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STAFFING AND HUMAN RESOURCE ASSIGNMENT IN U-SHAPED PRODUCTION CELLS

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Abstract: *Today, U-shaped production cells play an important role in manufacturing, as their flexibility allows for highly efficient production with a small number of operators. Since the cost of human resources has a significant impact on the total cost of the overall production process and the assignment of operators to tasks can have a major impact on the efficiency of the production process, it is important to develop design methods that allow the assignment of resources to tasks in a way that maximizes the efficiency of the U-cell manufacturing system. In this paper, the authors present a mathematical model for assigning operators to task sets using different objective functions. Calculations based on the presented mathematical model demonstrate that, given a suitable choice of objective functions, it is possible to determine an optimal operator-task assignment that can improve the efficiency of the manufacturing system.*

Keywords: *assignment, human resource optimisation, U-shaped production cells, cost efficiency, productivity, logistics process*

1. INTRODUCTION

When designing manufacturing processes, the overall aim is to create structures that ensure a high degree of flexibility to meet customer needs. One such solution is the design of U-shaped production cells, which allow a small number of operators to service a large number of technological devices. The design of U-shaped cells requires the solution of a number of design problems such as layout planning [1], line balancing [2], taking stochasticity of the production environment into consideration [3], sequencing [4], implementation of lean paradigm in U-shaped cells [5], implementation of one-piece flow [6] and costing [7]. While automation and digitalisation are having an increasing impact on the technological and logistics efficiency of production processes, the role of human resources has not diminished, as human resources still account for a significant share of the costs of production processes. One of the major advantages of U-shaped production cells is that the number of operators required can be greatly reduced compared to conventional production system structures due to the special layout. In the present research work, the authors investigate how the available human resources can be allocated in a manufacturing system of U-shaped production cells in such a way that, in addition to the efficiency parameters derived from the historic data, the cooperative skills of the operators are taken into consideration. The article is organized as follows. Chapter 2 focuses on the available research results related to the connection between human resource management and assignment problems in production and services. Chapter 3 presents the mathematical model of human resource assignment problems focusing on the assignment of operators to operation groups of U-shaped production cells in a manufacturing systems. Chapter 4 presents a Solver supported solution of the proposed models, and summarizes the results of

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the numerical analysis. Conclusions, managerial impacts, and future research directions are discussed in the remaining part of the article.

2. LITERATURE REVIEW

The human resource assignment problems can be applied in different fields of economy. As a research of Crowly et al. demonstates [8,9], military is a special field, where human resource assignment can be implemented in a global meaning, where the location of object can be taken into conmsidertation as a geographical entity.Other application fields, optimization methods and approaches are described by En-Nahli in the field of health case [10], by Trappey et al. in the field of logistics infrastructures focusing on distribution centres [11], by Wu et al. in the case od audit firms [12], by Khalili et al. in the field of maintenance operations [13], by Fini et al. in the field of construction engineering [14] and by Ma in the case of sport management [15]. These application fields of assignment problems related to human resource management shows, that a wide range of human resource management problems can be modelled by assignment probems. Dependign on the complexity of the human resource allocation and assignment problems, a wide range of algorithms, analytical and heuristic algorithms and methods can be used to solve the human resource assignment problems including hybrid heuristics [16], knapsack problems [17], genetic algorithms [18], non-linear assignment solutions [19], Petri-Net models [20], fuzzy queuing models [13].

Human resource skills play an important role in increasing efficiency, as when multi-skilled human resources are available, much more flexibility in planning is allowed, as an operator can be assigned to multiple tasks, thus allowing a more efficient human resource - task assignment to be determined. The advantages of multi-skilled operators are discussed by, among others, by Heimerl et al [21] focusing on qualification of multi-skilled human resources under knowledge depreciation and company skill level targets, by Małachowski et al. [22] discussing the competence-based human resource assignment problems, and by Shahhosseini et al. [23] focusing on competency-based selection and assignment of human resources. An important principle of system design is that considering a single objective function in the design process can often lead to wrong results, since the objective functions describing the individual objectives and efficiency indicators of a system to be developed can be influenced in different directions by the variables of the optimization tasks. For this reason, it is important to develop integrated models that allow the simultaneous satisfaction of several objectives. An example of this is the research by En-Nahli et al. [10], which resulted in an integrated planning model that combines the objectives and constraints of assignment and route planning tasks.

The allocation of human resources cannot be understood only at the local level (company level, workshop level), since, as many studies show, in many cases, it is necessary to solve global human resource management tasks on an international scale. Examples of such projects include the researches by Inkson et al [24] focusing on contrasting models of international human resource development, by Kollinger [25], by Waxin et al. [26], describing the strategic human resource management aspects of international assignments, and by Zaharie et al. [27] fousing on human capital resources and subsidiary performance.

Other important research directions in the field of human resource management concern the application of assignment tasks in the following areas: taking uncertainties into consideration [28], social aspects of human resource management focusing on women as human resources [29], impact of policies of human resource assignment problems [30] and special cascading staff group problem [31] and. saving labor cost [32],

This short literature review demonstrates, that human resource assignment is an important research field in all areas of economy. The efficiency of processes can be significantly increased by suitable human resource management. This reseacr paper demonstrates this potential in the case of production system including U-shaped production cells.

3. MATERIALS AND METHODS

In this chapter, a general mathematical model is presented which is suitable for the assignment of operators and tasks for a manufacturing system consisting of u-shaped manufacturing cells.

The known parameters of the model are the followings:

- an assignment matrix of operators and possible operations, which defines which operator is suitable for which operation of which U-shaped manufacturing cell:

$$Z = \left[z_{i,j,k}\right], \tag{1}$$

  where Z is the assignment matrix of availability of operators for operations, $z_{i,j,k} = 1$ if operator *i* is availabel for operation *j* of U-shaped production cell *k*, otherwise , $z_{i,j,k} = 0$, $i = 1 \dots i_{max}$, $j = 1 \dots j_{max}(k)$ and $k = 1 \dots k_{max}$. i_{max} is the total number of operators, k_{max} is the total number of U-shaped production cells and $j_{max}(k)$ is the number of operations in U-shaped production cell *k*.
- average operator efficiency for each operation of the U-shaped cell:

$$E = \left[e_{i,j,k}\right], \tag{2}$$

  where E is the efficiency matrix, which defines the average efficiency of operators, $e_{i,j,k}$ defines the efficiency of operator *i* for operation *j* in U-shaped production cell *k*. In practice, it is possible to determine the efficiency of operators on the basis of historic data over a well-defined period of time.
- The cooperative efficiency of each operator, which defines the impact of each operator on the efficiency of each other's work:

$$CO = \left[co_{i,m}\right], \tag{3}$$

  where CO is the copperation efficiency matrix describing the impact of each operators on the work efficiency of each other’s work efficiency, $co_{i,m}$ describes this impact of operator *i* on operator m and $m = 1 \dots i_{max}$. This matrix can be both sparse and dense matrix. If CO is a sparse matrix, it indicates that the operators are more specialised, i.e. an operator is capable of performing only a small number of activities, which may indicate shortcomings in the training programme or skill gaps of the operators. If the CO matrix is a dense matrix, then operators may be selected to perform many tasks in a manufacturing system of U-shaped production cells, suggesting that training operators with good skills will result in human resources with universal skills, which will allow greater flexibility in assigning operators to tasks to solve the assignment task.

When assigning operators to U-shaped production cells and tasks, a number of objective functions can be formulated, with the common objective to increase efficiency. To describe the efficiency of an assignment task, it is possible to formulate an objective function in the following forms.

Objective function 1: Operators shall be assigned to each task of U-shaped manufacturing cells in such a way that the parameter describing the sum of the efficiency of each operator during the manufacturing activity performed during the time interval under consideration after the assignment is maximal, which means that the sum of the efficiency values modified to take into account the cooperation impact is maximal:

$$C_1 = \sum_{i=1}^{i_{max}} \sum_{j=1}^{j_{max}} \sum_{k=1}^{k_{max}} \left(x_{i,j,k} \cdot e_{i,j,k}^T \right) \to max., \quad (4)$$

where the total efficiency of the operators taking the cooperative impact into consideration can be calculated as follows:

$$\forall\, i \left(x_{i,j,k} = x_{m,j,k} \right): e_{i,j,k}^T = e_{i,j,k} + co_{m,i} \quad (5)$$

where $e_{i,j,k}^T$ defines the total efficiency of operator i, after assigned to operation j of U-shaped production cell k together with operator m.

Objective function 2: Operators shall be assigned to each task of the U-shaped production cell in such a way that, after assignment, the minimum value of the efficiency of each operator (taking into account the cooperation impact) during the production activity performed in the time interval under consideration is maximised:

$$C_2 = \min_i e_{i,j,k}^T \to max., \quad (6)$$

which means, that it is taken into consideration, that all operators are assigned to one operation of one U-shaped production cell.

Objective function 3: A possible approach is not to optimize the whole production system, but to equalize the efficiency of each U-shaped production cell, i.e., first determine the efficiency of each production cell for a given operator assignment, and then minimize the variance of these efficiency values:

$$C_3 = D(C_{3k}(k)) \to min., \quad (7)$$

where $D(C_{3k}(k))$ is the deviance of efficiency of U-shaped production cells resulted by an $X = x_{i,j,k}$ optimal assignment and

$$\forall\, k: C_{3k} = \sum_{i=1}^{i_{max}} \sum_{j=1}^{j_{max}} \left(x_{i,j,k} \cdot e_{i,j,k}^T \right). \quad (8)$$

Objective function 4: If some kind of priority rule can be formulated for each U-shaped production cell, it is possible to maximise a weighted efficiency that expresses the maximisation of the value produced rather than the quantity produced. I we maximize the total added value of the operations, the objective function can be written as follows:

$$C_4 = \sum_{i=1}^{i_{max}} \sum_{j=1}^{j_{max}} \sum_{k=1}^{k_{max}} \left(x_{i,j,k} \cdot e_{i,j,k}^T \cdot v_{j,k} \cdot q_{jk} \right) \to max. \quad (9)$$

where $v_{j,k}$ is the specific added value of operation *j* of U-shaped production cell *k* and q_{jk} is the planned amount of manufactured product related to operation *j* of U-shaped production cell *k*.

Objective function 5: Other potential way to focusing on the maximization of the added value is to maximize the sum of added values of U-shaped production cells. In this case the objective function is as follows:

$$C_5 = \sum_{k=1}^{k_{max}} \left[q_k \cdot v_{j,k} \cdot \min_{i,j} \left(x_{i,j,k} \cdot e_{i,j,k}^T \right) \right] \rightarrow max. \quad (10)$$

We can define various *constraints*. The most important constraints define, that all operations of the U-shaped production cells must be performed, which means, that operators must be assigned to all operations of U-shaped production cells:

$$\forall\, j, k{:}\ \sum_{j=1}^{j_{max}} \sum_{k=1}^{k_{max}} x_{i,j,k} = 1. \quad (11)$$

The decision variable of the optimization problem is the $X = \left[x_{i,j,k} \right]$ assignment matrix, where $\forall\, i, j, k{:}\ x_{i,j,k} \in (0,1)$. If $x_{i,j,k} = 1$, then operator *i* is assigned to operation group *j* of U-shaped production cell *k*, otherwise $x_{i,j,k} = 0$.

Within the frame of the next chapter the numerical results of some scenarios are demonstrated.

4. Results and discussion

The case study investigates the assignment of operators to operation groups for a production system consisting of 5 U-shaped production cells. Each U-shaped production cell has two operation groups, i.e. at least 10 operators are needed for the smooth operation of all U-shaped production cells. In the case study, the following parameters are considered as known:

- Assignment matrix of operators and possible operations, in our case the $Z = I$, which means, that all operators can perform all required operations in all U-shaped production cells.
- Initial efficiency of operators based on historical data from the ERP as an average value of a predefined time frame (see Table I). The initial efficiency can be calculated in different way, it is generally generated b the ERP, which filter the impacts of cooperative operators and compute a pure efficiency value, which will be modified by the cooperative efficianecy factor.
- Cooperative efficiency of each operator (see Table II). The cooperative efficiency matrix can be symmetric and asymmetric. The matrix is symmetric, if the cooperating operators have the same impact on each other and the matrix is asymmetric, if the cooperating operators influce the efficiency of their partner in different way.

The $E^T = \left[e_{i,j,k}^T \right]$ values can be calculated based on Table I and Table II. For example if operator 2 and operator 7 is assigned to the 1st operation of U-shaped production cell 4 (see operation G in Table I), then $e_{2,1,4}^T$ and $e_{7,1,4}^T$can be calculated as follow:

$$e_{2,1,4}^T = 67\% + 7\% = 74\% \text{ and } e_{7,1,4}^T = 66\% - 1\% = 65\%. \quad (12)$$

This equation represents, that in this small assignment example, operator 7 has positive impact on the efficiency of operator 2, while operator 2 has negative impact on the efficiency of operator 7.

Table I.
Initial efficiency of operators based on historical data from the ERP as an average value of a predefined time frame in [%]

	Cell 1		Cell 2		Cell 3		Cell 4		Cell 5	
	A	B	C	D	E	F	G	H	I	J
1	68	90	75	82	66	75	74	71	72	81
2	66	89	68	79	91	76	67	69	88	87
3	71	65	72	75	65	69	88	85	73	90
4	70	67	79	83	89	80	66	89	70	91
5	82	80	72	70	71	65	69	77	74	73
6	78	91	89	89	80	87	68	76	74	83
7	76	77	77	88	74	82	66	82	71	84
8	76	76	65	81	79	91	68	72	71	76
9	79	70	76	69	68	83	89	84	82	83
10	80	82	69	87	83	72	77	85	91	71

Table II.
Cooperative efficiency factor in [%]

	1	2	3	4	5	6	7	8	9	10
1	0	-9	0	1	-2	-7	2	-6	-4	-4
2	-9	0	-7	4	6	4	-1	5	1	5
3	-7	-6	0	-9	1	8	1	7	-3	4
4	-2	2	-9	0	-3	-5	-5	-4	0	7
5	-7	6	5	-6	0	5	7	5	3	3
6	-6	-1	1	1	0	0	8	8	-5	-4
7	-2	7	7	-7	0	4	0	5	2	7
8	3	4	1	7	-5	6	8	0	6	-1
9	-6	2	-7	-3	5	6	-1	-7	0	7
10	-6	-2	-1	3	-7	-5	-1	-2	7	0

Conventional assignment problems are LP problems, but in our case, the search space is more comple, so we have used an Evolutive Solver to find the optimal assignment of operators and operatio groups of U-shaped production cells.

The solution represented by Table III can be summarised as a permutation array including integers from 1 to 10 as follows: (9,1,6,7,2,8,3,5,10,4).

In the case of solution represented by Table III, the value of the objective function 1 is $C_1 = 902\%$, which is a logical decision variable. We can transform this value to a real physical value, it is the average efficiancy of operators, which is 90.2% in the case of the first scenario.

Table III.

The optimal assignment using objective function 1

	Cell 1		Cell 2		Cell 3		Cell 4		Cell 5	
	A	B	C	D	E	F	G	H	I	J
1	0	1	0	0	0	0	0	0	0	0
2	0	0	0	0	1	0	0	0	0	0
3	0	0	0	0	0	0	1	0	0	0
4	0	0	0	0	0	0	0	0	0	1
5	0	0	0	0	0	0	0	1	0	0
6	0	0	1	0	0	0	0	0	0	0
7	0	0	0	1	0	0	0	0	0	0
8	0	0	0	0	0	1	0	0	0	0
9	1	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	1	0

If we take into account the predefined initial required amount an the specific added values of each operation groups (see Table IV), then the total added value in the case of this solution is $AV = 20770$ €.

Table IV.

Predefined initial required amount (PIRA) an the specific added values (SAV) of each operation groups

	Cell 1		Cell 2		Cell 3		Cell 4		Cell 5	
	A	B	C	D	E	F	G	H	I	J
PIRA	100	130	120	200	122	95	200	120	100	60
SAV	4	6	12	15	24	9	32	21	41	7

The distribution of the added value in the production system is shown in Fig. 1.

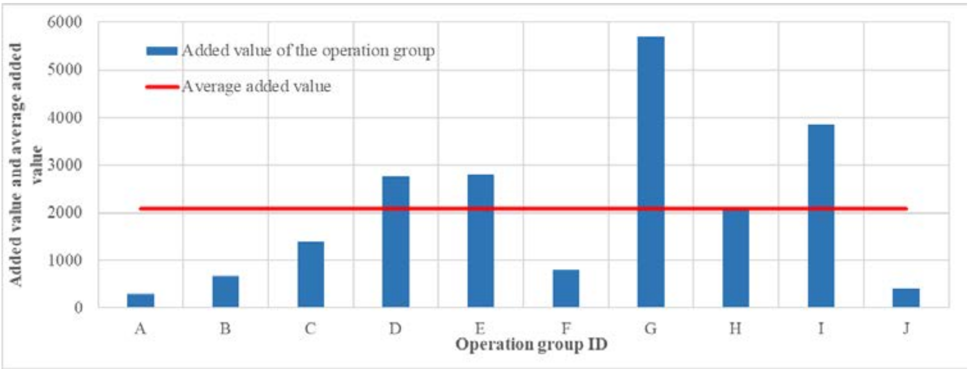

Figure 1. Distribution of the added value in the production systems and the average added value in the first scenario

If we use (10) as objective function, then the total added value is $AV = 21089$ € and the distribution of the added value in the production system is shown in Fig. 2.

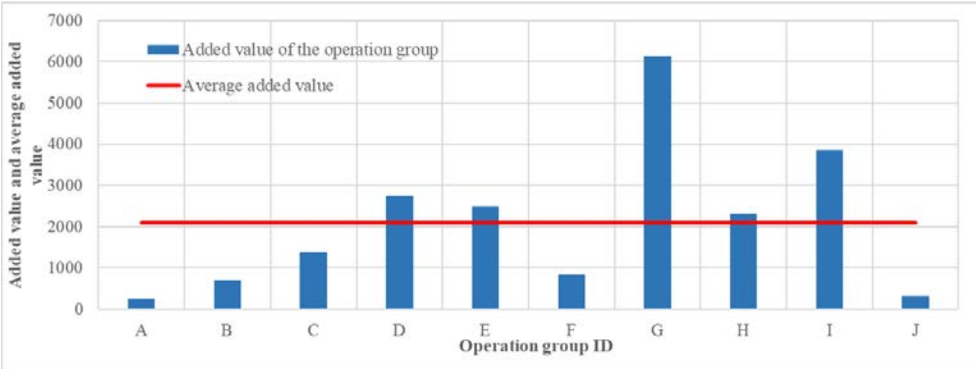

Figure 2. Distribution of the added value in the production systems and the average added value in the second scenario

These scenarios shows, that the objective functions must be chosen carefully, because depending on the chosen objective function, different total added values can be resulted by the optimization of the operator assignment problem. It is trivial, that dpepending on the density of the Z matrix, the flexibility of the optimization can be increased or decreased. In our scenarios, we have choisen the ideal $Z = I$ parameters, which means, that all operators are available for all potential operation groups in all U-shaped production cells.

5. Conclusions

The role of human resources has not decreased with the spread of automation and digitalisation. The reason is that there are many manufacturing structures in which, despite their high flexibility and efficiency, human resources (operators) still play an important role. In this research work, the authors investigated the possibilities of assigning human resources to groups of operations in a manufacturing system consisting of U-shaped production cells. A mathematical model has been developed that allows solving the optimal resource assignment task by applying different objective functions. Based on the mathematical model developed, a case study was used to validate the models.

The presented model is suitable for optimal resource allocation based on deterministic parameters. A possible future research direction could be the development of a complex mathematical model that takes into account environmental uncertainties using stochastic parameters.

References

[1] Aase, G. R., Olson, J. R. & Schniederjans, M. J. (2004). U-shaped assembly line layouts and their impact on labor productivity: An experimental study, *European Journal of Operational Research* **156**(3), 698-711, https://doi.org/10.1016/S0377-2217(03)00148-6

[2] Ağpak, K. & Gökçen, H. (2007). A chance-constrained approach to stochastic line balancing problem, *European Journal of Operational Research* **180**(3), 1098-1115, https://doi.org/10.1016/j.ejor.2006.04.042

[3] Chiang, W.-C. & Urban, T. L. (2006). The stochastic U-line balancing problem: A heuristic procedure, *European Journal of Operational Research* **175**(3), 1767-1781, https://doi.org/10.1016/j.ejor.2004.10.031
[4] Kim, Y. K., Kim, J. Y. & Kim, Y. (2006). An endosymbiotic evolutionary algorithm for the integration of balancing and sequencing in mixed-model U-lines, *European Journal of Operational Research* **168**(3), 838-852, https://doi.org/10.1016/j.ejor.2004.07.032
[5] Kumar, M., Antony, J., Singh, R. K., Tiwari, M. K. & Perry, D. (2006). Implementing the lean sigma framework in an Indian SME: A case study, *Production Planning and Control* **17**(4), 407-423, https://doi.org/10.1080/09537280500483350
[6] Miltenburg, J. (2001). One-piece flow manufacturing on U-shaped production lines: A tutorial, *IIE Transactions (Institute of Industrial Engineers)* **33**(4), 303-321, https://doi.org/10.1023/A:1007642522626
[7] Modarress, B., Ansari, A. & Lockwood, D. L. (2005). Kaizen costing for lean manufacturing: A case study, *International Journal of Production Research* **43**(9), 1751-1760, https://doi.org/10.1080/00207540500034174
[8] Crowley-Henry, M. & Heaslip, G. (2014). Short-term international assignments. Military perspectives and implications for international human resource management, *European Management Journal* **32**(5), 752-760, https://doi.org/10.1016/j.emj.2014.02.002
[9] Crowley-Henry, M., Heaslip, G. & Martin, J. (2015). Corrigendum to "Short-term international assignments. Military perspectives and implications for international human resource management", *European Management Journal* **33**(6), 500, https://doi.org/10.1016/j.emj.2015.11.001
[10] En-Nahli, L., Allaoui, H. & Nouaouri, I. (2015). A multi-objective modelling to human resource assignment and routing problem for home health care services, *IFAC-PapersOnLine* **28**(3), 698-703, https://doi.org/10.1016/j.ifacol.2015.06.164
[11] Trappey, A. & Ho, P.-S. (2002). Human resource assignment system for distribution centers, *Industrial Management and Data Systems* **102**(1-2), 64-72, https://doi.org/10.1108/02635570210419609
[12] Wu, B., Wu, Y., Zhang, M. & Li, J. (2023). Opening the black box of human resource allocations in audit firms: The assignment of audit partners to audit engagements, *British Accounting Review* **1**, 101231, https://doi.org/10.1016/j.bar.2023.101231
[13] Khalili, S., Nasab, H. H. & Moobed, F. (2015). Optimal assignment of human resources for maintenance departments using fuzzy queuing systems, *International Journal of Production Research* **53**(15), 4583-4593, https://doi.org/10.1080/00207543.2014.998791
[14] Fini, A. A. F., Akbarnezhad, A., Rashidi, T. H. & Travis Waller, S. (2017). Job Assignment Based on Brain Demands and Human Resource Strategies, *Journal of Construction Engineering and Management* **143**(5), 04016123, https://doi.org/10.1061/(ASCE)CO.1943-7862.0001273
[15] Ma, X.-Y. (2011). Application of assignment model in PE human resources allocation, *Energy Procedia* **16**, 1720-1723, https://doi.org/10.1016/j.egypro.2012.01.266
[16] Tkatek, S., Abdoun, O., Abouchabaka, J. & Rafalia, N. (2015). A hybrid heuristic method to solve an assignment problem of human resource, *International Review on Computers and Software* **10**(9), 977-986, https://doi.org/10.15866/irecos.v10i9.7246
[17] Tkatek, S., Abdoun, O., Abouchabaka, J. & Rafalia, N. (2016). A multiple knapsack approach for assignment problem of human resources, *Journal of Theoretical and Applied Information Technology* **87**(3), 374-379.
[18] Tkatek, S., Abdoun, O., Abouchabaka, J. & Rafalia, N. (2019). The immigration genetic approach to improve the optimization of constrained assignment problem of human resources, *Advances in Intelligent Systems and Computing* **915**, 675-685, https://doi.org/10.1007/978-3-030-11928-7_60
[19] Turan, F. K. & Coruh, G. (2022). Sustainable human resource management: Improving employee satisfaction with a nonlinear assignment program involving uncertain utility

functions, *Journal of the Faculty of Engineering and Architecture of Gazi University* **37**(4), 2025-2040, https://doi.org/10.17341/gazimmfd.614325

[20] Wang, J. G. (2001). Study on Petri nets assignment model of human resources in complex system, *Xitong Gongcheng Lilun yu Shijian/System Engineering Theory and Practice* **21**(4), 106,

[21] Heimerl, C. & Kolisch, R. (2010). Work assignment to and qualification of multi-skilled human resources under knowledge depreciation and company skill level targets, *International Journal of Production Research* **48**(13), 3759-3781, https://doi.org/10.1080/00207540902852785

[22] Małachowski, B. & Zaikin, O. (2012). Competence-based human resource assignment in research projects, *IFAC Proceedings Volumes (IFAC-PapersOnline)* **14**, 1165-1169, https://doi.org/10.3182/20120523-3-RO-2023.00375

[23] 23Shahhosseini, V. & Sebt, M. H. (2011). Competency-based selection and assignment of human resources to construction projects, *Scientia Iranica* **18**, 163-180, https://doi.org/10.1016/j.scient.2011.03.026

[24] Inkson, K., Arthur, M. B., Pringle, J. & Barry, S. (1997). Expatriate assignment versus overseas experience: Contrasting models of international human resource development, *Journal of World Business* **32**(4), 351-368, https://doi.org/10.1016/S1090-9516(97)90017-1

[25] Kollinger, I. & Koris, R. (2022). I'm difficult, but not impossible: how millennials view international assignments and the implications for human resource management (HRM), *Personnel Review* **51**(6), 1707-1726, https://doi.org/10.1108/PR-01-2021-0042

[26] Waxin, M.-F., Katsioloudes, M. I. & Hadjidakis, S. (2007). Strategic human resource management of international assignments, *International Business: A Global Perspective* **1**, 387-438, https://doi.org/10.4324/9780080471464

[27] Zaharie, M., Poór, J., Ratiu, P. & Osoian, C. (2020). International assignments, human capital resources and MNC subsidiary performance in CEE countries, *Multinational Business Review* **28**(1), 65-85, https://doi.org/10.1108/MBR-08-2019-0094

[28] Gaspars-Wieloch, H. (2021). The assignment problem in human resource project management under uncertainty, *Risks* **9**(1), 25, https://doi.org/10.3390/risks9010025

[29] Harcar, T. & Harcar, T. (2004). Expatriate women's success in international assignments: Exploring the relationship between family issues and human resource policies, *Journal of Transnational Management Development* **8**(4), 19-35, https://doi.org/10.1300/J130v08n04_03

[30] Youngs, P., Pogodzinski, B. & Galey, S. (2015). How Labor Management Relations and Human Resource Policies Affect the Process of Teacher Assignment in Urban School Districts, *Educational Administration Quarterly* **51**(2), 214-246, https://doi.org/10.1177/0013161X14529148

[31] Hirose, Y., Sasaki, Y. & Kinoshita, A. (2001). Human resource assignment and role representation mechanism with the "cascading staff-group authoring" and "relation/situation" model, *Medinfo* **10**, 740-744.

[32] Dong, S. L. (2014). Research of human resources configuration by the model of assignment problem, *Applied Mechanics and Materials* **602-605**, 3765-3768, https://doi.org/10.4028/www.scientific.net/AMM.602-605.3765