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# Multi-criteria analysis of need factors for developing a Machine Learning-based system to track employees' digital activity

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*Abstract*—**The necessity of developing a system for Machine Learning (ML)-based employee digital activity monitoring is examined in this study. The need for developing and using ML-based remote employee monitoring systems in companies is assessed using the benefits associated with them. The development of such a system would require the application of suitable prediction models in addition to Machine learning methodologies and techniques. A Multi-criteria analysis is carried out on a sample of 102 superiors from IT (53 respondents) and non-IT (49 respondents) companies that allow their employees to work remotely, in order to determine the necessity of developing such a system. Applying the Multi-criteria Analytic Hierarchy Process (AHP), it is seen that among the respondents from IT companies, the enhancement of remote employees' job quality is the most significant factor for the development and deployment of this type of system. Conversely, non-IT respondents highlighted increased employee productivity as the primary advantage of the system implementation.**

***Keywords- multi-criteria analysis; machine learning; monitoring system; AHP; benefit factors.***

## I. Introduction

The need to develop a system for monitoring remote employees in companies that allow their employees to work remotely is evaluated in this research paper.

The evaluation is carried out by examining the advantages and benefits that superiors of companies that might implement such a system would anticipate from its implementation. Superiors in the role of respondents were provided with a survey to rate each of the specified benefits using a nine-point rating scale [1]. The respondents were given a detailed explanation of the system in the survey itself. It was explained to them that it is a system that would involve the application of ML algorithms in the analysis of data collected from the monitoring process.

The benefits that are most important to the respondents for the introduction of the ML-based remote employee monitoring system are the benefits assessed using Saaty's nine-point scale [1]. Below is a list of benefits that have been evaluated:

1) *improving productivity* - productivity implies the improvement of ongoing work - to achieve the best possible results with the least amount of work invested [2]. According to the respondents, productivity in non-IT companies can be defined as the ratio of labor force employed to the volume of production, services, or turnover. Respondents from IT companies noted that, in the medium term, one cycle of five sprints (Program Increment (PI)) with successfully completed planned tasks of employees can be considered as a productivity benefit.

2) *improving quality* – according to the benefit of improving quality for non-IT respondents, the system should continuously monitor employee work to ensure that there are as few deviations as possible, that employees are focused on their tasks, and that customer satisfaction levels rise as a result [3]. According to IT respondents, the benefit of quality suggests that the monitoring system would allow for both an improvement in task quality and on-time task completion. In this context, quality is defined as the percentage of open bugs that are resolved after a feature is closed and the degree to which customers are satisfied with newly developed and released features.

3) *better efficiency* - reduction of task solving time regardless of quality [4]. Timeliness and plan fulfillment are prioritized.

4) *reducing wasted time* - removing the opportunity to engage in personal or unproductive activities

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(gaming, social networking, newspaper reading, etc.) during working hours.

The analysis of factors that are most important to respondents from the point of view of introducing mentioned system in their companies is performed by applying the AHP methodology. As a result, the data obtained from each respondent's evaluation on a nine-point scale are further processed using the AHP analysis. The goal of implementing this methodology is to obtain results in the form of a ranking list of benefits to determine which benefits are most important to superiors from various groups of companies (non-IT and IT).

The AHP methodology is applied on three occasions. Initially, weight coefficients are computed for each of the 102 respondents' responses. Following that, the respondents were categorically separated into two groups: those from IT companies (53 respondents) and those from non-IT companies (49 respondents). As a result, the outcomes for each group are also taken into consideration independently. The goal of this approach was to determine whether superiors from IT and non-IT companies have different opinions.

## II. Literature Overview

The applied AHP analysis methodology is based on earlier research papers on related topics.

In the research [5], the development principles of the methodology of the Analytic Hierarchy Process (AHP) are presented. The significance of the paper [5] for the needs assessment research is reflected in defining steps of implementation of the AHP method. Authors have proposed principles for AHP methodology implementation in public work contracts. In contrast to the full implementation of the AHP methodology proposed in paper [5], the multi-criteria factor analysis of remote employee monitoring system implementation used only the step of defining the AHP structure and comparing factors in relation to the goal. Therefore, the aim was to determine the weight coefficients of each factor and to define the matrix of priority factors according to weights.

It should be emphasized that Saaty's nine-point intensity scale [6] is used during the pairwise comparisons, i.e., comparing benefit factors of the monitoring system development and implementation in companies. The scale is presented in Saaty's research paper on various examples of AHP and Analytic Network Process (ANP) methods implementation [6, 7].

In the publication [8] an integrated methodology for evaluating existing legacy systems and migrating their architectures to modular and open ones is presented. The proposed model integrates open systems strategies with Analytical Hierarchy Process (AHP) and Goal Programming (GP) and is useful because steps of AHP implementation are also used in this paper.

A very important aspect in the AHP methodology is determining the degree of consistency. The paper [9] explains the importance of consistency degree and indicates that if the degree is greater than 0.10 (10%), the results should be reanalyzed and reasons for the inconsistency established and removed by partially repeating the comparison in pairs. If repeating the procedure in several steps does not lead to a lowering of the degree of consistency to the tolerance limit of 0.10 (10%), all results should be rejected and the whole procedure should be repeated from the beginning [9].

Many studies emphasize the importance of monitoring remote employees. According to a study conducted by a group of Australian and Chinese authors [10] about ensuring remote workers' productivity and quality during the COVID-19 pandemic, workers become indolent in the absence of adequate employee monitoring. The results of the study found that employee indolence happens even in the presence of a system for monitoring the work, like a daily meeting. However, authors emphasize that employees' performance can also be negatively impacted by excessive supervision. Employee resistance and unhappiness as a result of being under strict supervision and restricted in their ability to work independently are some of the detrimental effects. To obtain these results, the In vivo coding methodology for quantitative analysis and two path-analytical models are used in this study. On the other hand, descriptive statistics and respondents' opinions are analyzed in this research to examine possible employee behavior, stress, and emotional impacts from introducing Artificial Intelligence (AI) based monitoring system on remote employees.

## III. Theoretical Aspects

The following theoretical aspects of the paper are described, along with a description of the analyzed system and applied methodology:

### A. *Description of remote employee monitoring system*

This chapter presents the examination of the ML-based Remote Employee Monitoring System (REMS) that will be developed. The purpose of this system is to regularly supervise employees who work remotely for companies that offer the option of remote work.

The system aims to oversee employee performance and promptly alert company superiors in the event of elevated levels of employee stress, declining performance, or employee dissatisfaction.

The proposed system will be based on the Client-Server architecture model [11]. The Client Application (CA) will be installed on users' PCs with the purpose of collecting relevant data on users' behavior and sending it to the server side.

The Monitoring Module (MOM) [12], which is part of CA, is responsible for collecting data regarding the behavior of remote employees:

1) the mouse actions such as moving, clicking, scrolling, and recording its trajectory.
2) data related to the memory and the Central Processing Unit (CPU).
3) data regarding the tracking of time.
4) data from keyboard hooks.

The Data collection module (DCM) [12] will be responsible for handling external events and receiving all information from the MOM through callback methods in order to relieve the workload of the MOM threads. DCM would also have the responsibility of managing temporary data storage on the client side.

Data transmission and communication between the client and server sides would utilize Representational State Transfer (REST) endpoints [13].

The server side will receive raw data regarding the behavior of remote employees and store it in a NoSQL database. In addition, the REMS architecture will include a relational database that stores business logic, user data, and raw user activity data obtained through the utilization of ML algorithms from the Machine Learning module (MLM) [12]. The inclusion of the MLM module will distinguish REMS from other systems in the market that lack comprehensive machine learning analysis of the collected data. The MLM module would be able to classify employees into different roles (such as developer or administrative worker) based on their actions during the monitoring phase. The MLM module would also be responsible for analyzing employee behavior data to extract information about the employee's level of stress and emotional state, and subsequently notifying superiors.

The process of visualizing the processed data will be carried out using the Data Visualization Module (DVM) [12] and the Admin Single Page Application (SPA) [12]. The implementation of JSON Web Tokens (JWT) using JavaScript Object Notation (JSON) will ensure the security of data during transmission [14].

### *B. Analytic Hierarchy Process (AHP) method*

The Analytic Hierarchy Process (AHP) is a well-known multi-criteria methodology created by Thomas Saati in 1980. The method employs a hierarchical structure to enable the ranking of alternatives based on well-defined criteria and sub-criteria [15].

Comparisons of benefit factors for the development and implementation of a ML-based monitoring system are conducted using Saaty's nine-point scale. The determination of weight coefficients for these factors is carried out through the AHP methodological steps. The AHP is a robust and adaptable approach for conducting multi-criteria decision analysis. The AHP assists decision-makers in establishing priorities and selecting the optimal alternative by considering both qualitative and quantitative aspects [16]. AHP is an intuitive method for formulating and analyzing decisions, based on hierarchical problem structuring (see Figure 1), and making pairwise comparisons [17].

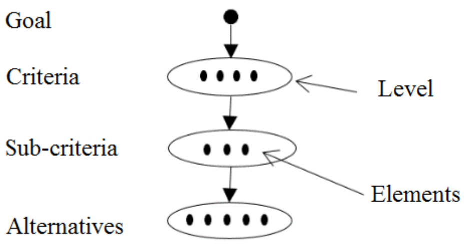


Figure 1. AHP hierarchical structure [18]

Making pairwise comparisons is based on the 1-9 comparison scale (see Table 1) [17].

TABLE I. SAATY'S FUNDAMENTAL SCALE [19].

| Numerical scale | Verbal scale |
|---|---|
| 1 | Equal importance |
| 3 | Moderate importance |
| 5 | Strong importance |
| 7 | Very strong importance |
| 9 | Extreme importance |
| 2,4,6,8 | Intermediate values |

The procedure of implementation the AHP method will be carried out through the following steps [20]:

1) developing the AHP hierarchy,
2) comparing pairs of decision-making elements,
3) determining the local weight coefficients and consistency verification (weights based on each individual respondents' response),
4) determining the overall priority vector based on geometric means of all comparisons of all respondents.

The AHP method will be applied to make comparisons exclusively at the highest level of the hierarchy, specifically regarding the goal. To ensure reliable and pertinent outcomes, the respondents' evaluations of the various factors will be utilized to derive the overall priority vector, which will ultimately determine the weighting coefficients for the consideration factors. The overall priority vector is derived by calculating the geometric mean of all comparisons made by the 102 respondents, consisting of 53 individuals from IT companies and 49 individuals from non-IT companies. By adopting this approach, the potential subjectivity inherent in the AHP methodology has been eliminated.

### *C. Structure of the survey*

The AHP method is used solely for comparing alternatives (represented as system benefits) in relation to the goal, without the need to establish specific comparison criteria. The survey utilizes Saaty's nine-point scale for comparative analysis to gather responses. The survey is based on the research conducted by Yuji Sato, where data was gathered using a nine-point scale and subsequently utilized as inputs in the AHP method to calculate the weighting coefficients [21]. Below is a set of questions answered by all 102 respondents:

**Q1:** Choose which benefits of introducing the system are more important to you: productivity (better results in realization of employee tasks and higher percentage of finished tasks) or improving quality (higher quality of the work of employees when they know that someone is interested in their work).

**Q2:** Choose which benefits of introducing the system are more important to you: productivity or efficiency (faster execution of tasks if supervision exists).

**Q3:** Choose which benefits of introducing the system are more important to you: productivity or reducing wasted time (reducing time spent on activities unrelated to work tasks).

**Q4:** Choose which benefits of introducing the system are more important to you: improving quality or reducing wasted time.

**Q5:** Choose which benefits of introducing the system are more important to you: efficiency or reducing wasted time.

## IV. RESULTS

The basic alternatives between which will be determined the priority ranking list are defined as follows:

**A1** – productivity,

**A2** – improving quality,

**A3** – efficiency,

**A4** – minimizing unproductive time spent on non-business-related tasks.

The structure of the first level of comparison in relation to the goal is shown in Figure 2.

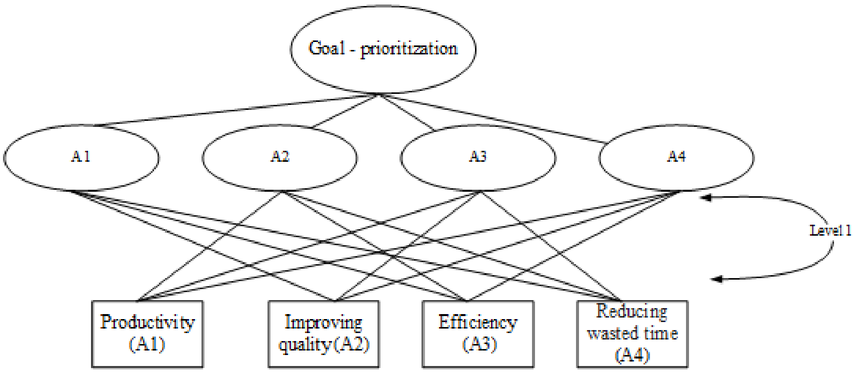


Figure 2. AHP structure

Therefore, the prioritization is performed at the first level of comparison, and it is based on the obtained weighting coefficients.

The purpose of using this AHP structure is to obtain weight coefficients and prioritize system benefit factors through the comparative analysis of alternatives in relation to the goal. The overall weight vector is based on the expert decision-making of 102 superiors from various IT and non-IT companies. It is calculated by taking the geometric mean of comparisons made by these experts. Overall weights based on the geometric mean of responses of 102 superiors are shown in Table 2.

TABLE II. OVERALL WEIGHT VECTOR BASED ON GEOMETRIC MEAN – ALL RESPONDENTS.

| **Goal** | **A1** | **A2** | **A3** | **A4** | $w_j$ |
|---|---|---|---|---|---|
| A1 | 1.0 | 1.04100 | 1.99947 | 2.32923 | 0.33519 |
| A2 | 0.96061 | 1.0 | 1.95195 | 2.29157 | 0.33836 |
| A3 | 0.50013 | 0.51231 | 1.0 | 2.08061 | 0.19915 |
| A4 | 0.42933 | 0.43638 | 0.48063 | 1.0 | 0.12730 |
| *Degree of consistency: CR = 0.01582 < 0.10* | | | | | |

By conducting a comprehensive analysis of the comparisons made by all 102 respondents and constructing an overall comparison matrix, the weight coefficients for the system benefit factors (alternatives) are determined based on the geometric means of all the comparisons made by the superiors.

$$w_{all} = \begin{pmatrix} 0.33519 \\ 0.33836 \\ 0.19915 \\ 0.12730 \end{pmatrix} \quad (1)$$

The AHP methodology enables detection and analysis of inconsistencies in the process of comparing pairs of alternatives by calculating the Consistency Ratio (CR). If the degree of CR is below 0.10 (10%), the result is deemed sufficiently accurate, and there is no requirement for adjustments in comparisons and repetition of calculations [22].

In this scenario, the degree of consistency ratio, represented by CR=0.01582, falls below the specified threshold of 0.10. Therefore, there is no inconsistency observed in the comparisons.

The obtained results of the overall priority of the considered alternatives are given in descending order:

$A_2$ (Quality) → $A_1$ (Productivity) → $A_3$ (Efficiency) → $A_4$ (Reducing wasted time).

Thus, based on the analysis of the entire sample of 102 respondents, it can be concluded that the quality factor holds the utmost significance. In other words, implementing such a system would enhance the quality of work for remote employees.

The data are also analyzed separately based on the division of respondents into two groups: those from IT companies and those from non-IT companies. The results of the comparisons can be found in Tables 3 and 4.

TABLE III. OVERALL WEIGHT VECTOR BASED ON GEOMETRIC MEAN – 49 RESPONDENTS FROM NON-IT COMPANIES.

| **Goal** | **A1** | **A2** | **A3** | **A4** | $w_j$ |
|---|---|---|---|---|---|
| A1 | 1.0 | 1.23396 | 2.98408 | 3.55676 | 0.41604 |
| A2 | 0.81039 | 1.0 | 1.81527 | 2.59529 | 0.30329 |
| A3 | 0.33511 | 0.55089 | 1.0 | 2.37699 | 0.17934 |
| A4 | 0.27367 | 0.38531 | 0.42069 | 1.0 | 0.10133 |
| *Degree of consistency: CR = 0.01953 < 0.10* | | | | | |

The priority vector matrix for respondents from non-IT is given below.

$$w_{non\text{-}IT} = \begin{pmatrix} 0.41604 \\ 0.30329 \\ 0.17934 \\ 0.10133 \end{pmatrix} \quad (2)$$

The obtained results of the overall priority of considered alternatives are given in descending order for non-IT group:

$A_1$ (Productivity) → $A_2$ (Quality) → $A_3$ (Efficiency) → $A_4$ (Reducing wasted time).

Thus, it can be concluded that among the 49 respondents from non-IT companies, the productivity factor holds the utmost significance. In other words, implementing an information system of this nature would enhance the productivity of remote employees. Furthermore, it can be inferred that the consistency CR = 0.01953 is lower than the specified threshold of 0.10.

TABLE IV. OVERALL WEIGHT VECTOR BASED ON GEOMETRIC MEAN –53 RESPONDENTS FROM IT COMPANIES.

| Goal | A1 | A2 | A3 | A4 | $w_j$ |
|---|---|---|---|---|---|
| A1 | 1.0 | 0.88957 | 1.38083 | 1.53608 | 0.27802 |
| A2 | 1.12414 | 1.0 | 2.08744 | 2.04249 | 0.35296 |
| A3 | 0.72420 | 0.47905 | 1.0 | 1.83957 | 0.21467 |
| A4 | 0.65101 | 0.48959 | 0.54360 | 1.0 | 0.15435 |
| *Degree of consistency: CR = 0.01808 < 0.10* | | | | | |

The priority vector matrix for respondents from IT companies is given below.

$$w_{IT} = \begin{pmatrix} 0.27802 \\ 0.35296 \\ 0.21467 \\ 0.15435 \end{pmatrix} \quad (3)$$

The obtained results of the overall priority of considered alternatives are given in descending order for the IT group:

$A_2$ (Quality) → $A_1$ (Productivity) → $A_3$ (Efficiency) → $A_4$ (Reducing wasted time).

Therefore, it can be concluded that among the 53 respondents from IT companies, the quality factor holds the utmost significance. Specifically, implementing and integrating such an information system would enhance the quality of work for remote employees.

## V. DISCUSSION

Considering the results of the AHP analysis, quality is identified as the factor with the highest weight coefficient in a total sample of 102 respondents. Respondents acknowledged the system's significance in enhancing the work quality of remote employees, which would contribute to the overall quality growth. Productivity is also a significant system benefit in the overall sample, carrying slightly less weight than the quality factor. So, the analysis of all respondents' responses clearly indicates that the primary advantage of implementing REMS is the enhancement of quality. However, it is crucial to ensure that this benefit aligns with the aim of maximizing the performance of remote employees while minimizing the effort invested (productivity).

Upon analyzing the separated group results of the AHP analysis, it becomes evident that the results of the IT group coincide with the prioritized order of system benefit factors observed in the entire sample. Thus, IT company superiors consider the quality factor to be the foremost advantage of implementing and adopting REMS.

Respondents from non-IT companies believe that the development and implementation of the ML-based employee monitoring system primarily enhances productivity, unlike the IT group.

So, in terms of the benefit factors, there is a certain difference in opinions of respondents from IT and non-IT group.

The outcomes could have varied if the sample size had been increased, and if the questionnaire had encompassed superiors from a more extensive range of companies. Moreover, the disparity in the proportion of participants from IT companies compared to those from non-IT companies may potentially affect the validity of findings, as the results could differ if the sample sizes were equal in both groups.

However, the chosen methodological procedure ensured that the results are both valid and devoid of any subjective bias. The applied Analytic Hierarchy Process (AHP) methodology eliminates any subjectivity by consolidating all results into a common comparison matrix. In this matrix, each value represents the geometric mean of all the respondents' comparisons.

## VI. CONCLUSION

The main advantage of REMS, as highlighted by superiors from non-IT companies, is the enhancement of employee productivity. Conversely, IT company superiors prioritize quality as the primary advantage. This expectation arises from the significant investments made by modern IT companies to enhance the quality of their projects.

Respondents from both groups identified two significant advantages of the system's implementation and advancement: increased productivity and improved work quality among remote employees.

The findings of this research paper indicate the necessity of creating an ML-based system to monitor employees who work remotely. Specifically, ML algorithms in data processing are highly desirable for conducting in-depth analysis of employee behavior. This confirmation is based on the explicit expression of the superiors through their answers and subsequent Analytic Hierarchy Process (AHP) analysis, which clearly demonstrates their recognition of the advantages of implementing such a system.

One proposed approach for future research is to enhance the AHP methodology by incorporating Fuzzy logic. This would help mitigate the inherent subjectivity associated with benefit comparisons and enable a comparative analysis of the results. The authors intend to utilize the Fuzzy Analytic Hierarchy Process (FAHP) Yüskel's matrix calculation [23], which is based on triangular Fuzzy numbers.

The future research plan is to extend the matrix calculation procedure by incorporating Cheng's extent analysis and Wang's corrective procedure [24]. Additionally, the optimism index will be applied. For each matrix with triangular Fuzzy values, a set of formulas will be utilized to directly compute the exact values of the weighting coefficients and continue with the classic matrix calculation. Thus, the vector of weighting coefficients of benefits derived from the FAHP methodology can be obtained, enabling a comprehensive comparative analysis with the results produced by the conventional AHP approach.

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