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IMPACT OF SHIFT PATTERN ON OPTIMAL HUMAN RESOURCE MANAGEMENT STRATEGY: AN OPTIMISATION APPROACH

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Abstract: Today, human resource management plays an increasingly important role, as both production and service activities require a large number of employees, so an optimal human resource management strategy can have a direct impact on the efficiency of the production and service process. Within the frame of this article, a new approach is described, which focuses on the scheduling of employees having different shift patterns. The numerical analysis of different scenarios shows the impact of the scheduling on the number of required employees and the total cost of human resources.

Keywords: *shift patterns, human resource management, employees, cost efficiency, operator*

1. INTRODUCTION

Human resource management has always been at the heart of process improvement, one of the main reasons being that changes in systems and processes have required a continuous rethinking of the human resource management required [1]. The Institute of Logistics at the University of Miskolc has always analysed the industrial and service processes using methodologies focusing on a wide range of aspects of production and service processes. As the results of these researches show, the optimisation of human resource optimisation has a great impact on the efficiency of production and logistics processes [2-4].

The role of human resources in production and logistics systems is important at strategic, tactical and operational levels. The human resources (employees) at the strategic and tactical level are intellectual (for example engineers), while at the operational level they are basically physical workers and operators. In the case of production and logistics processes, the number of staff involved at the strategic and tactical levels is generally constant; changes are generally caused by large-scale projects. At the operational level, on the other hand, production and logistics processes must adapt to changing customer needs, which in turn means not only a dynamic use of technological and logistics resources, but also a dynamic use of human resources.

Since human resource planning must be linked to the requirements of technological and logistics processes, it is important that human resource optimisation is an integral part of the company's processes, i.e. it must fit in with production planning, logistics planning and financial planning. Companies can adopt a variety of shift patterns to ensure the flexibility to manage production and logistics tasks related to dynamically changing customer demands with as few employees as possible. Within the frame of this article, a new approach is described to model the optimisation problem of employees assigned to different shift patterns.

This paper is organised, as follows. Section 2 presents a short descriptive literature review to summarizing the available research background. Section 3 presents the model framework and mathematical model of the optimization of shift pattern distribution to optimise the human resource structure. Section 4 presents the results of the numerical

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analysis of scenarios, while conclusions and future research directions are discussed in the last section.

2. LITERATURE REVIEW

Within the frame of this chapter, we are summarising the research results in the field of human resource management, focusing on the optimisation approaches. This section includes the descriptive analysis of articles. Within the frame of the literature review, the Scopus database was used to identify the most important scientific results in the field of optimisation of human resource management. Firstly, the relevant terms must be defined. In this first crucial phase the (TITLE-ABS-KEY (human AND resource AND management) AND TITLE-ABS-KEY (optimisation) search key was used to find a wide range of articles to perform a descriptive analysis of articles. Initially, 4703 articles were identified. Our search was conducted in March 2023; therefore, new articles may have been published since then.

As Figure 1 shows, the optimisation of human resource management problems has been researched in the past 50 years. The number of published papers focusing on optimisation of human resource management problems has been increased in the last years; it shows the importance of this research field.

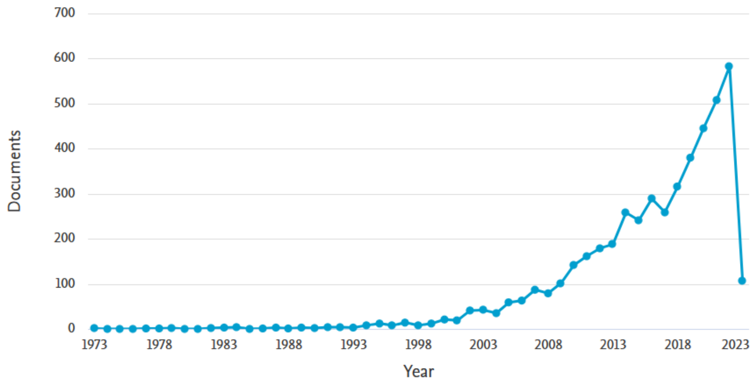

Figure 1. Published articles per year in the field of facility location resulted by a Scopus search using keywords (TITLE-ABS-KEY (human AND resource AND management) AND TITLE-ABS-KEY (optimisation) (Source: www.scopus.com)

We can analyse the distribution of published articles per year and per source, as shown in Figure 2. It can be seen, that a wide range of articles in the field of optimisation of human resource management problems has been published in five scientific journals: International Journal of Environmental Research and Public Health, Journal of Environmental Management, Advances in Intelligent Systems and Computing, Science of the Total Environment and Lecture Notes in Computer Science. The title and the main topic of these scientific journals shows, that human resource management problems are covering not only economical aspects, they have significant impact on the efficiency of industrial processes including production and logistics. The complexity of human resource optimisation problems lead to the application of complex numerical methods, heuristics and metaheuristics. As the descriptive analysis of journal titles shows, the application field of the researches cover a wide range of economy including health care, manufacturing and services. The human resource management optimisation is especially important in the case of emergency.

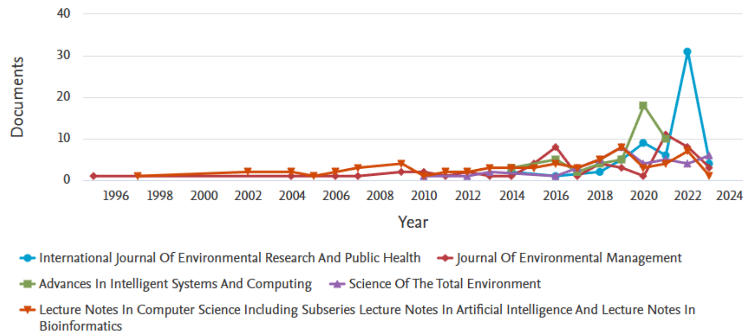

Figure 2. Published articles per year per source in the field of facility location resulted by a Scopus search using keywords (TITLE-ABS-KEY (human AND resource AND management) AND TITLE-ABS-KEY (optimisation) (Source: www.scopus.com)

Most of the research results have been published in journal articles, but a significant number have been published in conference proceedings and books, as shown in Figure 3. There are also the occasional erratumes, notes and short surveys.

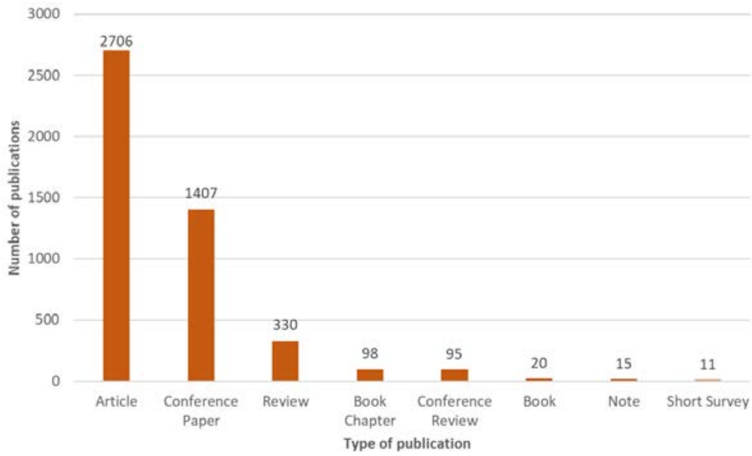

Figure 3. Published articles by type in the field of facility location resulted by a Scopus search using keywords (TITLE-ABS-KEY (human AND resource AND management) AND TITLE-ABS-KEY (optimisation) (Source: www.scopus.com)

The analysis of the subject area of research works shows (see Figure 4), that the ten most important subject area in the Scopus are the followings: engineering, computer science, medicine, environmental sciences, mathematics, energy, business, decision sciences and social sciences. These subject areas highlight the importance of multidisciplinary approach of human resource management optimisation because they are focusing on the following aspects:

- Engineering: the processes of human resource management have great impact on the efficiency of industrial processes including manufacturing and service era, therefor it is important to focus on human resource management problems while planning industrial systems and processes [5-7].
- Computer science: optimisation of human resource management problems can represent NP-hard optimisation problems, and NP-hard optimisation problems can be solved using heuristic and metaheuristic algorithms using computers [8-13].
- Medicine: human resource management is important in all fields of economy, but most of the articles are focusing on employee problems related to emergency [14,15] and health care [16-20].
- Environmental sciences: the sustainability plays and important role in production and service processes. The sustainability can be defined from environmental, technological, financial and human resource point of view [3].
- Mathematics: the definition of optimal human resource management strategies must be supported by mathematical models including objective functions of optimisation, constraints and decision variables [6].

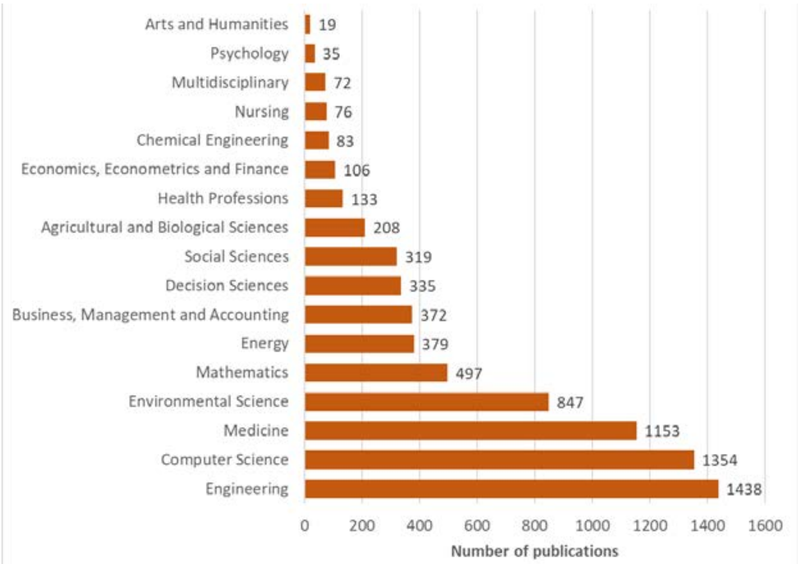

Figure 4. Published articles by subject area in the field of facility location resulted by a Scopus search using keywords (TITLE-ABS-KEY (human AND resource AND management) AND TITLE-ABS-KEY (optimisation) (Source: www.scopus.com)

- Business and economics: the cost efficiency is the core problem of production and service processes; the success of human resource management significantly increases the financial success of production and service processes, therefore business and economics sciences are unavoidable to design and operate an efficient human resource management strategy [2].
- Decision sciences: human resource management can be described as a three level hierarchical process including strategy, tactics and operational level [3].

3. MATERIALS AND METHODS

The different shift patterns used in companies can significantly increase the efficiency of human resource strategies. Shift patterns are different patterns describing the schedule of employees. Shift schedules can be defined using a shift pattern matrix, which defines the forecasted schedule of employees depending on the required number of operators for technological and logistics operations:

$$\boldsymbol{SP} = \left[sp_{\alpha,i,j}\right], \tag{1}$$

where $sp_{\alpha,i,j}$ represents the schedule of shift pattern α of shift j in day i. If $sp_{\alpha,i,j} = 1$ then workers assigned to shift pattern α of shift j in day i, otherwise not. For example, in the case of a common work shift of a university teacher the shift pattern matrix can be described as follows:

$$\boldsymbol{SP} = [1,1,1,1,1,0,0], \tag{2}$$

because there are five work days and the weekend is free.

The literature defines a wide range of shift pattern depending on the industry. These most important shift patterns are the followings [21]:

- first shift: the most common shift pattern for employees for a time interval between 6 am and 18 pm,
- second shift: this shift pattern is known as swing shift for a time interval between 2 pm and 2 am,
- third shift: this shift pattern is known as graveyard shift or night shift for a time interval between 10 pm and 8 am,
- rotating shift: this shift pattern has a wide range of combinations, where employees are changing their shift between first, second and third shift,
- swing shift: in this case the employees are working for a predefined period in a given shift, than changing to another one, for example two weeks in night shift and after that two weeks in day shift.

The schedule of employees depends on the required number of operators, therefore the human resource requirement must be defined for the analysed time window as follows:

$$\boldsymbol{RE} = \left[re_{i,j}\right], \tag{3}$$

where $re_{i,j}$ is the number of required employees in the shift j in day i.

The employees generally get different payments for their work depending on their shift pattern. These payments can be defined as follows:

$$\boldsymbol{p} = [p_\alpha], \tag{4}$$

where p_α is the payment of the employee working in shift pattern α within the analysed time window.

It is possible to define different objective functions for the optimisation of the number of employees and the type of shift patterns. The first potential objective function is the minimisation of employees within the analysed time window:

$$C_1 = \sum_{\alpha=1}^{\alpha_{max}} \sum_{i=1}^{i_{max}} se_{\alpha,i} \rightarrow min., \tag{5}$$

where $\boldsymbol{SE} = [se_{\alpha,i}]$ is the decision variable of the optimisation problem defining the number of employees starting their shift α in day i.

The second potential objective function takes the different costs of different shift patterns into consideration and in this case the objective function is the minimisation of the payments while the payments for different shift patterns are not changing:

$$C_2 = \sum_{\alpha=1}^{\alpha_{max}} p_\alpha \cdot \sum_{i=1}^{i_{max}} se_{\alpha,i} \rightarrow min., \quad (6)$$

where p_α is the payment for one employees working in shift pattern α within the analysed time window.

The third potential objective function focuses on the minimisation of redundant employees:

$$C_1 = \sum_{\alpha=1}^{\alpha_{max}} \sum_{i=1}^{i_{max}} \sum_{j=1}^{j_{max}} we_{\alpha,i,j}(se_{\alpha,i}) - re_{i,j} \rightarrow min., \quad (7)$$

where $we_{\alpha,i,j}$ is the number of working employees in shift pattern α of shift j in day i.

The first constraint of the optimisation problem defines, that the required number of employees must be available in each shift:

$$\forall i,j: \sum_{\alpha=1}^{\alpha_{max}} we_{\alpha,i,j} \geq re_{i,j}, \quad (8)$$

while the second constraint defines, that it is not allowed to exceed the available number of employees for each shift:

$$\forall \alpha: \sum_{i=1}^{i_{max}} se_{\alpha,i}. \quad (9)$$

4. RESULTS

Within the frame of this chapter, the numerical results of the analysis of impact of shift patterns on the human resource strategy are described. The analysis discusses the shift distribution problem in the case of a manufacturing company, where the predefined time window of the analysis is 12 days including 3 shift for every day. Table I shows the number of required operators for production and logistics operations to be performed within the time window.

Table I.

Required number of employees in the scenario

Day	*Shift 1*	*Shift 2*	*Shift 3*
1	*18*	*19*	*20*
2	*21*	*20*	*19*
3	*18*	*20*	*22*
4	*19*	*21*	*19*
5	*21*	*19*	*21*
6	*21*	*21*	*22*
7	*18*	*19*	*20*
8	*19*	*19*	*22*
9	*21*	*20*	*18*
10	*18*	*20*	*22*
11	*18*	*21*	*20*
12	*20*	*19*	*21*

The upper limit of available employees for the first shift is 25, for the second shift is 30, for the third shift is 28, for the first rotating shift is 20 and for the second rotating shift is 5.

Using the Excel Solver the optimisation of the total number of the employees, the number of required employees is 97. Table II shows the result of the optimisation including the number of employees starting their shift in a given day. As Table II shows, the time window defines a 12 days long period, but the results can be defined for a 6 days long period, because each shift has its own cycle time. In the case of the first, second, third shift, and the second rotating shift the cycle time is 6 days, while in the case of the first rotating shifts the cycle time is 4 days because the shift patterns is defines for the days as follows:

$$\boldsymbol{SP} = \begin{bmatrix} 1,0,0,1,0,0,1,0,0,1,0,0,0,0,0,0,0,0 \\ 0,1,0,0,1,0,0,1,0,0,1,0,0,0,0,0,0,0 \\ 0,0,1,0,0,1,0,0,1,0,0,1,0,0,0,0,0,0 \\ 1,0,0,0,0,1,0,0,0,0,0,0 \ldots \\ 1,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0,0 \end{bmatrix}. \tag{10}$$

Table II.

Results of the optimisation: number of employees starting their shift in a given day in Scenario 1

Day	*First shift*	*Second shift*	*Third shift*	*Rotating shift I*	*Rotating shift II*
1	*7*	*0*	*10*	*3*	*0*
2	*1*	*9*	*1*	*4*	*0*
3	*8*	*2*	*8*	*2*	*2*
4	*0*	*8*	*0*	*3*	*0*
5	*9*	*2*	*9*	*0*	*0*
6	*0*	*9*	*0*	*0*	*0*

Figure 1 shows the distribution of working employees in every day of the time window. As the figure shows, there are days having employees only from one shift, but we can also find days having employees from three different shifts.

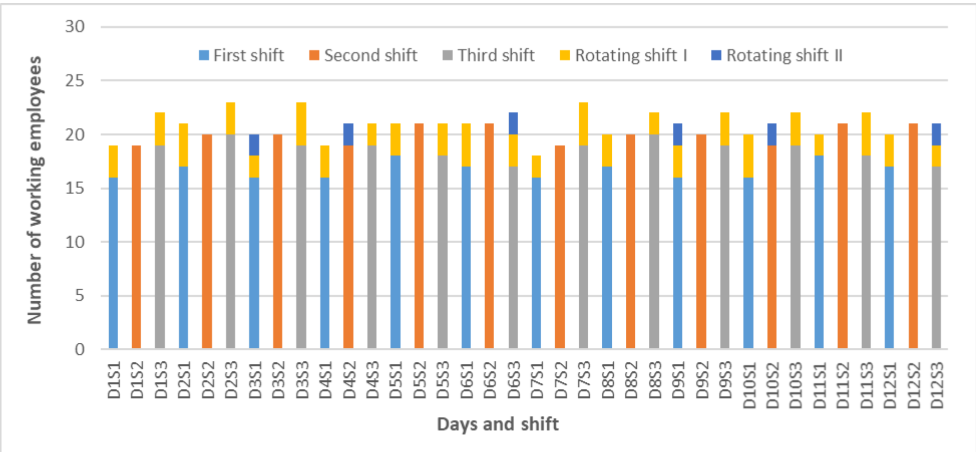

Figure 1. Number of working employees

In this first scenario, the specific costs of shifts were taken into consideration with the value shown in Table III. In this case, the total cost is 14240 USD per time window.

Table III.
Specific shift costs for the scenarios [USD per time window]

Scenario	Scenario 1	Scenario 2
First shift	12	12
Second shift	14	14
Third shift	16	16
Rotating shift I	18	8
Rotating shift II	20	10

In the next scenario, we take objective function 2 into consideration (6), which focuses on the minimisation of payments. Solving the optimisation problem in this case, the results have significant differences (see Table IV and Figure 2).

Table IV.
Results of the optimisation: number of employees starting their shift in a given day in Scenario 2

Day	First shift	Second shift	Third shift	Rotating shift I	Rotating shift II
1	0	0	7	5	1
2	0	10	1	6	0
3	7	0	8	4	1
4	0	0	0	5	0
5	7	0	7	0	2
6	0	8	1	0	0
7	7	0	0	0	0
8	0	0	0	0	0
9	0	1	0	0	0
10	0	10	0	0	0
11	0	0	0	0	0
12	1	1	0	0	0

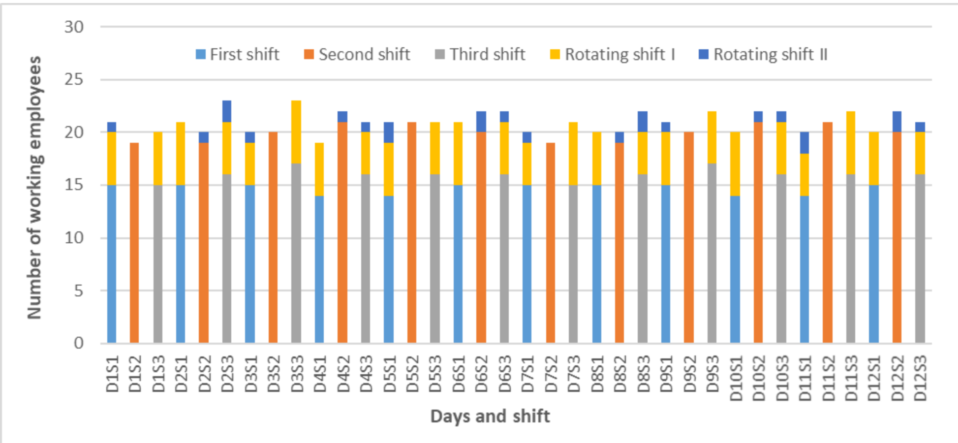

Figure 1. Number of working employees

As the above-mentioned scenarios show, the shift patterns can significantly influence the human resource strategy, because depending on the available number of employees, available shift patterns and payments in the case of different shifts.

5. Summary

Human resource management become a more and more important field in production companies. The optimisation of human resource strategy can significantly increase the cost efficiency of production and logistics operations, while the costs of human resources can also be reduced. Within the frame of this article, the author describes a new approach focusing on the optimisation of human resources depending on the available shift patterns, number of available employees and related costs. The suggested model can take three different objective functions into consideration: the minimisation of the number of required employees to fulfil the total demand on working operators per shift per days; the minimisation of payments within the time window; the minimisation of redundant employees. As the above described scenario analysis shows, the optimisation can lead to significant cost reduction, therefore, it is important to take into consideration the existing shift patterns and continuously upgrade them, because the dynamic optimisation of shift patterns can lead to the minimisation of human resource cost. The future research direction of the above mentioned research work is to extend the described model to integrate the optimisation of shift patterns and the scheduling of employees.

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