Proceedings of the 2018 Winter Simulation Conference
M. Rabe, A.A. Juan, N. Mustafee, A. Skoogh, S. Jain, and B. Johansson, eds.

APPROACH TO IMPROVE THE WORK-LIFE BALANCE OF EMPLOYEES USING AGENT-BASED PLANNING AND SIMULATION-BASED EVALUATION

Thilo Gamber

University of Applied Sciences Ostwestfalen-Lippe
Department of Production and Economics
Liebigstrasse 87
D-32657 Lemgo, GERMANY

Gert Zülch

Karlsruhe Institute of Technology
ifab-Institute of Human and Industrial Engineering
Kaiserstrasse 12
D-76131 Karlsruhe, GERMANY

ABSTRACT

Working hours that are based on operating requirements may lead to conflicts between working and private times of the employees. In an attempt to reduce or even to avoid conflicts between employees' and operating needs, a hybrid approach is presented here. This approach reduces, or even avoids, conflicts between employees' needs and operational requirements. Starting from a preliminary shift schedule, an improved solution is developed through agent-based time swaps between the employees. The resulting solution is then dynamically evaluated using simulation. The simulation results show the advantages of the improved work schedules by means of personnel-oriented and logistics criteria. With the help of lexicographical preference ordering, an overall solution can be developed that improves the work-life balance of the employees and fulfills operating requirements. Finally, this hybrid approach is demonstrated using the intra-plant logistics department of a process automation devices manufacturer. Furthermore, the effects of diverse swapping heuristics are shown.

1 PREVIOUS ACADEMIC WORK

A common method to schedule working hours of employees is to first determine work shifts and then give the employees the opportunity to swap whole or parts of shifts individually, sometimes with the help of a human resources manager. However, this method is vulnerable to benefiting the particularly assertive employees and disadvantaging those who are more restrained in expressing their working hours preferences.

This kind of behavior may not only lead to a certain degree of dissatisfaction within the workforce, but also to an increased number of individual conflicts between their working and leisure times. Therefore this paper presents a hybrid approach that starts with an agent-based planning procedure to improve the preliminary shift schedule. The solution found by that procedure is then simulated, in order to analyze it dynamically using multiple criteria. Consequently, the individual working hours preferences of each employee are considered, before an actual schedule is implemented.

Up until now, there has been no agent-based planning procedure that is based on preference-oriented swapping of work shifts, or parts of shifts and which also addresses fairness considerations (e.g. Chiaramonte and Chiaramonte 2008; Wang and Wang 2009). Furthermore, existing agent-based planning procedures that already utilize individual working time preferences, take neither legal regulations concerning working times, nor ergonomic recommendations into account (Cheang et al. 2003; Ernst et al. 2004; Haspeslagh and De Causemaecker 2007), both of which are considered here. Moreover, there is no procedure that combines agent-based modeling and the discrete-event simulation of operation processes and working times.

Other authors take the individual employee's working hours preferences into account, but they do not consider the global objectives of the organizational unit (e.g. Gershman et al. 2008). Furthermore, goal achievement is calculated solely statically on the basis of agent-based planning and not dynamically based on simulation results.

The so-called compatibility-simulator from the University of Applied Sciences, St. Gallen, Switzerland, became known only recently (Paulus and Meyer 2018). For this purpose, the life situation of an individual employee is determined, existing factors of personal stress and dissatisfaction are then recorded. From this, with computer assistance, long-term time management possibilities are generated. But this tool is not a discrete-event simulation, as in the case discussed here, nor is it the collective redesign of the operational shift schedule of a working group.

In contrast, an agent-based planning procedure is presented here in which agents, as representatives of employees, can exchange their working hours. The solution that has been created in this way, with due regard to fairness, is then transferred to a discrete-event simulation procedure and subjected to a multi-criteria evaluation, taking the dynamics of the upcoming work tasks into account.

2 COMBINATION OF AGENT-BASED PLANNING AND SIMULATION FOR SCHEDULING OPERATING TIMES

In this paper, the common practice of individually swapping a work shift or parts of it is compared with a hybrid software approach. In this procedure, it is assumed that a preliminary shift schedule already exists. This preliminary schedule shall be improved by an agent-based procedure that enables virtual swaps of full, or parts of, time shifts. A prerequisite for this improvement is that all relevant employees possess a comparable qualification so that they are all capable of performing any of the upcoming work tasks. Furthermore, all relevant working time preferences of the employees involved need to be known and can thus be modeled as agents' preferences.

The agent-based improvement procedure, however, delivers a static output, since work processes are not explicitly regarded. Therefore, the solution reached is subsequently handed over to a simulation procedure that dynamically evaluates the work system with the working hours of the employees and the work tasks, which need to be carried out within a certain planning horizon.

Therefore, a combination of an agent-based improvement procedure *ProSis* and a discrete-event simulation *OSim-GAM* is presented here. The abbreviation *ProSis* stands for "*Pr*eference-*o*riented Planning and *Si*mulation of Shift *S*chedules" (Gamber 2015); *OSim-GAM* is a German acronym for "*O*bject *Sim*ulator for the Design of Working Time Models" (Bogus 2002). Both procedures have been developed at the ifab-Institute of Human and Industrial Engineering of the Karlsruhe Institute of Technology (KIT) in Germany.

Solely taking operating requirements into account often causes problems with work-life balance of the employees. *ProSis* is a new software tool with a specific focus of avoiding rostering conflicts between employees' professional and private lives (Gamber and Börkircher 2008; Gamber et al. 2010; Gamber and Zülch 2012; Gamber 2015). During its development, a number of regulatory mechanisms were investigated (e.g. national working time law, established results of ergonomic research), to further the aim of rostering based on individual preferences and also to achieve a fair balance of interests. One reason for developing a software-based planning tool was that regulatory mechanisms for social systems cannot simply be tested in real-life studies. Basically, involved employees are modeled as agents.

The input for this approach is the initial individual schedules and working time hours. A precondition of the approach is that only agents (as well as the employees represented by them) with the same qualifications can swap working hours. Consequently, a necessary attribute of an agent is individual qualifications. Further, we added some personal attributes such as age, sex, period of employment, etc. Regarding the work system environment, we modeled legal rules and ergonomic recommendations as swapping restrictions.

Moreover, we developed several heuristics for swapping jobs. The result provided by the software tool is an improved shift schedule for each agent. Key figures point out that satisfaction and preference fulfillment increased due to the improvement of individual working hours. These key figures are focused basically on the advantage of an individual employee and fairness within the working group.

The evaluation by *ProSis* is a static one that means we do not take the processes of the real work system investigated into consideration, especially the time dependences of jobs and the limited resources available. For this purpose, we have to link the software tools *ProSis* and *OSim-GAM*. The latter is a discrete-event simulation tool which was initially developed by Jonsson (2000) and later expanded by Bogus (2002), for rostering in the service sector. *OSim-GAM* was first applied to problems in retail stores, later in hospitals and other services (Bogus 2002; Zülch et al. 2006, 2007). Processes are modeled as network-like throughput plans. Resources required, employees as well as machinery and physical workplaces, are modeled in *OSim-GAM* separately. With stochastic events and several production programs simulation studies can be performed. A comparison between initial and improved shift schedule solutions provide information regarding the swapping procedure used in *ProSis*.

Figure 1 shows the relationship between the *ProSis* and *OSim-GAM* procedures. Through their combination, it is possible to check which advantages can be achieved for the individual employee in the work system considered and how fairness develops within the observed working group. The term fairness means that the individual advantage improvement by this rescheduling is distributed more equitably and more evenly among the workforce.

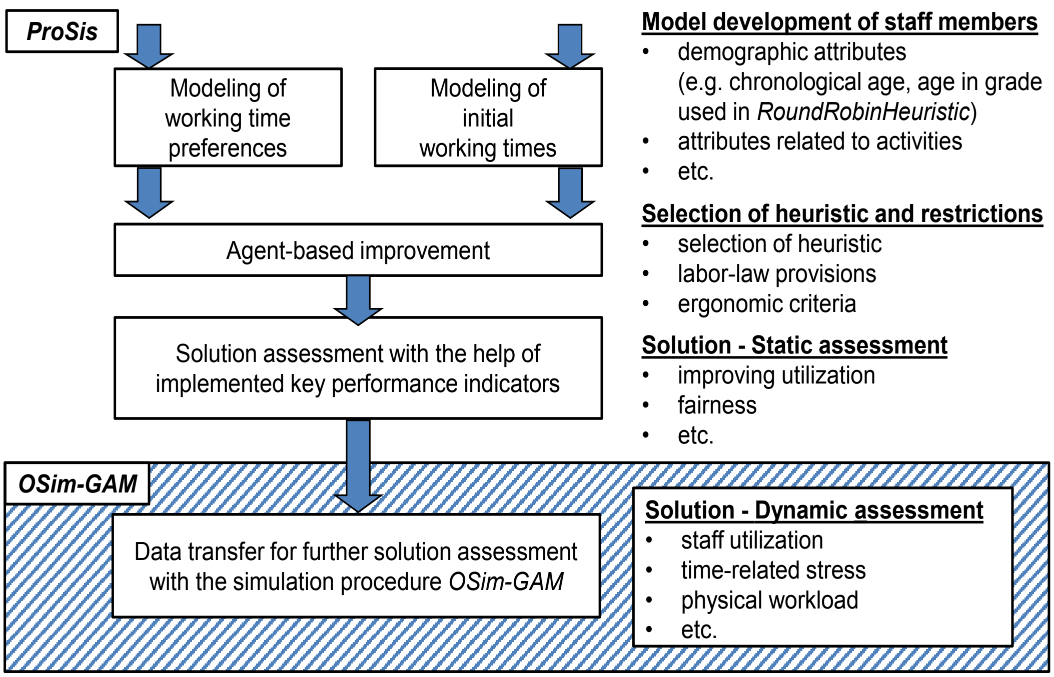


Figure 1: Structure of the planning procedure *ProSis* and connection with the simulation procedure *OSim-GAM* (following Gamber 2015).

3 KEY FIGURES FOR THE STATIC EVALUATION OF IMPROVEMENT SOLUTIONS

For the static evaluation of improvement solutions, new key figures have been developed in the planning procedure *ProSis*, e.g. "Average number of swaps" (*ANS)* and "Average degree of satisfaction" (*ADS)* within the working group (Figure 2). Their standard deviations, *SSN* and *SSD* respectively, serve to measure the degree of fairness within the observed workforce. The simulation procedure *OSim-GAM* already possesses implemented key figures for dynamic evaluation, e.g. "Staff utilization" (*SUT)*, "Time-related stress degree" (*TSD)* and "Physical workload" (*PWL)*. All key figures are on proportional, interval and ordinal scales and thus can be aggregated to an overall value using lexicographical preference ordering. This will be explained further in section 5.3.

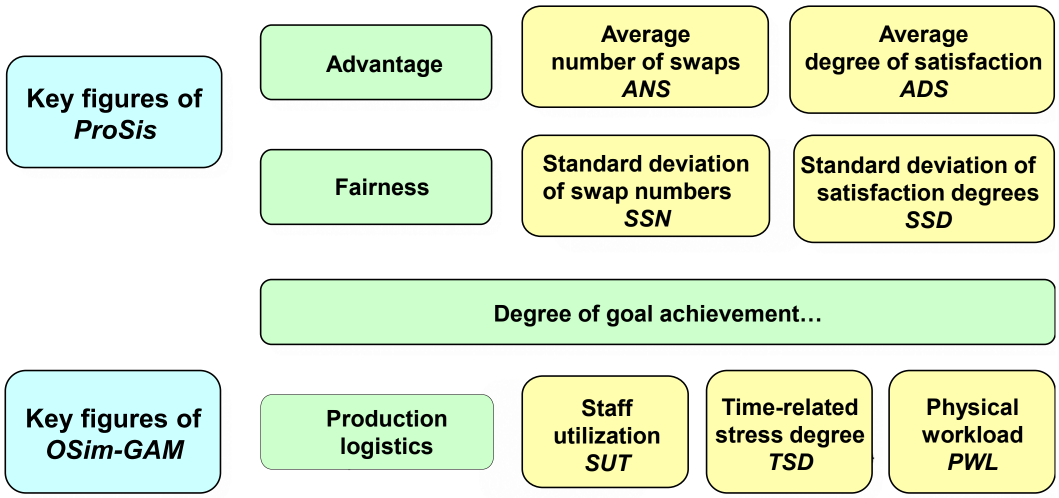


Figure 2: Examples of key figures for working hours evaluation (following Zülch et al. 2011).

In order to review an improved planning solution, conformity with legal regulations concerning working times and ergonomic recommendations must be verified. For the avoidance of possible contradictions between the design rules implemented for this purpose, the rules can be prioritized by the user.

Moreover, it is possible to set up a negotiation strategy with which an improved planning solution can be derived. This negotiation strategy is adjustable and can be composed of swapping restrictions, a negotiation heuristic and a coordination mechanism which regulates the bargaining between the agents. The relevant negotiation strategies are explained in more detail in the following section.

4 HEURISTICS FOR DERIVING IMPROVED PLANNING SOLUTIONS

Agent-based heuristics function according to the principles of the agent paradigm (Wooldridge and Jennings 1995) and communication. This primarily means that negotiations are led by autonomous agents which take decisions independently (FIPA 2002; Freytag 2011). These virtual negotiations run over a communication protocol which is called Contract Net Protocol (CNP).

An agent can play two different roles: initiator or responder. The initiator starts the communication and proposes a desired swap to the other agents, the other agents in the system evaluate the proposed swap and give the initiator an answer of whether they are willing to accept the offer or not.

Concerning the development of the agent's individual advantage, called "Rate of satisfaction" (*ROS),* the initiator has an inherent advantage from his role compared to the responder. The reason for this advantage is due to the fact that an initiator is in the position to propose a desired swap to all other agents. Thus, a heuristic that coordinates the negotiation between the agents needs to ensure that the agent's roles can also be swapped.

The role reversal ability must satisfy the procedure's fairness criteria, namely all agents have the same chance of improving their *ROS.* When a role swap needs to take place can be determined by the *ROS*. After each swap x and for every agent a the "Rate of satisfaction" $ROS_{a,x}$ can be calculated. With this it is possible to assess the individual preference situation of every agent before the next swap $x+1$.

A selection of heuristics was implemented to learn which kind of negotiation performs best in virtually swapping working hours. Basically, negotiation heuristics can be categorized into three categories: random-based, time-based and trigger-based heuristics. The heuristics used were either taken from the literature (e.g. Chiaramonte and Chiaramonte 2008) or were newly developed for the application presented here (Gamber 2015). Using a test data set, these heuristics were compared and the resulting solutions were then evaluated using the key figures from *ProSis* and *OSim-GAM*. Comparing the heuristics in test scenarios made apparent that:

- The trigger-based heuristic *RoundRobinAgressive*, as well as
- The, also trigger-based, heuristic *BiasedTrigger*.

These are the most promising candidates. Additionally, the following heuristic was used:

- The time-based heuristic *TimeBiased*.

It is assumed that this last heuristic, which performed worst in the test scenarios, would also perform badly in the following application.

Table 1 shows the main aspects of trigger-based heuristics. In the *BiasedTriggerHeuristic* case, the "Rate of satisfaction" $ROS_{a,x}$ reached is the main influence of controlling the agent's *a* action. The flow chart of this heuristic is shown in Figure 3. Gamber (2015) provides an overview of all heuristics used.

Table 1: Trigger-based heuristics negotiation strategies (following Gamber 2015).

<table>
<tr><th colspan="2">Trigger-based heuristics</th></tr>
<tr><td colspan="2">Coordination uses a central agent:
• Initiator sends triggers to all staff member agents as responders.
• Staff member agents can decide if accept or not.
• After decision responders send triggers back.
• After decision has been taken by initiator negotiation is closed.
• As negotiations can be split into several rounds, new triggers are sent.</td></tr>
<tr><th>Implementation variants</th><th>Specifications</th></tr>
<tr><td>RoundRobinHeuristic</td><td>Agents alternate.</td></tr>
<tr><td>RoundRobinAgressive</td><td>If agent is in initiator role
he remains in this role
until he finished swaps.</td></tr>
<tr><td>BiasedTriggerHeuristic</td><td>Agent accepts negotiation,
the better his current advantage
(e.g. compare current $ROS_{a,x}$
to previous $ROS_{a,x-1}$).</td></tr>
</table>

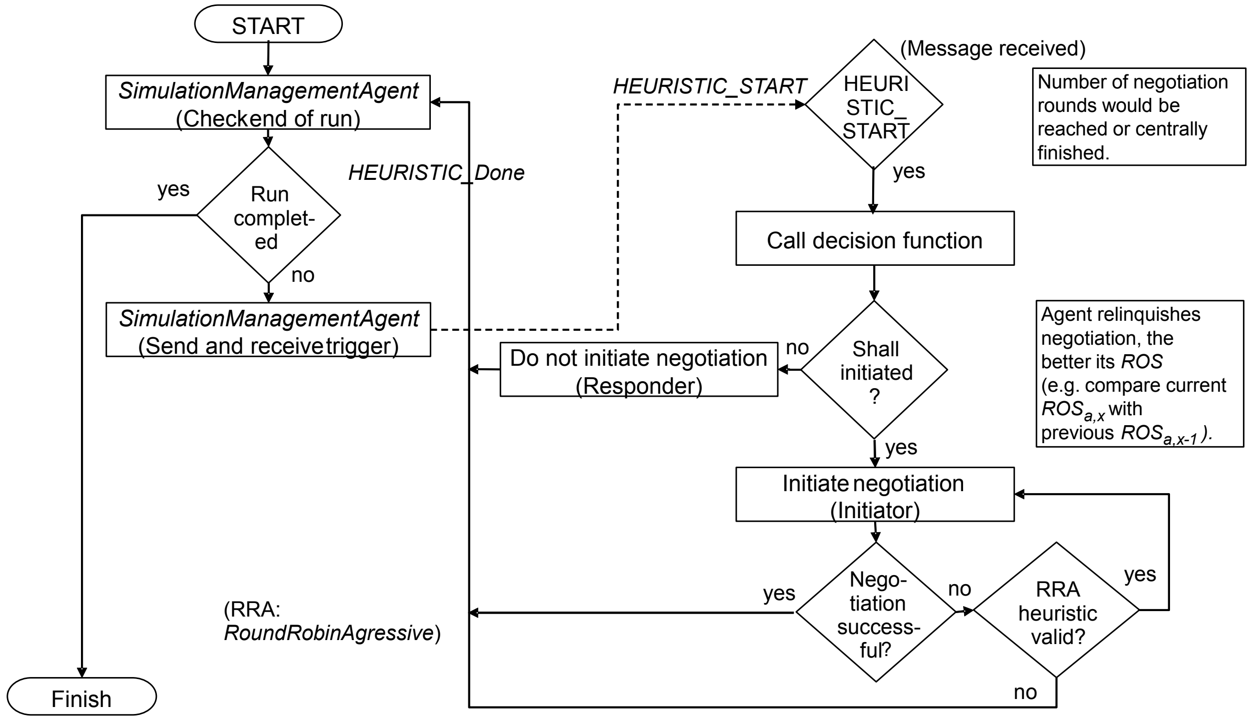


Figure 3: *BiasedTriggerHeuristic* flow chart (following Gamber 2015).

5 ILLUSTRATIVE APPLICATION OF AN INTRA-PLANT LOGISTICS DEPARTMENT

5.1 Initial Situation of the Logistics Department

The intra-plant logistics department of a company that focuses on devices for process automation is introduced here as a verification study of the hybrid procedure. Data from previous investigations was used concerning the work system and work tasks to be carried out (Graichen et al. 2011).

There are 10 employees in the work system. All of them work full time and are allocated to different areas of responsibility. For this verification study, the employees are assumed to have equal qualifications (although the *OSim-GAM* simulation procedure used is capable of handling employees with varying skill levels). Each employee is employed for eight hours a day, with a five-day week and a rotating shift system with an early shift and a late shift (starting at 6 am and 2 pm respectively), changing weekly.

The working hours preferred by the employees were collected via personal interviews. As an example, Figure 4 shows the preference calendar of a logistics employee. It is assumed that swapping a two-hour part of a shift is possible.

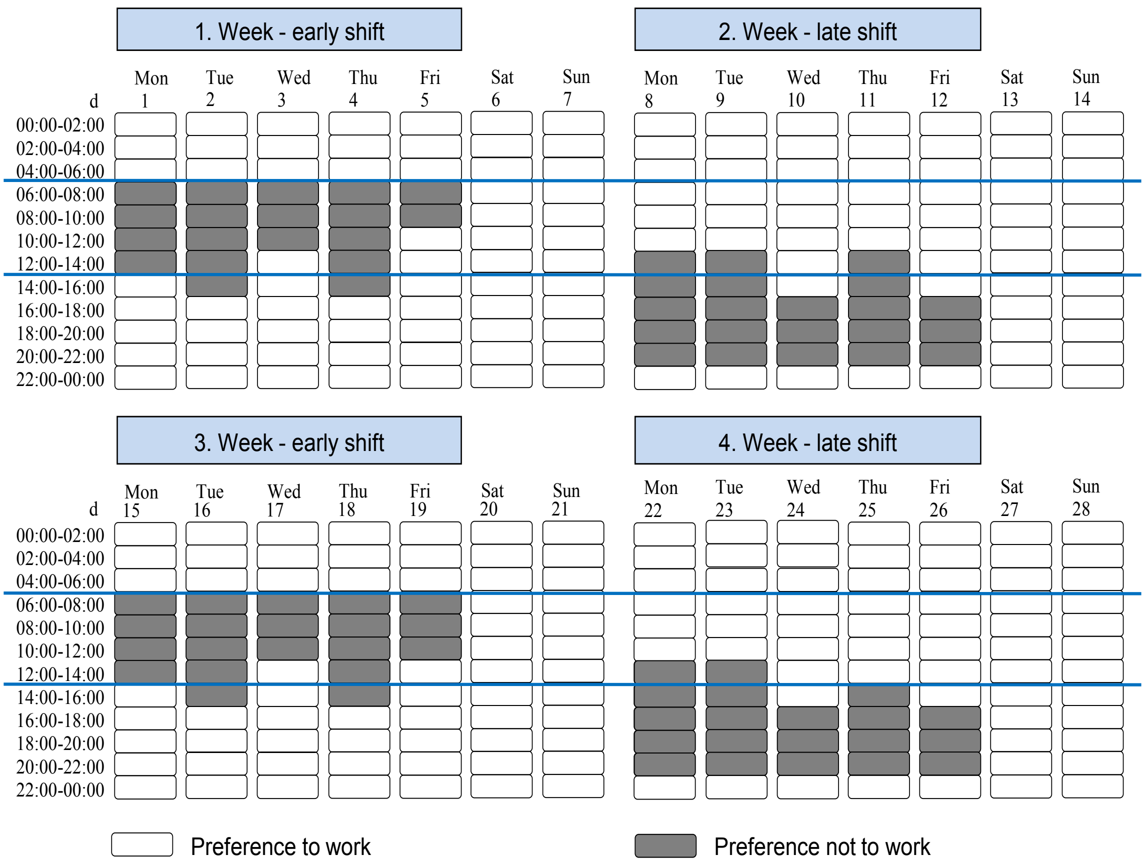


Figure 4: Example of a logistics employee preference calendar (following Gamber 2015).

The employees in the department examined need to carry out classic intra-plant logistics department work procedures (Figure 5). They are responsible for material provision and waste disposal in the production area. Further, the employees transport finished products from manufacturing to the logistics sector.

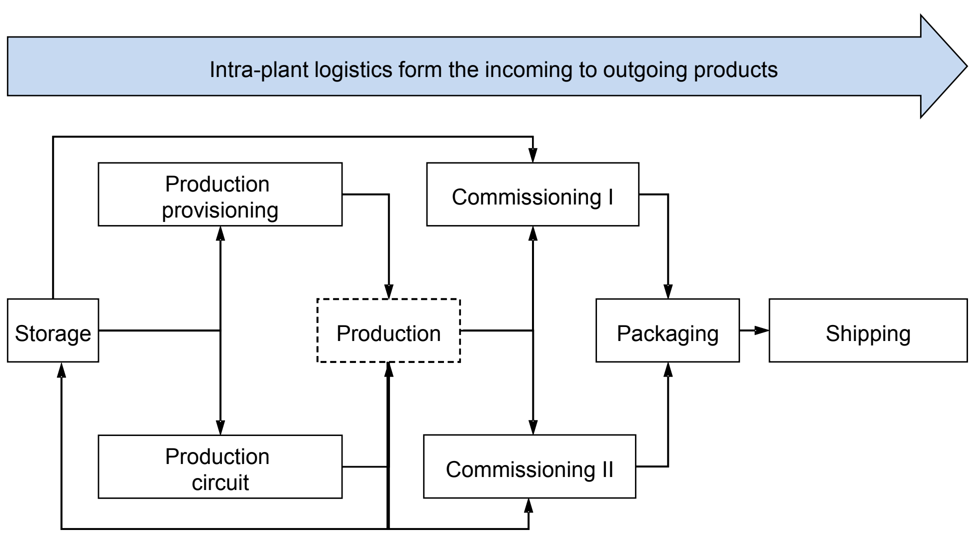
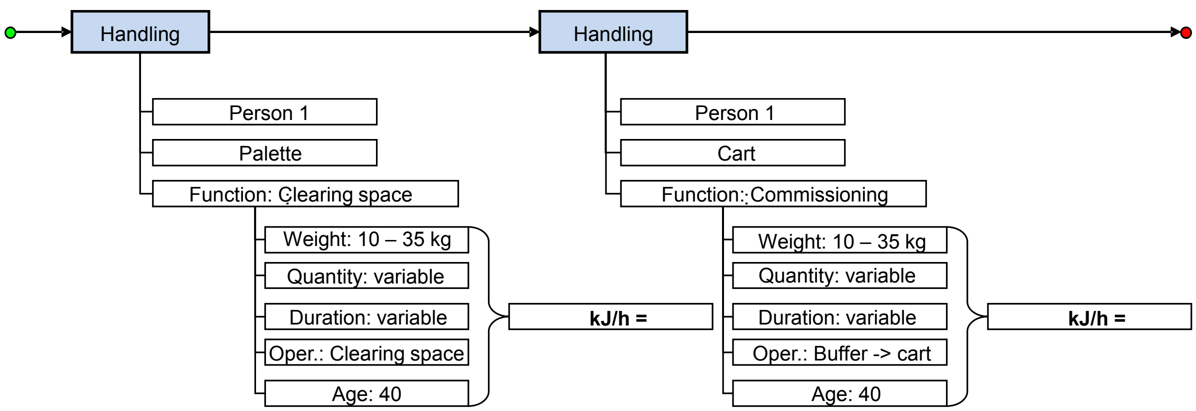


Figure 5: Intra-plant logistics department work processes (following Andris 2011).

There are two types of order picking in the work system examined. This differentiation is made based on three criteria, namely the different products, e.g. dependent on the weight and the class of the device, the customers, e.g. the location of the customer (i.e. is the product to be sent to Europe or Asia) and what kind of customs regulations need to be considered. Furthermore, requirements concerning transport safety must be observed. Finally, the packaging and the commissioning of shipments are tasks that also need to be carried out by employees in the logistics department.

In the simulation procedure, workflows are modeled as network-like throughput plans. Figure 6 shows, as an example, the related flow chart for the main activity "Long good order picking". The previous study investigated solely main activities of the logistics staff. Since the focus there was on the investigation of age-related physiological changes in the employees' performance, modeling transportation times was omitted as being independent of the personal performance. Therefore, in the present study, this aspect was also not taken into consideration.



No.	Work task definition			Scope of activity			Responsible person	
	Activity definition	Predecessor	Successor	Job content	Job duration	Other	Age	Experience
12	Long good-commissioning to cart	*Production* *Warehouse*	*Shipping*	Lift packed products from buffer car to cart.	Proportional to the quantity of delivered goods	Weight: 10 - 35 kg Place: buffer car Destination: cart		
13	Large packaged good-commissioning to cart	*Production* *Warehouse*	*Shipping*	Pick needed products to buffer palet; Lift packed products from buffer conveyor to cart.	Proportional to the quantity of delivered goods	Weight: > 20 kg Place: buffer conveyor Destination: cart		

Figure 6: Flow chart of the main activity "Long good order picking".

5.2 Improvement Procedure Study Assumptions

With the aim of virtually swapping shift times of two or four hours, the agent-based improvement procedure is based on a preliminary shift schedule. Using an appropriate parameter setting, swapping restrictions can be activated. In this application, several central German labor-law provisions (according to ArbZG 1994) and ergonomic recommendations (Hornberger and Knauth 2000; Knauth 2002) are used. Specifically, these are the following:

- 10 hours maximum daily working time,
- 48 hours maximum weekly average working time, as well as
- 4 hours shortest shift duration.

In the application case, the following heuristics *h*, which were derived from the previous test scenarios (see section 4), are examined (Gamber 2015):

- The time-based heuristic *TimeBiased* (*h=1*),
- The trigger-based heuristic *RoundRobinAgressive* (*h=2*),
- As well as the, also trigger-based, heuristic *BiasedTrigger* (*h=3*).

At first, the agent-based procedure *ProSis* is used to generate an improved solution and subsequently the simulation *OSim-GAM* is employed to dynamically evaluate this solution. Triggers of throughput plans are stochastically distributed over the entire simulation duration. A trigger is the initiation of a work task arising within the 26 week planning horizon.

5.3 Results of the Study

The evaluation in this application case is based on standardized goal achievement levels ranging from 0% to 100% (Wedemeyer 1989) with the two extreme values often being impossible to reach in realistic settings. The lower limit will be associated with the least favorable solution, whereas the upper limit indicates an optimum solution, each regarding only one specific goal.

The results of the procedures *ProSis* and *OSim-GAM* are shown in Table 2. Regarding the advantage of the heuristic *h*, the key figures "Number of swaps" (NOS_h), "Average number of swaps" (ANS_h) and "Average rate of satisfaction" (ARS_h) are provided by the planning procedure *ProSis*.

Table 2: Assessment of heuristics using the example "Intra-plant logistics department" (data provided by Gamber 2015; partially based on Huck 2011).

Heuristic		**Key performance indicator from *ProSis***			
h		Rank and number of swaps *rnk* (NOS_h)	Rank and average number of swaps *rnk* (ANS_h)	Rank and average rate of satisfaction *rnk* (ARS_h)	
1	*TimeBiased*	3 (24)	3 (4.8)	3 (0.96)	
2	*BiasedTrigger*	1 (37)	1 (7.4)	1,5 (0.98)	
3	*RoundRobinAggressive*	2 (36)	2 (7.2)	1,5 (0.98)	
		Difference of goal achievement from *OSim-GAM*			**Overall rank**
		Rank and difference of staff utilization *rnk* (DSU_h)	Rank and difference of time-related stress *rnk* (DTS_h)	Rank and difference of physical workload *rnk* (DPW_h)	Goodness of heuristic *rnk* (GOH_h)
1	*TimeBiased*	1 (-0.15 %)	1 (-0.63 %)	1,5 (0.09 %)	2
2	*BiasedTrigger*	2 (-0.25 %)	2 (-1.59 %)	1,5 (0.09 %)	1
3	*RoundRobinAggressive*	3 (-0.35 %)	3 (-1.89 %)	3 (0,01 %)	3

With the help of the *OSim-GAM* simulation procedure, the following goal achievement key figures are calculated: "Staff utilization" (SUT_h), "Time-related stress degree" (TSD_h) and "Physical workload" (PWL_h). The differences of the goal achievements from the initial (preliminary) solution are formalized in the key figures "Goal achievement difference staff utilization" (DSU_h), "Goal achievement difference time-related stress degree" (DTS_h) und "Goal achievement difference physical workload" (DPW_h).

Using lexicographical preference ordering, it is possible to aggregate the key figures described above to an overall result and thus to evaluate their advantage. The lexicographical preference ordering function used here works according to the principal of the "Best of majority" (e.g. Bassett and Persky 1994). This decision rule assigns the best rank, 1, to the heuristic that exhibits the most frequent best rank of the evaluation criterion. If there is no simple majority concerning the frequency of the first criterion, then the simple majority of the frequency of the second criterion is used and so on. As the value of a criterion gets worse, the rank for that criterion increases (Table 3). Characteristics with the same values receive the split rank. Here the overall result of the heuristic *h* is called "Goodness of heuristic" (GOH_h).

Table 3: Lexicographical preference ordering according to the principal of the "Best of majority".

Indexes for heuristics *h*	$h = 1, 2, 3, \ldots$
Indexes for ordinally scaled criteria *c*	$c = 1 \succ 2 \succ 3 \succ \ldots$
Ordinal rank *r* of heuristic *h* for criterion *c* (numerically split ranks if necessary)	$r_{h,c}$
Lexicogaphical order *lexmin* of heuristics *h*	*if* $(r_{h,1} \succ r_{h^*,1} := h=1 \succ h^*=2)$, *else* $(r_{h,2} \succ r_{h^*,2} := h=1 \succ h^*=2)$, *else* … , *else:* $h=1 \prec h^*=2$

6 CONCLUSION AND OUTLOOK

Apparent from the verification study, the heuristic *BiasedTrigger* is the most expedient one. However, it is notable that this statement is not generalizable. In another application, namely in the case of a hospital, a different heuristic, the *RoundRobinAggressive*, performed best (Gamber 2015). The choice of the best heuristic to improve shift schedules depends on several influences. These influences should be determined on a case-by-case basis. Thus, the best heuristic depends on the peculiarities of the individual application case. Therefore, further investigation and research into the mechanism behind the heuristic's influence is still required.

Furthermore, the approach presented can be applied to other work systems. Possible areas of application are, for example, the scheduling of operating times in outpatient social service, in the retail sector or for air traffic controllers. Moreover, a possible enrichment of the hybrid approach presented could be that the employees' wishes concerning team building are considered. Additional steps are needed, especially regarding the question of how employees with differing or overlapping qualifications can be considered in the improvement procedure *ProSis*.

Thus, further research is required in this area. In addition, the developed combination of agent-based improvement procedure and dynamic solution evaluation by means of simulation needs a practice-oriented design.

REFERENCES

Arbzg. 2013. "Arbeitszeitgesetz". From June 6, 1994, as amended on April 20, 2013. Http://Www.Gesetze-Im-Internet.De/Arbzg/Arbzg.Pdf, Accessed 31.03.2018.

Andris, T. 2011. *Arbeitszeitgestaltung Unter Berücksichtigung Individueller Präferenzen Der Mitarbeiter Durch Agentenbasierte Optimierung Und Bewertung Durch Simulation.* Study Work, Karlsruhe Institute Of Technology, Ifab-Institute Of Human And Industrial Engineering.

Bassett, G. W., and J. Persky. 1994. "Rating Skating". *Journal Of The American Statistical Association* 89(427):1075-1079.

Bogus, T. 2002. *Simulationsbasierte Gestaltung Von Arbeitszeitmodellen In Dienstleistungsbetrieben Mit Kundenfrequenzabhängigem Arbeitszeitbedarf.* 1st Ed. Aachen: Shaker Verlag.

Cheang, B., H. Li, A. Lim, and B. Rodrigues. 2003. "Nurse Rostering Problems – A Bibliographic Survey". *European Journal Of Operational Research* 151(3):447-460.

Chiaramonte, M. V., And L. M. Chiaramonte. 2008. "An Agent-Based Nurse Rostering System Under Minimal Staffing Conditions". *International Journal Of Production Economics* 114(2):679-713.

Ernst, A. T., H. Jiang, M. Krishnamoorthy, and D. Sier. 2004. "Staff Scheduling And Rostering: A Review Of Applications, Methods And Models". *European Journal Of Operational Research* 153(1):3-27.

FIPA - Foundation For Intelligent Physical Agents. 2002. "Contract Net Interaction Protocol Specification". Http://Www.Fipa.Org/Specs/Fipa00029/SC00029H.Pdf, Accessed 31.03.2018.

Freytag, R. 2011. *Koordinationsmechanismen Bei Der Verhandlung In Agentensystemen*. Bachelor Thesis, Karlsruhe Institute Of Technology, Ifab-Institute Of Human And Industrial Engineering.

Gamber, T. 2015. *Entwicklung Eines Verfahrens Zur Agentenbasierten Einsatzzeitgestaltung*. 1st Ed. Aachen: Shaker Verlag.

Gamber, T., and M. Börkircher. 2008. "Vereinbarkeit Von Familien- Und Berufsleben Bei Der Gestaltung Flexibler Arbeitszeiten", In *Mittelpunkt Mensch,* Edited By Deutscher Studienpreis, 227-247, Wiesbaden: VS Verlag Für Sozialwissenschaften.

Gamber, T., M. Börkircher, and G. Zülch. 2010. "Vereinbarkeit Von Berufs- Und Privatleben Im Krankenhausbereich Durch Gestaltung Sozialverträglicher Arbeitszeiten“. In *Arbeits- Und Lebenswelten Gestalten*, Edited By Gesellschaft Für Arbeitswissenschaft, 409-412, Dortmund: Gfa-Press.

Gamber, T., and G. Zülch. 2012. "Agent-Based Planning And Simulation-Based Assessment Approach To Improve The Work-Life Balance Of Hospital Staff. In *Advances In Social And Organizational Factors*, edited By P. Vink, 424-433, Boca Raton, FL: CRC Press.

Gershman, A., A. Grubshtein, A. Meisels, L. Rokach, and R. Zivan. 2008. "Scheduling Meetings By Agents". Http://Www.Patatconference.Org/Patat2008/Proceedings/Meisels-HC3c.Pdf, Accessed 31.03.2018.

Graichen, S., D. Schmidt, and G. Zülch. 2011. "Load-Oriented Work Organisation Due To An Ageing Workforce". In *Conference Proceedings, 21st International Conference On Production Research, Stuttgart, 2011*, edited by D. Spath et al., 427-432, Stuttgart: Fraunhofer IAO.

Haspeslagh, S., P. De Causmaecker, and G. V. Berghe. 2007. "Distributed Decision Making In Hospital Wide Nurse Rostering Problems". In *Proceedings Of The 3rd Multidisciplinary International Conference On Scheduling: Theory And Applications (MISTA 2007),* edited by P. Baptiste et al., 192-199, Paris: Mista.

Hornberger, S., and P. Knauth. 2000. "Innovative Flexibilisierung Der Arbeit". In *Innovatives Arbeitszeitmanagement*, edited by P. Knauth, And G. Zülch, 23-49, Aachen: Shaker Verlag.

Huck, S. 2011. *Gestaltung Von Arbeitszeiten Unter Berücksichtigung Individueller Präferenzen Der Mitarbeiter Durch Agentenbasierte Optimierung Und Bewertung Durch Simulation*. Diploma Thesis, Karlsruhe Institute Of Technology, Institute Of Human And Industrial Engineering.

Jonsson, U. 2000. *Ein Integriertes Objektmodell Zur Durchlaufplanorientierten Simulation Von Produktionssystemen.* 1st Ed. Aachen: Shaker Verlag.

Knauth, P. 2002. "Arbeitszeitflexibilisierung Aus Arbeitswissenschaftlicher Sicht". In *Arbeitszeitflexibilisierung Im Dienstleistungsbereich*, edited by G. Zülch, P. Stock, And T. Bogus, 51-74, Aachen: Shaker Verlag.

Paulus, S., and B. Meyer. 2018. "Mit Dem Vereinbarkeitssimulator Zur Work-Life-Balance". Https://Www.Fhsg.Ch/Fhs.Nsf/Files/Kommunikation_Medienmitteilungen_2018_Vereinbarkeitssimulator/$FILE/MM_Vereinbarkeitssimulator_Work-Life-Balance_FHS.Pdf, Accessed 31.03.2018.

Wang, Z., and C. Wang. 2009. "Automating Nurse Self-Rostering: A Multiagent Systems Model". In *Proceedings Of The 2009 IEEE International Conference On Systems, Man, And Cybernetics*, edited by Institute Of Electrical And Electronics Engineers, 4422-4425, San Antonio: IEEE.

Wedemeyer, H.-G. V. 1989. *Entscheidungsunterstützung In Der Fertigungssteuerung*. 1st Ed. Düsseldorf: VDI-Verlag.

Wooldridge, M., and N. Jennings. 1995. "Intelligent Agents: Theory And Practice". *Knowledge Engineering Review* 10(2):115-152.

Zülch, G., T. Gamber, and R. Freytag. 2011. "Improving The Work Life Balance Of Hospital Staff Through An Agent-Based Rostering Procedure". In *Healthcare Systems Ergonomics And Patient Safety 2011*, *Oviedo*, edited By S. Albolino et al., 291-295. London: Taylor and Francis Group.

Zülch, G., P. Stock, and J. Hrdina. 2006. "Working Time Configuration In Hospitals Using Personnel-Oriented Simulation". In *Lean Business Systems And Beyond*, edited By T. Koch, 331-336, Wroclaw: University Of Technology.

Zülch, G., P. Stock, and J. Hrdina. 2007. "Process Optimization And Efficient Personnel Employment In Hospitals". In *Operations Research Proceedings 2006,* edited by K.-H. Waldmann and U. M. Stocker, 325-332. Berlin, Heidelberg: Springer.

AUTHOR BIOGRAPHIES

THILO GAMBER is professor in the Department of Production and Economics at the University of Applied Sciences Ostwestfalen-Lippe in Lemgo (Germany) since 2017. Previously, he worked in various positions within Continental AG. He holds a Ph.D. in Mechanical Engineering from the Karlsruhe Institute of Technology in Germany where he worked at the ifab-Institute of Human and Industrial Engineering. His research interests include agent-based planning and discrete-event simulation, assembly systems as well as strategy topics in production and operations management. His e-mail address is thilo.gamber@hs-owl.de.

GERT ZÜLCH is retired professor and former director of the ifab-Institute of Human and Industrial Engineering of the Karlsruhe Institute of Technology in Germany. In addition, he was scientific director of a private consultancy for more than three decades. He continues to be a member of various national and international scientific organizations. Especially he is interested in staff-oriented simulation of production and service systems, strategies of production planning and control as well as production-logistic and ergonomic evaluation of assembly and disassembly systems. His e-mail address is gert.zuelch@gefora-beratung.de.