proportional to (WP).

2) Second cost due to poor product:

If the execution quality (EQ) is less than 1, this means there are wrong products. Assume that (Cnq(Qp_i)) corresponds to the cost of non-quality incurred when producing the planned quantity (Qp_i) of the activity (i).

Let,

$$\text{wrong product } (Qp_i) = (1 - EQ_i) \cdot Qp_i = (1 - EQ_i) \cdot \frac{Qd_i}{EQ_i} \quad (16)$$

We considered that $(Cr_{i(1\ unit)})$ corresponds to the production cost and it's equal to the sum of the raw material cost $(Cmp_{i(1\ unit)})$ and the manufacturing cost $(Cf_{i(1\ unit)})$, so:

$$Cnq(Qp_i) = \frac{1 - EQ_i}{EQ_i} \cdot Qd_i \cdot Cr_{i(1\ unit)} \quad (17)$$

Thus,

$$Cnq_{i(1\ unit)} = \frac{1 - EQ_i}{EQ_i} \cdot Cr_{i(1\ unit)} \quad (18)$$

Therefore, we can deduce that when (EQ) decreases, (Cnq) will increase. As a result, the value of (Cnq) is inversely proportional to (EQ).

3) *Third cost due to damaged components:*

If the consumption ratio (CR) is less than 1, this means there are damaged components due to improper use. Assume that $(C_d(Qp_i))$ corresponds to the cost of "damaged components" incurred when producing the planned quantity (Qp_i) of the activity (i) and $(Cmp_{i(1\ unit)})$ corresponds to the raw material cost needed to produce one unit, with: $Cmp_{i(1\ unit)} = \sum_{k=1}^{m_i} n_{ik} \cdot Cmp_{ik}$, where (Cmp_{ik}) corresponds to the purchase cost of components (k), then $(C_d(Qp_i))$ is:

$$C_d(Qp_i) = \sum_{k=1}^{m_i} \left(\frac{1 - CR_{ik}}{CR_{ik}} \right) \cdot n_{ik} \cdot Qp_i \cdot Cmp_{ik} \quad (19)$$

$$C_d(Qp_i) = \frac{Qd_i}{EQ_i} \cdot \sum_{k=1}^{m_i} \left(\frac{1 - CR_{ik}}{CR_{ik}} \right) \cdot n_{ik} \cdot Cmp_{ik}$$

We propose the following hypothesis: $CR_{ik} = cte, \forall k$. So, $CR_i = \left[\prod_{k=1}^{m_i} CR_{ik} \right]^{1/m_i} = CR_{ik}$

So:

$$C_d(Qp_i) = \frac{Qd_i}{EQ_i} \cdot \left[\frac{Cmp_{i(1\ unit)}}{CR_i} - Cmp_{i(1\ unit)} \right] \quad (20)$$

Therefore:

$$C_d(Qp_i) = \frac{1 - CR_i}{EQ_i \cdot CR_i} \cdot Qd_i \cdot Cmp_{i(1\ unit)} \quad (21)$$

$$C_{d_{i(1\ unit)}} = \frac{1 - CR_i}{EQ_i \cdot CR_i} \cdot Cmp_{i(1\ unit)} \quad (22)$$

We can deduce that (Cd) is related to (CR), when (CR) decreases the cost (Cd) will increase. As a result, the value of (Cd) is inversely proportional to (CR).

For weighting the three sub-criteria (WP, EQ and CR) in an objective manner, we have used the three factors (Cat, Cnq and Cd) because they are homogeneous and they are all inversely proportional to the three evaluation criteria. As an illustrative example we assume the following input data shown in Table 5.

TABLE V. Quantitative input data (Example)

	$WP_{average}$	$EQ_{average}$	$CR_{average}$	$Cat_{(1\ unit)}$	$Cnq_{(1\ unit)}$	$Cd_{(1\ unit)}$
A 1	0,8	0,95	0,92	5,3	2,6	2,7
A 2	0,9	0,92	0,87	2,0	3,6	4,1
A 3	0,78	0,9	0,9	2,1	5,2	4,9
A 4	0,85	0,95	0,94	5,6	2,9	1,7

For instance, when we express a judgment where (WP) is compared to (EQ) by reference to the activity (A1), the corresponding comparison assumes the value of $\frac{Cat_1}{Cnq_1} = 2.05$. And, when (EQ) is compared to (WP), the corresponding comparison assumes the value of $\frac{Cnq_1}{Cat_1} = 0.49$. A similar interpretation is true for the other comparisons.

The next step is to extract the relative importance of each assessment criterion (WP, EQ and CR) by reference to each activity. Tables 6(a), 6(b), 6(c) and 6(d) represent comparison matrixes of the three criteria respectively for the four activities.

For the first activity (A1), the judgment matrix with the pair-wise comparisons is calculated as follows(23):

$$[a_{ij}] = \begin{bmatrix} 1 & Cat_1/Cnq_1 & Cat_1/Cd_1 \\ Cnq_1/Cat_1 & 1 & Cnq_1/Cd_1 \\ Cd_1/Cat_1 & Cd_1/Cnq_1 & 1 \end{bmatrix} \quad (23)$$

TABLE VI (a). Criteria pair-wise comparison matrix for Activity 1

A 1	a_{ij}			r_{ij}			ω_{ic}
	WP	EQ	CR	WP	EQ	CR	
WP	1,00	2,04	1,96	0,50	0,50	0,50	0,50
EQ	0,49	1,00	0,96	0,25	0,25	0,25	0,25
CR	0,51	1,04	1,00	0,25	0,25	0,25	0,25
total	2,00	4,08	3,93	1,00	1,00	1,00	1,00

In the same way, we develop the three comparison matrix for the others activities:

TABLE VI (b). Criteria pair-wise comparison matrix for Activity 2

A 2	a_{ij}			r_{ij}			ω_{ic}
	WP	EQ	CR	WP	EQ	CR	
WP	1,00	0,56	0,49	0,21	0,21	0,21	0,21
EQ	1,80	1,00	0,88	0,37	0,37	0,37	0,37
CR	2,05	1,14	1,00	0,42	0,42	0,42	0,42
total	4,85	2,69	2,37	1,00	1,00	1,00	1,00

TABLE VI (c). Criteria pair-wise comparison matrix for Activity 3

A 3	a_{ij}			r_{ij}			ω_{ic}
	WP	EQ	CR	WP	EQ	CR	
WP	1,00	0,40	0,43	0,17	0,17	0,17	0,17
EQ	2,48	1,00	1,06	0,43	0,43	0,43	0,43
CR	2,33	0,94	1,00	0,40	0,40	0,40	0,40
total	5,81	2,35	2,49	1,00	1,00	1,00	1,00

TABLE VI (d). Criteria pair-wise comparison matrix for Activity 4

A 4	a_{ij}			r_{ij}			ω_{ic}
	WP	EQ	CR	WP	EQ	CR	
WP	1,00	1,93	3,29	0,55	0,55	0,55	0,55
EQ	0,52	1,00	1,71	0,28	0,28	0,28	0,28
CR	0,30	0,59	1,00	0,17	0,17	0,17	0,17
total	1,82	3,52	6,00	1,00	1,00	1,00	1,00

The Table 7 summarizes the calculation made previously:

TABLE VII. Relative importance of assessment criterion

ω_{ic}	A1	A2	A3	A4
WP	$\omega_{11} = 0,50$	0,21	0,17	$\omega_{41} = 0,55$
EQ	$\omega_{12} = 0,25$	0,37	0,43	$\omega_{42} = 0,28$
CR	$\omega_{13} = 0,25$	0,42	0,40	$\omega_{43} = 0,17$

VI. THE PROPOSED MODEL FOR ASSESSMENT OF MULTI-SKILLED WORKFORCE USING TOPSIS LOGIC

TOPSIS (Technique for order performance by similarity to ideal solution) [11] is a practical and useful technique for ranking and selection of a number of alternatives through distance measures. [11] further proposes that the ranking of alternatives will be based on the shortest distance from the positive ideal solution and the farthest from the negative ideal solution. It originates from the concept of a displaced ideal point from which the compromise solution has the shortest distance [2] [27]. TOPSIS has been successfully applied to various areas such as transportation [12], product design [13], manufacturing [15], plant location analysis [24], etc. In our case we have used the TOPSIS logic for order workers according to their relative closeness, and to provide an aggregated evaluation. The major weaknesses of TOPSIS technique are in not providing for weight elicitation, and consistency checking for judgments [20]. To make an objective assessment, we suggest an integrated approach that simultaneously uses the AHP technique for weighting and TOPSIS logic for ranking.

For TOPSIS technique, a decision matrix is required at the beginning of the process. The decision matrix contains competitive alternatives (activities), with their attributes' ratings. Originally TOPSIS utilizes Euclidean distances; the best alternative should be at the shortest distance from the ideal solution and the farthest distance from the anti-ideal solution. The detailed procedure is illustrated with an example in the following sections.

A. Construct judgment matrix

The structure of the matrix can be expressed as shown in Table 8: where Op_j denotes the operators (j), $j \in M$; A_i denotes activity (i), $i \in N$; AC_c represents sub-criterion c , $c \in L$. v_{ikj} indicates the performance rating of operator (Op_j) with respect to activity (A_i) and assessment criterion (AC_c). The performance rating is calculated using the three formulas (7), (8) and 9.

TABLE VII. Judgment matrix with performance rating

A_i	AC_c	T_{ic}	Op_1	Op_2	Op_3	Op_4
A 1	WP	0,9	$v_{111} = 0,86$	0,77	0,72	$v_{114} = 0,76$
	EQ	0,95	0,91	0,83	0,83	0,91
	CR	0,96	0,9	0,81	0,94	0,92
A 2	WP	0,92	0,81	0,85	0,77	0,8
	EQ	0,98	0,83	0,9	0,93	0,9
	CR	0,95	0,8	0,89	0,82	0,87
A 3	WP	0,89	0,76	0,83	0,94	0,94
	EQ	0,97	0,87	0,8	0,89	0,86
	CR	0,9	0,8	0,82	0,88	0,85
A 4	WP	0,85	0,93	0,79	0,78	0,81
	EQ	0,96	0,93	0,82	0,81	0,87
	CR	0,95	0,89	0,89	0,95	$v_{434} = 0,95$

B. Calculation of the degree of importance of each activity and each assessment criterion

Using pair-wise comparisons, the relative importance of each activity and assessment criterion was previously computed. The Table 9 summarizes the calculation made previously with:

TABLE IX. Relative importance of each activity and assessment criterion

A_i	φ_i	AC_c	ω_{ic}
A 1	0,287	WP	0,50
		EQ	0,25
		CR	0,25
A 2	0,229	WP	0,21
		EQ	0,37
		CR	0,42
A 3	0,245	WP	0,17
		EQ	0,43
		CR	0,40
A 4	0,239	WP	0,55
		EQ	0,28
		CR	0,17

C. Determination of the ideal levels and anti-ideal levels

By analogy with the TOPSIS method, we choose for each activity the best and the worst performance rating as ideal and anti-ideal performance level.

$$V_{ic}^- = \{v_{11}^-, \dots, v_{1l}^-, \dots, v_{nl}^-\} \tag{24}$$

Where:

$$v_{ic}^- = \text{Min}(v_{icj}) \quad \forall i \in N; \forall c \in L \tag{25}$$

And:

$$V_{ic}^+ = \{v_{11}^+, \dots, v_{1l}^+, \dots, v_{nl}^+\} \tag{26}$$

Where:

$$v_{ic}^+ = \begin{cases} \text{Max}_{ic}(x_{icj}) & \text{if } T_{ic} < \text{Max}(v_{icj}) \\ T_{ic} & \text{if } T_{ic} > \text{Max}(v_{icj}) \end{cases} \quad \forall i \in N; \forall c \in L \tag{27}$$

The idea is to minimize the gap between the required performance level and the acquired performance level. The Table 10 summarizes the ideal and anti-ideal performance level.

TABLE X. Ideal levels and anti-ideal levels

A_i	AC_c	v_{ic}^+	v_{ic}^-
A 1	WP	0,9	0,72
	EQ	0,95	0,83
	CR	0,96	0,81
A 2	WP	0,92	0,77
	EQ	0,98	0,83
	CR	0,95	0,80
A 3	WP	0,94	0,76
	EQ	0,97	0,80
	CR	0,9	0,80
A 4	WP	0,93	0,78
	EQ	0,96	0,81
	CR	0,95	0,89

D. Normalization

Originally TOPSIS utilized Euclidean distances. The best alternative should have the shortest distance from the ideal solution and the farthest distance from the anti-ideal solution. In our case, the separation measures from ideal level and anti-ideal level are computed through Minkowski's distance with p=1.

Considering the difficulty in comparing various criteria with different natures and different thresholds (Maximum performance and minimum performance for each criteria and each activity), this step was employed to normalize the scales of different selected criterion. In this case, the min-max normalization is introduced to scales the data from $(v_{ik}^+; v_{ik}^-)$ to $(0, 1)$ in proportion as shown in Fig. 7. The advantages of this method can be concluded as:

- 1) It preserves all relationships of the data values exactly since it carries out a linear normalization;
- 2) It does not introduce any potential bias into the data, and 3) it functions to nondimensionalize different indicator, further making them comparable [14] [25]. A parameter $\lambda_{icj} \in [0, 1]$ is identified to normalize (v_{icj}) given by the following formula:

$$\lambda_{icj} = \frac{v_{icj} - v_{ic}^-}{v_{ic}^+ - v_{ic}^-} \quad (28)$$

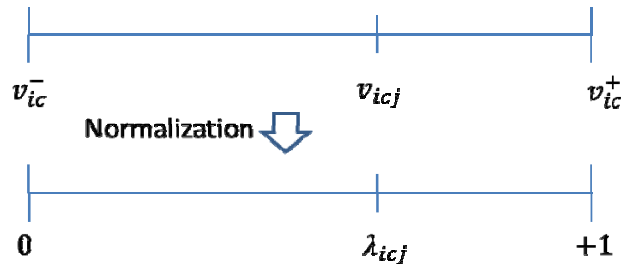


Fig. 7. The principal of normalization

The Table 11 presents the judgment matrix after normalization of the performance rating.

TABLE XI. Normalization of the performance rating

A_I	AC_c	T_{ic}	Op1	Op2	Op3	Op4
A 1	WP	0,9	$\lambda_{111} = 0,78$	0,28	0	$\lambda_{114} = 0,22$
	EQ	0,95	0,67	0	0	0,67
	CR	0,96	0,6	0	0,87	0,73
A 2	WP	0,92	0,27	0,53	0	0,2
	EQ	0,98	0	0,47	0,67	0,47
	CR	0,95	0	0,6	0,13	0,47
A 3	WP	0,89	0	0,39	1	1
	EQ	0,97	0,41	0	0,53	0,35
	CR	0,9	0	0,20	0,8	0,5
A 4	WP	0,85	1	0,07	0	0,2
	EQ	0,96	0,8	0,07	0	0,4
	CR	0,95	$\lambda_{431} = 0$	0	1	$\lambda_{434} = 1$

E. Calculation of the relative closeness PL_j and ranking

For a compound competence, performance level $PL_j \in [0, 1]$ is an indicator of the degree of excellence in the use of all individual competencies by worker (j) in execution of all activities. The value of performance level is calculated using the following formula:

$$PL_j = \frac{D_j^-}{D_j^+ + D_j^-} \quad (29)$$

Where,

The distances from ideal level:

$$D_j^+ = \sum_{i=1}^N \varphi_i \sum_{c=1}^L \omega_{ic} \cdot D_{icj}^+ \quad , \forall j \in M \quad (30)$$

The distances from anti-ideal level:

$$D_j^- = \sum_{i=1}^N \varphi_i \sum_{c=1}^L \omega_{ic} \cdot D_{icj}^- , \forall j \in M \tag{31}$$

With:

$$D_{icj}^+ = 1 - \lambda_{icj}$$

$$D_{icj}^- = \lambda_{icj}$$

$$\sum_{i=1}^N \varphi_i = 1; \sum_{c=1}^L \omega_{ic} = 1 , \forall i \in N$$

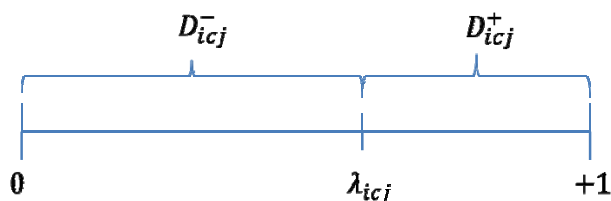


Fig. 8. The principal of distances calculation

Therefore,

$$PL_j = \frac{D_j^-}{D_j^+ + D_j^-} = \sum_{i=1}^N \varphi_i \sum_{c=1}^L \omega_{ic} \cdot \lambda_{icj} , \forall j \in M \tag{32}$$

We need to calculate the relative closeness and rank workers in descending order. The larger is the index value; the better is the performance of the operator. The Table 12 and Fig. 9. present the relative closeness and ranking of operators with respect to the ideal performance level.

TABLE XII. The relative closeness and ranking

	Op1	Op2	Op3	Op4
D+	0,556	0,788	0,652	0,552
D-	0,444	0,212	0,348	0,448
PL	0,444	0,212	0,348	0,448
Rank	2	4	3	1

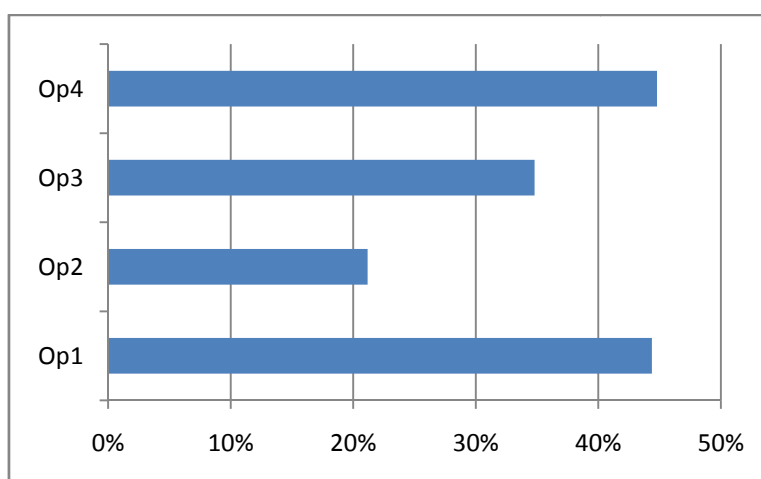


Fig. 9. The relative closeness and ranking

In this paper, we have proposed a hybrid TOPSIS-AHP model for synthesizing priorities and rating values into a single integrated indicator.

VII. CONCLUSION

This approach seems more meaningful since it involves a decision process using AHP and TOPSIS techniques for assessment of multi-skilled workforce in an objective way. In the manufacturing industry human resources are reconsidered as a key element of performance. In this context, we have defined different criteria and we have used decision making techniques to provide an operational tool for assessment of multi-skilled workforce. In this paper, we have proposed a method using AHP technique and TOPSIS logic for classification of workers; we have expressed the worker's efficiency through tangible results. We have used AHP technique as decision support tool for weighting assessment criteria and activities. On the other hand, we have also used TOPSIS logic as a decision support tool for distance measuring between acquired levels and required levels. The model proposed in this study is meaningful for aggregation, simple to use for real-world applications and allows the company to better determine the available performance levels of human resources they possess.

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