CPSL
CONFERENCE ON PRODUCTION SYSTEMS AND LOGISTICS
CPSL 2020

1st Conference on Production Systems and Logistics

Current Knowledge Management in Manual Assembly – Further Development by the Analytical Hierarchy Process, Incentive and Cognitive Assistance Systems

Robin Sochor[1], Teresa Sofie Schick[2], Lukas Merkel[1], Stefan Braunreuther[1], Gunther Reinhart[1]

[1] Fraunhofer Research Institution for Casting, Composite and Processing Technology IGCV, Provinostr. 52, D-86153 Augsburg, Germany
[2] Technische Universität München, Arcisstraße 21, D-80333 München, Germany

Abstract

The complexity of manual assembly is continuously increasing due to a large variety of products, multi-product assembly or a batch size of one. To stay ahead in competency and competition, and to ensure adaptability and flexibility in today's dynamic production environment, awareness of knowledge as the 4th factor of production, as well as the effective management of knowledge, are crucial. The present research therefore aimed at further advancing knowledge management in manual assembly by (1) assessing cognitive assistance systems and organisational incentive systems by use of an online survey distributed to German production companies, and by (2) applying the Analytical Hierarchy Process (AHP) as a transparent decision-making tool for knowledge-based improvements in the manual assembly process and workplace design. By employing an exemplary case of two feasible assembly alternatives, the AHP was applied as a method of knowledge measurement in a specific use case revealing priorities for knowledge-based ideas. To properly compute a final priority ranking of workers' knowledge ideas, an algorithm written in Python programming language in accordance with the problem-solving framework previously published by Thomas L. Saaty (Decision Sciences, 18: 157-177, 1987). The performance of the algorithm shows that the rating process can be standardised and automated to a high level, and that the AHP may thus provide supportive evidence for assembly optimisation. The AHP-derived results can be used as a suitable basis for a bonus-point incentive system, which should contain both material and immaterial incentives. To operationalise this, it is therefore recommended to integrate the AHP rating process into a knowledge management application of hand-held devices, such as tablets, which are widely used in the production environment.

Keywords

Knowledge Management; Manual Assembly; Analytical Hierarchy Process; Incentive Systems; Cognitive Assistance Systems

1. Introduction

"Progress depends on the exchange of knowledge" [1]. This quote by the physicist, Albert Einstein, may well be applied to the present dynamic production environment driven by ongoing digitalisation and challenged by a demographical shift within the workforce. Multiple changeovers and adjustments during the individual steps of a given production cycle, smaller batch sizes and a growing variety of products significantly contribute to increased complexity in manual assembly [2, 3, 8]. Manual assembly operations

put a high demand on assembly workers with the speed, precision and quality of their work being essential requirements [3]. The optimal fulfilment of these requirements is strongly related to the workers' comprehensive cognitive abilities, distinct sense of touch and individual experience and capabilities. Thus, experienced workers fulfil the role of knowledge-carriers and problem-solvers in production companies [4]. On the basis of their detailed knowledge concerning various assembly processes and their implementation, workers might be able to suggest alternative assembly sequences for products, different from those determined by the work instructions, thereby potentially increasing efficiency. To systematically benefit from workers' prevailing implicit knowledge, a platform is needed [6] by which workers may share their knowledge and participate in decision-making processes with regard to product assembly, workplace design or product development [5]. Whilst it is widely accepted that an adequate knowledge management system does represent such a suitable platform [11], the issue of 'how to assess knowledge' remains an unsolved problem of knowledge management, as has been consistently documented by previous research [11, 12, 13]. Up to now, available tools for the assessment of knowledge have predominantly been of a quantitative nature [12]. These tools, however, are considered rather inadequate, or even counterproductive, for the purpose and, therefore, qualitative aspects also need to be included into an assessment process [11].

The present research was therefore designed (1) to determine relevant aspects of knowledge management in manual assembly by a web-based survey and a literature review, (2) to examine the suitability of the Analytical Hierarchy Process as an assessment tool for workers' knowledge-based ideas towards the advancement of manual assembly, and (3) to propose a knowledge management system employing both incentive systems and cognitive assistance systems.

2. Web-Based Survey – Results and Theoretical Framework

300 German production companies from various industrial sectors, using manual assembly, were approached for participation. Information on knowledge management and knowledge types, knowledge transfer, incentive systems, and cognitive assistance systems in manual assembly was obtained via a web-based survey from participating firms from 1st May 2019 to 30th June 2019. Out of the 300 companies, a total of 11 completed all sections of the survey, resulting in a response rate of 4%. This relatively low response rate should be kept in mind when interpreting the results which are expressed as percentages in Table 1.

Table 1: Web-Based Survey: Characteristics of the participating firms, n=11.

Industrial Sector		Department of Respondents		Annual Turnover in Million Euros		Number of Employees worldwide	
Mechanical Engineering	73%	Assembly	37%	<100	46%	<100	18%
Automotive	45%	Management	36%	>100	27%	>100	37%
Electronics	18%	Sales	9%	>10,000	18%	>1,000	18%
Assembly Technology	18%	HR	9%	Not available	9%	>10,000	27%
Medical Technology	18%	Production	9%				

2.1 Opportunities of knowledge management in manual assembly

All survey participants reported a high to very high estimate of their companies' expected opportunities secondary to the implementation of knowledge management in manual assembly. Benefit was particularly expected towards product quality and reduced error rate (100%), but also increased efficiency and customer satisfaction (91%), time expenditure (82%) and cost-savings (73%). Some companies also considered knowledge enhancement (45%) and workers' satisfaction (36%) as benefits of knowledge management.

2.2 Knowledge categories in manual assembly

To rate the importance of different categories of workers' knowledge relevant for continuous improvements in manual assembly, respondents of the survey were able to choose between five options, ranking from most important to least important. The relevant categories of knowledge employed were those previously defined by Berger et al. [4]. Our survey revealed that the most important categories of assembly workers' knowledge are knowledge of production means (91%), joining technologies (82%), product characteristics (82%), assembly procedures (73%) and of problem-solving in engineering processes (55%). Moreover, detailed knowledge of materials (45%), technologies (36%), product use (27%) and suppliers (9%) was also considered very important by some respondents.

2.3 Knowledge transfer

Knowledge transfer is not an end in itself. Especially in today's dynamic production environment where agility is a key for success, knowledge transfer across hierarchies, departments, business entities, organisations and generations of employees plays a decisive role [17]. However, in practice, knowledge transfer in manual assembly is often hindered [12], which is why this issue was also addressed in our survey. 73% of the responding companies reported that knowledge transfer in manual assembly is compromised because there is not enough time to share knowledge. Furthermore, the workers' lack of motivation to share knowledge, as well as the (lack of) a clear channel of information and communication, were considered as transfer barriers by 45%. The unwillingness to use somebody else's knowledge (27%), lack of trust (9%), but also the workers' insufficient language skills (9%) may be relevant barriers, as reported by some of the participating companies. To enhance the exchange of knowledge in manual assembly, the majority of companies use process modelling (73%) and knowledge maps (55%).

2.4 Knowledge management systems

A knowledge management system can be defined as a dynamic application system that contains tools to identify knowledge, to assist in the active search and transfer of knowledge, and to advance the distribution and usage of existing and development of new knowledge [16]. For our survey, items of existing knowledge management systems were used as previously published [1,16]. Our results show that content-orientated systems, such as document and content management systems or learning systems [16] are the most frequently (73%) used systems by the survey participants for knowledge management in manual assembly. Authoring systems, a sub-group of classified-as-content-orientated systems, are currently applied by 36% of the responding companies, which is in line with previous research suggesting suitability and the great potential of authoring systems for knowledge management in manual assembly [5]. Groupware systems, such as communication, collaboration and co-ordination systems, are currently used by 45% of the responding companies in our survey, while executive information systems, such as data warehouse or data mining systems, are used by 36%, and systems of artificial intelligence, e.g. text-mining systems or expert and agent systems, are not yet widely used with only a 9% reporting rate.

2.5 Incentive systems

Incentives, material or immaterial, have the potential to activate individuals' motivation and satisfy their needs. Thus, the implementation of incentive systems aims at motivating workers to share their knowledge within their company [6]. The present study revealed that the impact of material incentives on the motivation of workers to share their knowledge is strong for 30%, medium for 45%, and weak for 18% of the companies. Immaterial incentives, however, such as the personal recognition of workers (82%), corporate culture (73%), promotion opportunities (64%), work content and workplace design (55%), safety (45%) and playful incentives (36%) have a strong to very strong impact on employees' motivation to share knowledge. A variety of requirements have previously been identified as relevant for the design of incentive systems [7], and were employed as survey items in our study. The responding companies reported transparency as the single most relevant requirement (100%). This is in accord with previously reported findings by Bullinger et al., who similarly reported transparency to be the most important design feature of an incentive system based on a survey in both producing and non-producing companies (87.2%) [7]. In our study, the following requirements were also considered of high relevance: motivational stimulation (82%), economic efficiency (73%), flexibility (73%), performance orientation (73%), rewarding effects (64%), individual and group applicability (64%) and fairness (55%). The incentive systems currently in use by the majority of the production companies responding to our survey are point-based incentive systems (55%), balanced scorecard-based systems (27%), gamification (9%) and management by knowledge objective (9%).

2.6 Cognitive Assistance Systems in Manual Assembly

In view of the complexity and product variety in manual assembly [3, 8], an exchange of knowledge will undoubtedly benefit from support by cognitive assistance systems. 64% of the production companies in manual assembly in our study currently use cognitive assistance systems in manual assembly while 18% use none. Cognitive assistance systems, such as mobile devices (wearables, handhelds) or immersive technologies (Augmented Reality, Virtual Reality), can support assembly workers by providing, processing or collecting information [8]. Moreover, they might motivate workers to share their knowledge and support the externalisation of knowledge, from tacit knowledge (i.e. experience), to explicit knowledge (i.e. information) [9]. In our survey, the majority of companies use tablets as cognitive assistance systems (62%), while wearables, such as data glasses (26%) or smart watches (12%), are used to a lesser degree. The major area of application of such cognitive assistance systems is the one related to training of workers (86%). The higher acceptance of mobile devices, such as smartphones or tablets, as compared to smart watches or data glasses, has previously been reported [10, 3] and may be attributed to the widespread familiarity of these devices in the consumer sector [10]. On the basis of our survey, and in line with findings recently published, we propose handheld mobile devices as the most suitable cognitive assistance tool for purposes of knowledge management.

3. The Analytic Hierarchy Process (AHP)

The assessment of workers' knowledge-based ideas presents a major challenge in the field of knowledge management, as no validated decision-making tools have been agreed upon so far [11, 13]. In this paper, we suggest the Analytic Hierarchy Process (AHP) as a suitable tool for such decision-making.

The AHP, first described by Thomas L. Saaty, represents a mathematical method designed to assist in multi-criteria decision-making [15]. In this context, decision-making has the objective of finding the best alternative or set of alternatives by considering a number of criteria. Based on experts' judgements, a pairwise comparison of multiple criteria with the alternatives under consideration is mathematically performed and yields a ranking and value of alternatives which by the decision-maker is expected to be correct [14, 15]. The AHP method is particularly advantageous when both quantitative and qualitative criteria have to be considered simultaneously [18].

Up to now, the AHP method has been employed in quite a number of decision-making situations. Thus, the AHP has been proven useful to assess the risk of losing knowledge [13], to evaluate knowledge management tools [19] and to support innovation processes in organizations [20]. The AHP has also been applied in the field of operations management (e.g. choice of technology, product design or plant layout) [21], in the evaluation or selection of new product ideas [22, 23] or as one of the most commonly multi-criteria decision-making methods in the area of transportation research [18].

To our knowledge, however, in the field of manual assembly the AHP has not yet been tested to assess the superiority of workers' knowledge-based ideas versus established assembly procedures. Therefore, we attempted to determine the suitability of the AHP as an assessment tool in an exemplary decision-making case of two manual assembly alternatives.

For this purpose, an algorithm, following the previously published computation rules by Saaty [14, 15], was written in the Python programming language which allowed for an automated and standardised mathematical prioritisation of a particular worker's knowledge-based idea.

The AHP is carried out by the following fundamental steps according to Saaty T.L [15] and Saaty R.W. [14]: (1) A specific decision-making problem has to be structured into a multi-level hierarchy, descending from an overall objective at the top-level, to criteria at the intermediate level, and to alternatives at the lowest level. (2) Subsequently, comparative judgements in terms of pairwise comparisons between defined criteria are conducted. (3) Based on the resulting judgement matrix, local priorities can be derived by solving for the principal eigenvector of the matrix and normalising the result. (4) To determine the inconsistency of each matrix of pairwise comparisons, and also for the entire hierarchy, a consistency ratio (CR) has to be computed. Inconsistency is tolerated up to a level of 10%.

3.1 Application of the AHP in an exemplary decision-making case of a knowledge-based idea

3.1.1 Case description

For the manual assembly of a specific component, an assembly worker has to grab five springs individually. Based on his/her work experience, the worker is convinced that this assembly step could be optimised if he/she was allowed to grab five springs in one single movement. He/she therefore shares his/her knowledge-based idea with the company.

3.1.2 AHP Decision-Making Hierarchy

A company's overall objective is to continuously improve manual assembly processes, which may vary from company to company and therefore need to be specifically defined. In the exemplary decision-making case (3.1.1), a judgement has to be made which one of two alternatives should be preserved or implemented, respectively (Figure 1). For this purpose, seven criteria were considered relevant: (1) Time Advantage, (2) Cost Advantage, (3) Quality Improvement, (4) Employee Satisfaction, (5) Technical Feasibility, (6) Ergonomic Design, (7) Reduction of Waste (Figure 1).

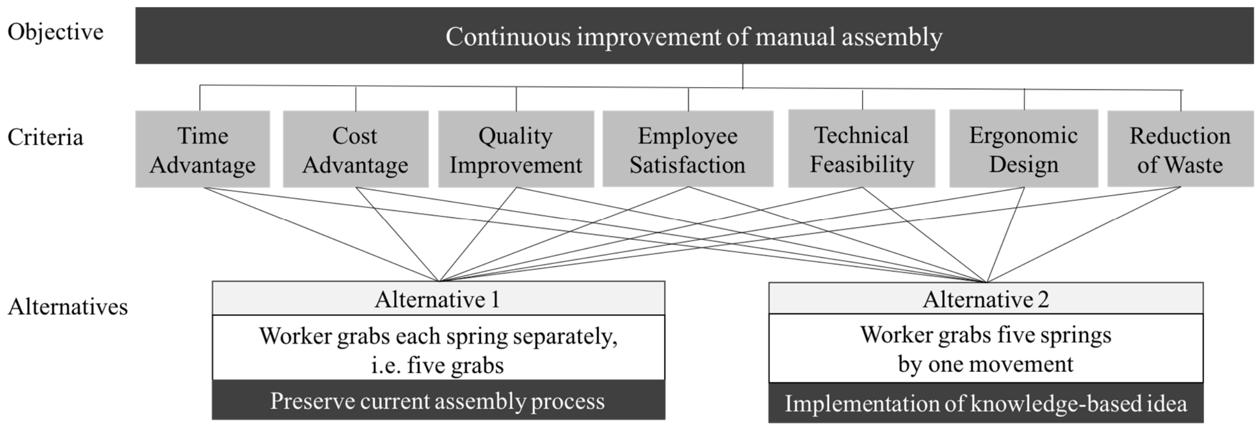

Figure 1: AHP decision-making hierarchy for the proposed exemplary manual assembly case.

3.1.3 Pairwise comparisons of assessment criteria

Based on the fundamental scale by Saaty [14, 18] ranging from 1 to 9, with 1 representing the equal importance of two criteria, and 9 the highest superiority of one criterion over the other, all seven criteria were weighted pairwise against each other with respect to the overall focus, the continuous improvement of manual assembly (Table 2). Based on work experience and professional judgement, decision-makers have to ask themselves the question: "How much more is quality improvement preferred over time advantage?" In our exemplary case, quality improvement in manual assembly is considered slightly more important than time advantage. Thus, the fundamental scale value of 3 is entered in the (3.1) position. The reciprocal value 1/3 is automatically entered for the transpose position (1.3).

Table 2: Pairwise comparisons of defined assembly assessment criteria.

Defined Criteria	TA	CA	QI	ES	TF	ED	RW
Time Advantage (TA)	1	0.33	0.33	4	3	5	7
Cost Advantage (CA)	3	1	1	3	3	5	5
Quality Improvement (QI)	3	1	1	3	3	5	7
Employee Satisfaction (ES)	0.25	0.33	0.33	1	1	5	7
Technical Feasibility (TF)	0.33	0.33	0.33	3	1	3	2
Ergonomic Design (ED)	0.2	0.2	0.2	0.2	0.33	1	5
Reduction of Waste (RW)	0.14	0.2	0.14	0.33	0.5	0.2	1

3.1.4 Local priorities (or weights) of assessment criteria and alternatives

Entry of weighted assessment criteria into the Python-written Saaty algorithm [14] of the AHP yielded the local priorities of each of the criteria. The seven local priorities constitute the principal eigenvector of all seven criteria together (Table 3, Column 2). In addition, matrices of paired comparisons were set up for the two assembly alternatives compared with respect to each of the seven criteria. There were seven matrices in total. The local priorities for the alternatives (Table 3, Column 3) were also computed by the Python written AHP-algorithm, yielding the principal eigenvector.

Table 3: Local priorities of criteria and alternatives in the proposed exemplary decision-making case.

Defined Criteria	Local Priorities of Criteria	Local Priorities of Alternatives (Alternative 1, Alternative 2)
Time Advantage	0.27	(0.100, 0.900)
Cost Advantage	0.26	(0.125, 0.875)
Quality Improvement	0.19	(0.833, 0.166)
Employee Satisfaction	0.11	(0.166, 0.833)
Technical Feasibility	0.08	(0.875, 0.125)
Ergonomic Design	0.04	(0.166, 0.833)
Reduction of Waste	0.02	(0.875, 0.125)

The consistency ratio (CR) calculation was also performed by the Python algorithm. The computed CR of the criteria matrix (Table 2) is 0.097 (i.e. 9.7%) and therefore below the acceptable inconsistency tolerance level of 10%. Thus, inconsistency has no adverse effect on the overall result. However, if a better CR was required, the pairwise comparisons would have to be redone with alternative ratings. Professional software packages, such as Expert [14] and others, will directly display inconsistency assessments in terms of critical judgement input [14]. A consistency check for the alternative matrices is unnecessary, as inconsistency cannot arise by comparing only two elements.

3.1.5 Global priorities (weights) of assembly alternatives

To finally derive an arithmetic basis for the ultimate decision on the best alternative from the computational results, the local priorities for the two assembly alternatives (Alt. 1, Alt. 2) are combined to an overall 2x7 matrix and are multiplied with the principal eigenvector, the 7x1 matrix of the seven predefined criteria, as follows:

A

$$\begin{matrix} \text{Alt. 1} \\ \text{Alt. 2} \end{matrix} \begin{bmatrix} 0.100 & 0.125 & 0.833 & 0.166 & 0.875 & 0.166 & 0.875 \\ 0.900 & 0.875 & 0.166 & 0.833 & 0.125 & 0.833 & 0.125 \end{bmatrix} * \begin{bmatrix} 0.27 \\ 0.26 \\ 0.19 \\ 0.11 \\ 0.08 \\ 0.04 \\ 0.02 \end{bmatrix} = \begin{bmatrix} 0.343 \\ 0.657 \end{bmatrix}$$

B

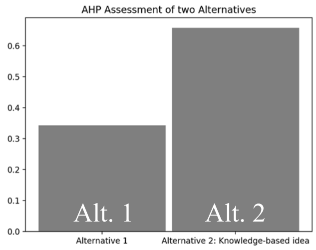

Figure 2: Matrix multiplication of both alternatives (Alt. 1, Alt. 2) and criteria ratings (A) yields the global priorities which are automatically displayed as a bar graph (B) by the Python-written AHP algorithm.

In our exemplary decision-making case, alternative 2 received a global priority of 0.657 and was, therefore, superior to alternative 1, which had a global priority of only 0.343 (Figure 2, A). The global priorities of both alternatives are automatically generated by the Python-programmed algorithm and displayed in a bar graph (Figure 2, B). Before a final decision with regard to the implementation of alternative 2 as the future assembly process is made, a sensitivity analysis should be considered. Hereby, the criteria weights are systematically altered to determine the inflection point where the ranking of the alternatives is reversed, i.e. alternative 1 would then display a higher global priority than alternative 2. In the case of strategic decisions in manual assembly, a sensitivity analysis is generally recommended to test whether the calculated priorities are stable [18].

4. Proposition of a Knowledge Management System Employing both Incentive Systems and Cognitive Assistance Systems

The present study revealed that mobile assistance systems, i.e. tablets, are most widely used as cognitive assistance systems in manual assembly (62%). Since tablets provide user-friendly display options [10], and may be flexibly used at multiple work stations [2], we recommend tablets as cognitive assistance systems for applications in knowledge management. For this purpose, the development of a knowledge management application software (app) is recommended which should (1) enable workers to share their knowledge via text messages, photos or videos, (2) enable supervisors to assess workers' knowledge-based ideas by the AHP method, and (3) to motivate workers to share their knowledge by a point-based incentive system allowing for both material and immaterial benefits. Since the application of AHP in our exemplary case has proven to be effective, we suggest the employment of the AHP as a suitable method to evaluate workers' knowledge-based ideas and to set up the incentive system on the basis of the AHP results obtained. In analogy to the fundamental scale published by Saaty, a point-based scale ranging from 1 to 9 could be implemented as proposed in Table 4. The worker in our exemplary decision making case would therefore receive six incentive points for sharing his/her knowledge by suggesting alternative 2 with its global priority of 0.657 (Table 4). Incentive points might subsequently be redeemed in real time in a reward shop. This proposed incentive system however shows certain constraints.

It should be noted, though, that such an incentive system also bears potential inherent risks. If more than two knowledge-based ideas were to be considered, the maximal achievable number of incentive points for a knowledge-based idea, derived from global priority values obtained by the AHP, would decrease, potentially leading to workers' disappointment and/or perhaps even resignation. Furthermore, such incentive systems need to be made resistant to manipulation. These issues will have to be examined in more detail in follow-on studies.

Table 4: Suggestion of an incentive system analogous to Saaty's fundamental scale [14] relating incentive points to global priority values obtained by the Analytical Hierarchy Process (AHP).

Global Priority AHP Result	Receiving Points
0 to 0.1	0
0.1 to 0.2	1
0.2 to 0.3	2
0.3 to 0.4	3
0.4 to 0.5	4
0.5 to 0.6	5
0.6 to 0.7	6
0.7 to 0.8	7
0.8 to 0.9	8
0.9 to 1.0	9

5. Summary and Suggestions for Further Research

Awareness of knowledge as the 4th factor of production, as well as the effective management of knowledge, are crucial in today's dynamic production environment. In particular, knowledge transfer, and the assessment of workers' knowledge-based ideas, pose major challenges in the field of knowledge management. The empirical results of this present research reveal that production companies expect high-quality improvements in manual assembly by means of effective knowledge management. Moreover, individual recognition of workers by their supervisors was identified as the most motivating immaterial incentive to share knowledge. The Analytical Hierarchy Process (AHP) as applied in our exemplary case displayed great suitability as a tool to assess workers' knowledge-based ideas. A knowledge management software application running on tablets is recommended as the preferred cognitive assistance system to enhance the intra-organisational knowledge transfer and also, by enabling the AHP assessment of workers' knowledge-based ideas, to reward the workers based on the AHP assessment of worker's knowledge based ideas.

The applicability of the AHP should therefore be examined in the production environment to obtain a larger number of results and to arrive at a consolidated judgement of its suitability in this particular setting. For the implementation of an incentive system, it is recommended to assess already existing company-specific systems in respect of their usefulness and, if needed, to adjust, expand or redesign them towards a purposeful knowledge transfer. For the design of a knowledge management app, as suggested in this paper, the technical implementation, as well as the user-interface of the application, need to be precisely defined and the integration into higher-level software applications needs to be studied in more detail.

Acknowledgements

This publication forms part of the 'SynDiQuAss' project for excellence in assembly in the context of Industry 4.0. It is funded by the German Ministry of Education and Research (BMBF) and the European Social Fund (ESF) (grant no. 02L15A281).

References

[1] Lehner, F. (2014). Wissensmanagement: Grundlagen, Methoden und technische Unterstützung: Carl Hanser Verlag GmbH & Company KG.

[2] Sochor, R., Kraus, L., Merkel, L., Braunreuther, S., Reinhart, G. (2019). Approach to Increase Worker Acceptance of Cognitive Assistance Systems in Manual Assembly, 52nd CIRP Conference on Manufacturing Systems (CMS), Ljubljana, Vol. 81, 926-931.

[3] Funk, M., Hartwig, M., Wischniewski S. (2019). Evaluation of Assistance Systems for Manual Assembly Work. IEEE/SICE International Symposium on System Integration (SII). 794-798.

[4] Berger, S., Mangold, C., Meyer, S. (2005). Ontologiebasiertes Wissensmanagement in der Montage, Wissen in turbulenten Zeiten strukturiert einsetzen, Ontology-based knowledge management for assembly. In: Industrie Management Zeitschrift für industrielle Geschäftsprozesse, Vol. 21, No. 1, 49-52.

[5] Schuh, G. Prof., Prote, J.-P., Gerschner, K., Molitor, M., Walendzik, P. (2017). Technologiebasierte Externalisierung von Wissen. Werkstattstechnik online. Vol. 9, 578-581.

[6] Friedrich, J., Becker, M., Kramer, F., Wirth, M. Schneider, M. (2019). Incentive design and gamification for knowledge management. Journal of Business Research. Vol. 50. Issue 5, 572-597.

[7] Bullinger, H.-J., Rüger, M., Koch, A., Staiger, M. (2001). Fraunhofer-Institut für Arbeitswirtschaft und Organisation (IAO). Knowledge meets Motivation - Anreizsysteme im Wissensmanagement. Fraunhofer IRB Verlag.

[8] Merkel, L., Berger, C., Schultz, C., Braunreuther, S., Reinhart, G. (2017). Application-specific design of assistance systems for manual work in production. IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). 1189-1193.

[9] Nonaka, I., Takeuchi, H. (1995). The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation: Oxford University Press.

[10] Merhar, L., Berger, C., Braunreuther, S., Reinhart, G. (2019). Digitization of Manufacturing Companies: Employee Acceptance Towards Mobile and Wearable Devices. In Tareq Z. Ahram (Ed.), Advances in Human Factors in Wearable Technologies and Game Design Advances in Intelligent Systems and Computing, Vol. 795, 187-197.

[11] Probst, G., Raub, S., & Romhardt, K. (2013). Wissen managen: Wie Unternehmen ihre wertvollste Ressource optimal nutzen. Gabler Verlag. Probst, G., Raub, S., & Romhardt, K. (2000). Managing Knowledge: Building Blocks for Success. Verlag Wiley.

[12] Bendt, A. (2000). Wissenstransfer in multinationalen Unternehmen. Gabler Verlag.

[13] Prinz, C. (2018). Wissensmanagementmethodik zur Organisation von Prozesswissen in der Produktion. Shaker Verlag GmbH.

[14] Saaty, R. W. (1987). The Analytic Hierarchy Process - what it is and how it is used. Mathematical Modelling. Vol. 9, Issues 3-5, 161-176.

[15] Saaty (1987): Rank generation, preservation, and reversal in the analytic hierarchy decision process, Decision Sciences. Vol. 18, Issue 2, 157-177.

[16] Cerchione, R., Esposito, E. (2017). Using knowledge management systems: A taxonomy of SME strategies. International Journal of Information Management. Vol. 37, Issue 1, Part B, 1551-1562.

[17] Argote, L., Ingram, P. (2000). Knowledge Transfer: A Basis for Competitive Advantage in Firms. Organizational Behavior and Human Decision Processes. Vol. 82, Issue 1, 150-169.

[18] Nalmpantis, D., Roukouni, A., Genitsaris, E., Stamelou, A., Naniopoulos, A. (2019). Evaluation of innovative ideas for Public Transport proposed by citizens using Multi-Criteria Decision Analysis (MCDA). European Transport Research Review. Vol. 11, Issue I, 1-16.

[19] Ngai, E. W. T., & Chan, E. W. C. (2005). Evaluation of knowledge management tools using AHP. Expert Systems with Applications. Vol. 29, Issue 4, 889-899.

[20] Grimaldi, M., Rippa, P. (2011). An AHP-based framework for selecting knowledge management tools to sustain innovation process. Knowledge and Process Management. The Journal of Corporate Transformation. Vol. 18, Issue 1, 45-55.

[21] Partovi, F., Burton, J., Banerjee, A. (1990). Application of Analytical Hierarchy Process in Operations Management. International Journal of Operations & Production Management. Vol. 10, Issue 3, 5-19.

[22] Yaralioglu, K., Koksal, H. (2003). Analytic Hierarchy Process As a Managerial Decision Tool in The Evaluation of New Product Ideas. Ege Academic Review, Ege University Faculty of Economics and Administrative Sciences. Vol. 3, Issue 1, 119-137.

[23] Calantone, R. J., Di Benedetto, C. A., Schmidt, J. B. (1999). Using the analytic hierarchy process in new product screening. Journal of Product Innovation Management. Vol. 16, Issue 1, 65-76.

Biography

Robin Sochor (*1992) obtained his Dipl.-Ing. (FH) degree in Mechanical Engineering and his M.Eng. degree in Industrial Engineering at the University of Applied Sciences at Kempten. Since 2017, he has been conducting research on cognitive assistance systems at Fraunhofer IGCV in Augsburg.

Teresa S. Schick (*1995) holds a Master's degree (M.Sc.) in Management & Technology from the Technical University of Munich with majors in Finance and Accounting and Mechanical Engineering. She currently serves as Scientific Officer to the Director of the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe.

Lukas Merkel (*1990) obtained his M.Sc. degree in Mechanical Engineering and Management from the Technical University of Munich. Since 2015, he has been conducting research on cognitive assistance systems at Fraunhofer IGCV.

Prof. Dr.-Ing. Stefan Braunreuther serves as professor at the Faculty of Mechanical and Process Engineering at the Augsburg University of Applied Sciences, and as head of the department of production planning and control at Fraunhofer IGCV.

Prof. Dr.-Ing. Gunter Reinhart serves as director of the iwb at the Technical University of Munich and as head of the Fraunhofer IGCV. He conducts research into assembly technology, automation and robotics, as well as production management and logistics.