THE APPLICATION OF THE FUZZY AGGREGATION NORMS TO TECHNICAL STAFF TASKS DELEGATION

Aleksandra Mrela
Faculty of Technology
Kujawy and Pomorze University, Bydgoszcz, Poland
a.mrela@kpsw.edu.pl

Oleksandr Sokolov
Faculty of Physics, Astronomy and Informatics
Nicolaus Copernicus University, Toruń, Poland
osokolov@fizyka.umk.pl

Grzegorz Śmigielski
Faculty of Mathematics, Physics & Technical Sciences
Kazimierz Wielki University, Bydgoszcz, Poland
gs@ukw.edu.pl

Oleksii Sokolov
Comarch S.A., Kraków, Poland
oleksii.sokolov@comarch.com

Szymon Uczciwek
Comarch S.A., Kraków, Poland
szymon.uczciwek@comarch.com
Abstract

The methods for calculating professional competence levels of technicians based on fuzzy relations and the optimistic fuzzy aggregation norm has been proposed. Since it is difficult to estimate levels of professional competence of all tasks by all members of a team of technicians, the proposed method depends on a sequence of fuzzy relations which values are relatively easy to estimate and which the S-T-compositions produces the fuzzy relation of professional competence of all technicians. The proposed method is compared with the application of Minkowski metrics which is one of the objective methods of searching the best object in multi-criteria decision systems. Based on these two methods, the ranking of technicians can be prepared. Moreover, the method of results visualization is proposed.

Key Words: professional competence, fuzzy relation, optimistic fuzzy aggregation norm, visualisation, Minkowski metric

Introduction. In our very fast-changing world, members of the technical staff of companies have to acquire more and more skills to keep technological equipment in a well-functioning condition. Since each year new technology and devices appear and the models used so far can be purchased only in new versions, highly improved, the technical staff of each company has to keep studying the instructions and develop their knowledge and skills in maintaining the equipment installed for their purpose or used for service business. It can range from specialist hardware (medical, telecommunication) to everyday office hardware.

Many researchers try to examine business processes to optimize them to make companies more competitive. One way is to find methods to control business actions [18], the other is proposing a method for searching the priorities of knowledge and technology factors to find sustainable competitive advantages [16]. Fuzzy logic based models can be applied to solve many business problems like, for example, controlling teams [10], estimating criteria for assessment of importance of risks for innovative projects [5] or calculating the levels of personal achievements. One of the primary targets for the companies is reducing the operations costs and increasing the valuable amount of job that can be done by a single resource in time [17].

Figure 1. The diagram of stages of business processes

To achieve these goals the companies are continuously trying to improve their processes and their internal systems, that they are using to fulfill the complete Business processes. Each business process contains from different stages (Fig. 1), for example [11]:

Initiating process
Planning process
Executing process
Closing process
1. Initiation,
2. Planning,
3. Execution,
4. Reporting.

Some industries like telecommunications built their standards related to technical operations including equipment maintenance and field operations. Frameworks standard introduces steps, applications and data processing for the process like “Failure to Repair” and “Workforce Management” [13].

- Each of these processes steps can be optimized by:
- Eliminating unnecessary steps,
- Optimized and efficient planning,
- Optimized routing and execution process.

The effective planning makes easier all further steps and execution of remaining work, and during the Planning stage, it is possible to utilize already known data about the job that should be done, locations, equipment, technologies and about the available resources.

The resources (Company Staff) is one of the most changeable objects in companies, as employees are always willing to improve their skills, they learn how to deal with new technologies and how to deal with continuously changing and upgrading equipment.

Such a problem is mainly for the following Business Directions, where usually the business processes are complex:

- Telecommunication operators [17],
- Software development and IT [3],
- Assurance,
- Insurance claims adjustment,
- Civil Defense.

Most of the companies use some systems and tools to support the execution of business processes or process stages. Such systems usually are complex and can apply complex mathematical models for activities optimization and accuracy.

Because of that, studying how to install new equipment and maintain the installed one, means that the technical employees have improved their skills and the employee's professional competence increased. The managers need a tool to estimate their employees' knowledge and skills to choose one to be the best to do the next task. One of the solutions to this problem is defining the function, called professional competence, showing levels of technicians' competence in maintaining office devices.

**Estimating levels of technicians’ skills.** Companies need help because the business environment is getting more and more complicated and competitive, and requires constant learning [7]. Business researchers and practitioners should help firms be more competitive, so they have to study the foundations of concepts used in business [8]. Managers should use lean thinking methods not only for manufacturing [9] but also for employee management. For any enterprise insufficient utilization of the resources is a problem [17]. Especially, for the second of these reasons, the use of a fuzzy relation can be beneficial.

Let us specify the following notation:
performing office tasks, where

Definition 2. The function \( \text{PC} : S \times T \rightarrow [0,1] \) is called professional competence of technicians in performing office tasks, where \( \text{PC}(S_i, T_j) \) denotes the level of employee \( S_i \)'s skills of performing task \( T_j \) and
after performing this task once more for $i = 1, 2, \ldots, I, j = 1, 2, \ldots, J$, $S$ is a fuzzy optimistic aggregation norm defined by (3), and the initial value of $PC(S_i, T_j)$ is estimated when employee $S_i$ starts working for this company.

Since after the maintaining or upgrading any of office devices, the professional competence of technician $S_i$ in performing task $T_j$ increases, also in the case when the technician knows how to do it very well, e.g., installing the same type of a printer as before, this task becomes routine. Hence, the professional competence of technicians in performing tasks is an increasing function.

Definition 3. The function $PC : S \rightarrow [0, 1]$ is called professional competence of technician $S_i$, where $PC(S_i)$ denotes the level of employee $S_i$’s skills of performing all technical tasks and, for $i = 1, 2, \ldots, I$,

$(2) \quad PC(S_i) = S_j = 1, 2, \ldots, J \quad PC(S_i, T_j)$.

Assume that the manager of the company possesses the records of the technician results containing the outcomes of the tasks of installation of new equipment, maintaining and exchanging the office devices and prepares the values of fuzzy relation $R_1$ between technicians and equipment indicating levels of experience in installing and maintaining these devices. Table 1 presents values of relation $R_1$. This type of evaluation of the skills is common for service organizations and is maintained in HRMS (Human Resource Management Systems) or in FSM (Field Service Management) systems [17].

Moreover, let Table 2 show values of fuzzy relation $R_2$ between devices and applied in them technologies.

Furthermore, Table 3 presents values of fuzzy relation $R_3$ between technologies and tasks indicating which tasks need knowledge of the specific technology.

Now, we calculate the initial levels of professional competence of the technicians, which are values of fuzzy relation $R$ calculated with the application of $max - min$-composition to formula (1) and relations $R_1 - R_3$. Hence, Table 4 presents levels of estimated knowledge and skill of all technicians in performing tasks:
Let us assume that initial values of the professional competence of all technicians in performing all tasks are equal to values of fuzzy relation $R$.

Assume that technician $S_1$ has performed task $T_1$ twice and task $T_3$ four times, technician $S_2$ – task $T_2$ three times, technician $S_3$ – all tasks once, technician $S_4$ was absent and technician $S_5$ has performed tasks $T_1$ and $T_2$ three times. Then, applying the optimistic fuzzy aggregation norm $S$ given by the formula (3), we get values of professional competence of the technician performing the tasks shown in Table 5.

For example, to calculate the value of professional competence of technician $S_1$ in performing task $T_1$ the formula (2) is applied:

$$PC(S_1,T_1) = S(S(PC(S_1,T_1),A),A)S(S(R(S_1,T_1),A),A) = S(S(0.7,0.01),0.01)$$

$$S(0.7+0.01-0.7\cdot0.01)=S(0.703,0.01)S(0.703,0.01)=0.70597.$$

Hence, we can calculate values of professional competence of all technicians applying the formula (4) and present them in Table 6.

Based on levels of professional competence (Table 6), managers can use this information in, e.g., two ways:
1) the manager wants to give the prize for each technician whose professional competence is higher than, e.g., 0.96, so the prize should get the following technicians: \( S_2 \) and \( S_5 \);
2) the manager wants to prepare the ranking of the technicians concerning their professional competence, so in this case, the ranking of them is as follows: \( S_2, S_3, S_1, \) and \( S_4 \).

<table>
<thead>
<tr>
<th>Technician</th>
<th>Professional competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_1 )</td>
<td>0.949</td>
</tr>
<tr>
<td>( S_2 )</td>
<td>0.984</td>
</tr>
<tr>
<td>( S_3 )</td>
<td>0.956</td>
</tr>
<tr>
<td>( S_4 )</td>
<td>0.850</td>
</tr>
<tr>
<td>( S_5 )</td>
<td>0.966</td>
</tr>
</tbody>
</table>

After developing this method for preparing rankings of technicians, we have also discussed the rank reversal phenomenon which causes some problems in some Analytic Hierarchy Processes [4,12]. In the case of calculating values of fuzzy relations, all professional competences of technicians achieved after performing tasks individually or all of them are calculated separately, so the problem of preparing rankings are reduced to subset of real numbers. Hence, this method does not cause the problem of rank reversal.

The method of preparing rankings based of optimistic fuzzy aggregation norm. Likewise A. Ameljańczyk [1], we define the ranking procedure as the transformation of the set of objects in the sequence of subsets which form the partition of the discussed set. The ideal situation is when all sets constituting the partition have only one element, such a ranking is called linear.

Nowadays, people prepare many rankings, especially in the area of public procurement such as tenders or grants, design contests and so on, which the result has commercial, prestige or financial consequences. These rankings are based on multicriteria procedures and very often the weighted averages are applied with weights adopted subjectively by persons deciding about the results of the competitions [2]. Because of that, it is really important to find a method of preparing rankings which are more objective.

Ameljańczyk proposed the application of Minkowski metrics and the ideal point in the space of objects to calculate distances of objects from this point as a foundation of a ranking procedure.
Table 7.
Professional competence of technicians after performing tasks in a given period of time

<table>
<thead>
<tr>
<th>Competitor</th>
<th>Criterion A</th>
<th>Criterion B</th>
<th>Criterion C</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₁</td>
<td>2</td>
<td>7</td>
<td>3</td>
<td>0.113615</td>
</tr>
<tr>
<td>C₂</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>0.139942</td>
</tr>
<tr>
<td>C₃</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>0.122479</td>
</tr>
<tr>
<td>C₄</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>0.139942</td>
</tr>
<tr>
<td>C₅</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>0.131254</td>
</tr>
<tr>
<td>C₆</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>0.104662</td>
</tr>
<tr>
<td>C₇</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>0.086483</td>
</tr>
<tr>
<td>C₈</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0.04901</td>
</tr>
<tr>
<td>C₉</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0.04901</td>
</tr>
<tr>
<td>C₁₀</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0.04901</td>
</tr>
</tbody>
</table>

We are going to propose the new method based on optimistic fuzzy aggregation norm (2). Let \( A=0.01 \) be one atomic unit. Assume that the competition is based on three criteria: A, B and D (exemplary data is presented in Table 7). Assume that estimated numbers estimated for competitors for criteria are integers.

The result function is \( S \) given as follows

\[
S(C_k) = 1 - (1 - A)^{\text{Crit } A} \cdot (1 - A)^{\text{Crit } B} \cdot (1 - A)^{\text{Crit } C}
\]

for \( k=1,2,\ldots,10 \). Hence, for competitor \( C_1 \), we have

\[
S(C_1) = 1 - (1 - 0.01)^2 \cdot (1 - 0.01)^7 \cdot (1 - 0.01)^3 = 0.113615.
\]

Hence, based on the values of the result function, the ranking of competitors can be prepared. Based on the result function the ranking can be prepared as follows: \( C_2 \) and \( C_4 \) on position 1, then \( C_5, C_3, C_1, C_6, C_7, C_8 \) and finally \( C_9 \) and \( C_{10} \) on the last position. Unfortunately, this ranking is not linear.

**Visualization.** After receiving fuzzy relation \( R \), we can visualize the employees reference to the tasks using the task maps – the digraph of the professional competence of technicians individually (for example \( S_1 \) in performing all tasks presented in Fig. 2a and the performance of given task (for example \( T_1 \) by all technicians applying vectors of professional competence (Fig. 2b).

Similarly to [6], we define digraphs \( G_i \), (\( i=1,2,\ldots,I \)) for each technician \( S_i \in S \), which vertices presents levels of performance of tasks required by the company. Moreover, the central point of the graph represents the situation of the technician \( S_j \) who cannot perform any task (\( PC(S_j,T_j)=0 \) for all \( j=1,2,\ldots,J \)).

Let \( P=\{\bar{P}_k, k=1,2,\ldots,K\} \) denote the set of position vectors of technician’s professional competence or task’s performance relative to the central point and their magnitudes are equal to the unit of measure.
Thus, to establish components of the position vectors of all tasks evenly, let

\[
\vec{P}_k = \begin{pmatrix}
\cos \left( \frac{\pi}{2} \frac{2\pi}{K} (k - 1) \right) \\
\sin \left( \frac{\pi}{2} \frac{2\pi}{K} (k - 1) \right)
\end{pmatrix}
\]

for all \( k = 1, 2, \ldots, K \).

Therefore, for each \( i = 1, 2, \ldots, I \), the result vector \( \vec{P}_{res}^i \) is equal to

\[
\vec{P}_{res}^i = \sum_{k=1}^{K} R(S_i, T_k) \cdot \vec{P}_k,
\]

where \( K = J \). Hence, e.g., for \( i = 1 \), we have (see Fig. 2a), the result vector representing the level of professional competence of technician \( S_1 \) in performing all tasks is green):

\[
\vec{P}_{res}^1 = 0.706 \begin{pmatrix} 0 \\ 1 \end{pmatrix} + 0.7 \begin{pmatrix} 0.5 \sqrt{3} \\ -0.5 \end{pmatrix} + 0.424 \begin{pmatrix} -0.5 \sqrt{3} \\ -0.5 \end{pmatrix} = \begin{pmatrix} 0.238 \\ 0.122 \end{pmatrix}.
\]

Now, we solve the opposite problem of calculating the result vector for tasks \( T_j \), \( j = 1, 2, \ldots, J \), where vectors are built on the basis of professional competence of technicians performing all tasks \( T_j \). Thus, for each task \( T_j \), the result vector \( \vec{M}_{res}^j \) is equal to
\( \vec{M}_{\text{res}}^1 = \sum_{k=1}^{K} R(S_k, T_j) \cdot \vec{P}_k, \)

where \( K = I. \)

Since there are five technicians, there are five position vectors \( \vec{P}_k. \) Let us consider the digraph for task \( T_1 \) (Fig. 2b, the result vector representing the levels of professional competence of the team is green). Thus,

\[
\vec{M}_{\text{res}}^1 = 0.706 \begin{pmatrix} 0 \\ 1 \end{pmatrix} + 0.8 \begin{pmatrix} 0.95 \\ 0.31 \end{pmatrix} + 0.703 \begin{pmatrix} 0.59 \\ -0.81 \end{pmatrix} + 0.5 \begin{pmatrix} -0.59 \\ -0.81 \end{pmatrix} + 0.806 \begin{pmatrix} -0.95 \\ 0.31 \end{pmatrix} = \begin{pmatrix} 0.114 \\ 0.229 \end{pmatrix}.
\]

Fig. 2c, d and e present the levels of professional competence of all technicians in performing tasks \( T_1, T_2 \) and \( T_3, \) respectively (the circles show the terminal points of the result vectors). Fig. 2f visualizes the levels technician in performing all tasks. The farther the terminal point of the result vector is, the higher level of the professional competence of the technician is observed. As it can be noticed all technicians possess great skills. However, if the manager needs more precise information, they have to look at visualizations for tasks, e.g., there is a big difference for task \( T_3 \) (Fig. 2d).

**Interpretation of visualization results.** The presented method of digital visualization helps to simplify the process of tasks delegation for company managers. The achievements of individual technicians or the teams of them concerning the levels of performing all tasks together or the specific subset of them chosen by the managers can be easily observed. This method of visualization enables the managers to take into consideration two points of view at the same time: the levels of individual technician’s professional competence and levels of professional competence of performing the discussed tasks.

Hence, the managers can estimate levels of professional competence of their team analyzing the graphs. Fig. 3a presents the visualization of the professional competence of the team of technicians when the performance of tasks are taken into consideration. As it can be noticed for this team, task 2 is the most difficult because two technicians have low professional competence in performing it and task 1 is the routine for them.

If the manager wants to see their technician team according to technicians, it might be better to use Fig. 3b. Technician 1 is the best in performing all tasks and Technician 5 is the poorest one. This presentation might also be used to see the professional competence of technicians according to time.
Table 8.
Professional competence

<table>
<thead>
<tr>
<th>Technician</th>
<th>Task</th>
<th>( T_1 )</th>
<th>( T_2 )</th>
<th>( T_3 )</th>
<th>( T_4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_1 )</td>
<td></td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>( S_2 )</td>
<td></td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Hence, taking into consideration all visualizations, it can be seen, that all technicians, except \( S_5 \), possess high levels of professional competence in all tasks and the weakest performance is observed for task \( T_2 \), so probably the team needs some training.

The following example presents a specific situation, when looking at these two visualizations is crucial for correct understanding of the professional competence of the team. Let us consider the following example. In the company there are two technicians, they have to perform four tasks and their levels of professional competence of performing these tasks are given in the Table 8.

Notice that in both cases, the result vector of their professional competence of performing these tasks is \( \vec{0} \), so we cannot distinguish their competence preparing only the digraph similar to presented in Fig. 2a. Because of that, we present the technicians’ professional competence on two diagrams (Fig. 4).

As we can see presenting only result vectors might cause misunderstanding, so we have to show both diagrams.

**Conclusions.** The proposed methods of calculating levels of professional competences of technicians or values of result functions based on levels of competition criteria are not difficult to understand and consists of a few steps, so levels of the interpretability of the presented are high. At the beginning of the process the experts have to prepare tables with the data, then there must be performed some calculations and in the part of making decision there are prepared some rankings or the decisions are made. These rankings are important aspect for operational use of Professional Competence in maintenance operations. Service Companies apply different strategies for people assignment to the job from assignment of the most skilled technician to the complex activity related to the specialist hardware to assignment of the technician with minimal acceptable level of Professional Competence for low priority and repetitive activities (like facilities preventive service or installation of CPE – Customer Premise Equipment in telecommunication industry). This is why trustful method of Professional Competence evaluations is required.

![Fig. 4a Visualization of tasks performance by technicians from the perspective of technicians: technician 1 (blue) and technician 2 (red). The resulting vector (green) in the case of both technicians is the null vector.](image1)

![Fig. 4b Visualization of tasks performance by technicians from the perspective of tasks: task 1 (blue) and task 2 (red).](image2)
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References

