DOI: 10.2195/lj_proc_haid_en_202410_01

Development of human-centered scheduling in logistics

Entwicklung einer menschzentrierten Schichtplanung für die Logistik

Charlotte Haid, Oliver Berchtel, Natalie Wagner, Johannes Fottner

Chair of Materials Handling, Material Flow, Logistics
Technical University of Munich

With the use of new technologies, more and more data are available in logistics. This applies not only to automated systems, but also to employee data that is collected with the aim of measuring employee performance. This performance is then used to generate the most efficient shift schedules possible. In this paper, we present in contrast a human-centered approach to shift planning in which we take employees' preferences for workplaces into account. This approach is applied once in a logistics area and once in a hospital with promising results in each case. With this human-centered scheduling approach we want to support companies to make their employees more satisfied in the long term and to retain them in their company.

[Keywords: human-centeredness, scheduling, logistics, employee data, preferences]

Durch den Einsatz neuer Technologien stehen in der Logistik immer mehr Daten zur Verfügung. Das gilt nicht nur für automatisierte Systeme, sondern auch für Mitarbeiterdaten, die mit dem Ziel erhoben werden, die Leistung der Mitarbeiter zu messen. Diese Leistungsdaten werden dann genutzt, um einen möglichst effizienten Schichtplan zu erstellen. In diesem Beitrag stellen wir im Gegensatz dazu einen menschenzentrierten Ansatz zur Schichtplanung vor, bei dem wir die Präferenzen der Mitarbeiter für ihren Arbeitsplatz berücksichtigen. Dieser Ansatz wird einmal in einem Logistikbereich und einmal in einem Krankenhaus mit jeweils vielversprechenden Ergebnissen angewendet. Mit diesem menschenzentrierten Planungsansatz wollen wir Unternehmen dabei unterstützen, ihre Mitarbeiter langfristig zufriedener zu machen und sie an das Unternehmen zu binden.

[Schlüsselwörter: Menschzentrierung, Schichtplanung, Logistik, Mitarbeiterdaten, Präferenzen]

1 INTRODUCTION

Digitalization and automation became standard in the industrial environment in recent years [1]. Digitalization increases the availability of data in production and allows detailed forecasts about processes or machines. Employee-specific data can also be recorded with tracking systems like smart phones or smart watches. These data enable statements about the daily performance of employees and even allow performance-based scheduling of employees [2]. Doubts about this techno-economic vision of industry 4.0 are being raised, particularly by employees in factories who see their role being changed or threatened [3]. Nowadays, industry 4.0 is transforming towards industry 5.0, mainly focusing on human-centeredness, sustainability and resilience in factories. Employee preferences and employee satisfaction in production and logistics move to the foreground. Requirements of employees for an attractive employer change; work-life-balance, flexibility in working hours, employment safety and health issues are some of the most important requirements. With the demographic change, human work in production becomes a scarce good. Employers need to adapt to this change and offer more attractive workplaces and work environments. The requirements for attractive workplaces also relate to the use of new technologies. Working in a workplace with constant monitoring by smart watches or even cameras and performance measurement doesn't seem attractive for employees. Potential negative consequences of new technologies need to be respected and investigated before using the technology - even if the technology supposedly increases the transparency and performance of a company.

To summarize, companies are currently facing the following challenges:

1) Employees are changing in their requirements on employer attractiveness, with an impact on job satisfaction. Human work as a production factor is becoming a rare good.

2) New technologies are used faster and with the desire to increase performance. Employee's needs and wishes are sometimes ignored in favor of technology.

3) The nature of work in the industrial environment is changing by using new technologies. Potential negative and ethically questionable consequences need to be respected and investigated.

This paper presents a method of how new decision-supporting technologies can be used and how the attractiveness of employers can be increased at the same time. The aim is not to create performance transparency, but to take the preferences of employees into account. This is done using the example of shift planning. Our assumption is that an increase in satisfaction can also have a positive influence on employee health and the length of employment in the company. Thereby employer attractiveness is enlarged.

Chapter 2 starts with the related papers in scheduling in production and logistics. Therefrom the research gap is derived. Chapter 3 presents the methodology on how to proceed with preference-based scheduling. Two use cases are shown then in chapter 4, one in logistics scheduling workers on workplaces and one in a hospital scheduling doctors on shifts. Chapter 5 discusses challenges and advantages of the work, chapter 6 closes with summary and outlook.

2 STATE OF THE ART

This section presents the current state of research on personnel shift planning systems in production and logistics. The publications were selected based on subject relevance and citation factor. The optimization goal and the consideration of aspects of job satisfaction are the two criteria focused on in this literature review.

Highly fluctuating demand in production makes it difficult for production and logistics to plan the exact number of staff required [4]. The seasonal business is another special characteristic: in the e-commerce sector, a lot of revenue is generated before Christmas, while in production many skilled workers are absent in summer due to holidays. Both fluctuations are compensated by temporary workers [4]. In some companies, work is often carried out in a fixed shift pattern, meaning that employees usually alternate between early and late shifts on a weekly basis. Night shifts are often planned separately and are popular with some employees due to the additional pay. Figure 1 summarizes the literature analysis.

2.1 RELATED WORK

Hochdörffer et al. focus on short-term personnel deployment planning, which considers the qualifications of the employees, the ergonomic workload of the workplace and the last workstations of the individual employees. Their scheduling use case is on assembly work in the automotive industry and is centered around ergonomic assessment of workplaces. All workstations are ergonomically assessed, with low, possible or high risk for individual areas of the employee's body. The scheduling considers worker's competencies and availabilities as well as workplace requirements and ergonomic assessment. The goal is to vary and reduce the strain on the body regions through rotation. [5]

Ruiz-Torres et al. deal with the allocation of employees to jobs, considering job satisfaction, performance and task preferences of employees. Performance is understood as the time employees need to complete a task. A high level of job satisfaction is seen as a high variety of tasks, so that optimization is based on task variance. A task can either be favored or not favored. As a result, the model can create efficient task schedules - measured by execution time - and with high employee satisfaction - measured by task variance - in a short computing time. [6]

Günther and Nissen compare three different possible solutions to a personnel planning problem for a fictitious logistics service provider. The jobs are divided into short tasks, which are then allocated to employees according to their qualifications. The aim is to optimize employee requirements - i.e. to avoid overstaffing and understaffing -, to meet the necessary requirements of the jobs and to minimize the number of rotations. [7] In contrast to Ruiz-Torres et al., a high level of employee satisfaction is achieved here with as few rotations as possible. In the corresponding use case, 65 employees are scheduled over two shifts at nine workstations for one month. Particle swarm optimization proves to be the best solution within the three solutions due to the short calculation time and the comparatively good results. [6, 7]

Wang et al. describe a model for solving the allocation of tasks to employees in production depending on their competence level. This is modelled by the experience of the employees per operation, their professional skills, their learning rate and work specifications. The execution time for individual processes in production is calculated and optimized for short-term planning according to the minimum execution time. In the two-stage planning process presented in this paper, individual skills of the employees are additionally developed and maximized in the long term by linking production planning with employee development. In the case study to validate the model, almost 75% of personnel costs were saved in a work process with eight employees. [8]

The publication by Kacmaz et al. uses a glass factory to conduct a study on the allocation of employees to jobs. Their focus is on a fair and balanced distribution of staff to shifts. In the glass factory, 80 people work in seven different process steps such as cutting, tempering or dispatching. The employees' skills are assessed in three stages and continuously developed through allocation. This gives the factory more flexibility in shift allocation, enables them to fill the jobs required for production and allows free shifts to be distributed more fairly. The results of the scheduling process are compared with the previous allocation options of the glass factory, but it is only described that the competences of the employees can be better utilized and thus employee satisfaction is increased compared to the previous method. [9]

The paper by Ladier et al. focuses on the various flexible labor contracts at logistics service providers such as temporary workers, fixed-term contracts and permanent employees. Three sub-problems are described in the modelling of the allocation: the size of the group, the assignment of tasks during the week and the detailed task planning for a day. The sub-problems are solved step by step, with the output of one step being the input for the next step. In this model, trade union agreements, collective agreements and statutory working time agreements for permanent and temporary employees are considered. In the optimization process, penalty points are awarded for undesirable situations such as unequal distribution of tasks, overstaffing or low rotations. The number of penalty points is then minimized. The model is compared with a manual allocation of labor and with Günther and Nissen's approach and can save up to 50 minutes calculation time. [4]

Tropschuh et al. handle physiological and psychological data of employees as input data for a task planning system in production. By considering the individual performance requirements of employees, employers expect less fatigue and fewer work errors as well as fewer sick days in the long term. Physiological workload and mental performance requirements are measured and the data is then used to calculate the specific workload per employee for certain jobs using a prediction model. The four-stage method presented is intended to improve cooperation between ergonomics departments and production management to achieve better, individualized personnel deployment planning. The subsequent utilization of the data in an allocation system is not discussed in the article. [10]

	Production and logistics						
Criteria	Hoc-2018	Rui-2019	Gün-2014	Wan-2018	Kaç-2019	Lad-2014	Tro-2023
Job satisfaction							
Attention to well-being		◑					
Observance of fairness					◑	◑	
Previous workplaces	●	●					
Optimization goal							
Minimization of competencies			●			●	
Maximizing of costs						◑	
Maximizing preferences		●					
Maximizing Fairness					●	●	
Maximizing ergonomic aspects	●					●	
Maximizing throughput		●		●			
Minimization of rotations			●				
Fulfillment of staff number			●		●	●	

● Criterion fulfilled ◑ Criterion partly fulfilled - Criterion not fulfilled

Figure 1. Literature analysis

2.2 Research Gap and Goals

This literature analysis provides a short overview of the current state of research in shift planning problems in production and logistics. Some publications consider employee-related criteria such as competencies, ergonomic criteria and preferences in their scheduling approaches. In some papers, workplace requirements in terms of employee qualifications are considered as well. However, the publications from the logistics sector lack a broad human-centered approach. So far, only partial aspects of human-centered planning have been depicted.

To fulfill this research gap, our goal is to develop a human-centered, algorithmic scheduling system, that supports the complex scheduling process for managers and considers worker's preferences besides other factors. The preferences are of central importance in the model. The development is to be tested in logistics and comparable areas working in shifts. The practical suitability and resulting benefits are the main research goal in the application.

3 Methodology

To offer a broad human-centered approach, requirements for algorithmic shift scheduling from workers, managers and work council were recorded in interviews in the first step [11]. The model was then created using previous scheduling systems from literature but extending these by some aspects. Especially preferences of employees for tasks and shifts are considered. Aim of this model is to support companies on their way to human-centered shift and task scheduling. The model defines how similar projects should be executed and provides methods that should be used in each step.

The following model we propose includes seven steps. The first five steps are preparatory and only need to be executed once. The last two steps are iterative and are carried out in the company's shift planning cycle. The model is shown in figure 2. If new employees join the team, it is necessary to start from step four, for the integration of new workplaces from step two.

3.1 Record Status Quo (Step 1)

The first step is to record the shift pattern, how and by whom the shift plan is currently created, how many employees and workstations are considered and how the final shift plan is communicated to the employees. It is recommended to conduct this step in the company with the persons doing the regular shift plan. For the shifts, it should be recorded in which shift pattern the company works (early, late, night shifts), whether weekends are worked, when the shifts start and end, whether there is a rotation rhythm, and which employees work in which shift pattern. Regarding the group of employees, it is necessary to know, how many people and workplaces are in the respected logistics area, if there is a rotation rhythm between the workplaces, if there are workplaces that cannot be fulfilled one after the other and if certain company-specific details need to be respected

DOI: 10.2195/lj_proc_haid_en_202410_01

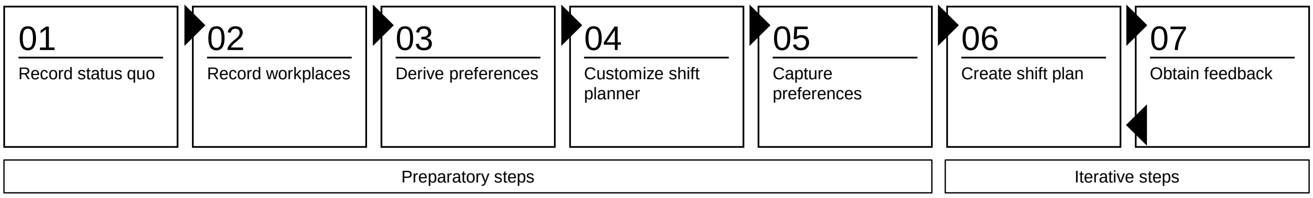

Figure 2. Process-model of human-centered scheduling

for the scheduling. For the shift planning, it needs to be included who creates the shift schedule currently, how it is created, and how vacation, illness and shift preferences are respected so far. For the current communication to the employees, the form of communication, the timeline and the decision of changes needs to be recorded.

3.2 Record Workplaces (Step 2)

The jobs are then recorded with their characteristics and qualifications required to carry out the jobs. It is easiest to get an idea of the workplaces during an on-site visit. Companies often have workplace descriptions, which can be used in addition to this step. A morphological box with the following categories can be used to note the workplaces, but other methods for workplace recording can be used as well. Categories for logistics workplaces which need to be respected are equipment and devices, working model, ergonomic factors, organization of tasks, work environment and required competencies.

3.3 Derive Preferences (Step 3)

In step three, the preferences that employees can select later are derived from the characteristics of the jobs recorded in step two. A preference list with two attributes per preference category is created from the list of jobs recorded. The selected categories must apply to all of the recorded workplaces. It is recommended to create a list of four to six categories with two attributes each. Once the categories and attributes have been selected, it must be recorded which characteristic is fulfilled for each workplace. This is the key to assign which workplace fulfills which employee preferences.

3.4 Customize Shift Planner (Step 4)

The parameters, workstations and preferences recorded up to this point are adapted in step four in the code for assigning shifts. The code is modular and consists of a constraint programming (CP) algorithm. This algorithm has been found most feasible for this specific scheduling problem in pre-studies [12]. One of the main advantages of CP is the ability to quickly find solutions for complex problems. Shift planning for up to 100 employees with six preferences each can easily become complex. For customizing the code, the input data needs to be determined first. Then the model is created. In the next steps the decision variable, the objective as well as the constraints for the company-specific problem are defined. Then the algorithm can be executed. The customizable code is available on github [13].

3.5 Capture Preferences (Step 5)

The five preparatory steps conclude with the capturing of the employee's preferences. Depending on the company's possibilities, this can be done digital or on printed paper. The preferences derived in step 3.3 need to be listed in a questionnaire, which is then handed to the employees. For data protection, it is recommended to work with employee's ID number, which they enter on the questionnaire or in the digital system for data capturing. These ID number can later be fed into the system and after getting the results be translated back to employee's names.

3.6 Create Shift Plan (Step 6)

The new shift plan is then created for the employee group by entering all data into the code and running the code. It is possible to create more than one schedule, so the shift manager can select one. In every case, the shift manager needs to crosscheck the shift plans before the communication to the employees. The shift planning system is not intended to work completely autonomous; the aim is to support in scheduling by making proposals with different schedules, that fulfill general and individual worker requirements.

3.7 Obtain Feedback (Step 7)

After the communication of the shift plan and a defined working cycle like a week or a month has been set with the new shift plan, feedback from the employees is required in step seven. The feedback can then be considered again in the input data of the scheduling process. This must be in consent with the employees and is optional. Feedback questions can be on the satisfaction with the shift schedule, the matching of competencies respected in the schedule, social relationships or the subjective feeling of the preference fulfillment. It is possible to use a digital tool or printed paper for obtaining the feedback. Figure 3 shows an example for the feedback questionnaire.

DOI: 10.2195/lj_proc_haid_en_202410_01

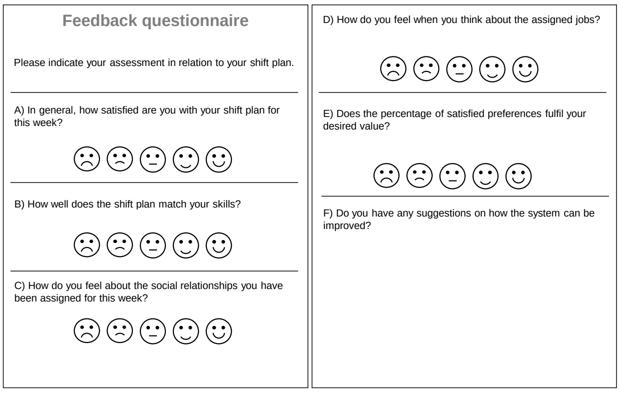

Figure 3. Feedback questionnaire for step 7

4 USE CASES

In this section, the process model presented before is tested in two selected use cases. First, the application is examined in a company's logistics area with 15 employees. The employees are involved in picking, packing and shipping. Then the transferability to other areas is examined. A hospital is selected for this purpose. There, shift requests from a group of 30 doctors were considered for a monthly shift planning.

4.1 USE CASE 1: LOGISTICS

In the following use case, a packaging and dispatch department with 15 employees from a company producing hinges was chosen. The shift schedule is currently created manually by the shift supervisor. The supervisor of the group was involved in all steps of the study and in the coordination. The study took a total of six weeks to complete, including recording the workplaces, creating the shift plan and evaluating each two-week period and was conducted in July and August 2022.

4.1.1 RECORD DATA (STEP 1-5)

The department consists of three groups that work in a three-shift system with early, late and night shifts. The study was conducted with one of those groups. No work is done on weekends and special shifts were not considered. A group alternates between early and late shifts every week for six weeks and then works in the night shift for three weeks in a row. Each team has a shift supervisor who rotates with the shift. The examined group worked early and late shifts during the invested period. When the shift plan is mentioned below, this refers to the allocation of employees to specific workstations within a shift. Employees rotate their workstations daily. In addition, the company tries to assign no employees to the same workstation twice in one week. The frequent rotations are greatly appreciated by most members of the group. The shift planning is done weekly for the upcoming week by the supervisor; the schedule is presented at the last workday of a week for the next week. Preferences of workers for tasks are not respected in the scheduling so far.

After recording the status quo, the 14 different workplaces were recorded in an on-site visit. The workplace of the supervisor was excluded from the study because this job cannot rotate. For the dispatching, the storing and the loading task, it is necessary to have a special training. Dispatcher training have only two workers, loading qualification own four people. For the storing process, only one person has the special training. The other 11 workplaces require no further training. As selectable preferences we derived the categories "work environment", "work with PC", "working in team" and "physical activity". Figure 4 shows the questionnaire for workers to choose their preferences.

Category	Attribute 1		Attribute 2	
Task profile	Fixed task assignment in a shift		Switch between different tasks in one shift	
Technical support	Working with technical support		Working without technical support	
Working environment	Working alone		Working in a team	
Posture	Standing		Sitting	

Figure 4. Selectable attributes per category in use case 1

The code was then adjusted according to the 14 workstations and the selectable preferences. Finally, the employees' preferences were obtained via a paper questionnaire and entered in the code.

4.1.2 RESULTS OF SHIFT PLAN (STEP 6)

The shift plan was then created based on the preferences of the workers from the questionnaire. Employee data could only be traced by the company and were pseudonymized in the code. Optimization goal of the code is to maximize the preference fulfilment for each worker. The rotation preference of a daily rotation could not be adhered, as the algorithm couldn't find a solution for that. Due to the small number of employees who were able to carry out the dispatching task, this is as expected. A compromise was therefore searched by manually changing the rotation numbers, with some employees being assigned a rotation preference of two and a few three days.

For the resulting schedule, ehe average preference score per employee was 78.5 points out of 100 points. The average preference score is influenced here by individual effects. For example, one employee was the only one qualified for the storing task. He was therefore assigned to the job daily. He did not indicate this job as a preference, so this individual case significantly reduces the average preference score. In the feedback to the company, this individual case was highlighted as weak point in the distribution of worker's qualifications.

DOI: 10.2195/lj_proc_haid_en_202410_01

4.1.3 FEEDBACK OF WORKERS (STEP 7)

The resulting shift schedule was discussed with the group's shift supervisor and prepared in the company's usual design. The shift schedule was presented to the employees in addition to the shift manager's usual, manually created shift schedule. However, it had already been decided beforehand that the manually created shift plan is the one to work with and the resulting schedule from the study would only serve as a theoretical alternative. Compared to the manually created shift plan, the algorithmically created shift plan has deviations in the rotation. In some cases, employees need to work at the same workstation on two or three days in a row. This was not only due a limited number of qualified workers for certain workplaces, but also due to very similar tasks for different workplaces. That means that an employee can be assigned to a different workplace but still carry out similar activities. That was not seen as real rotation by the workers. A feedback questionnaire with the following questions was used to determine how employees rated the algorithmically created shift plan in comparison to the manually created shift plan.

A) In general, how satisfied are you with your shift plan for this week?

B) How well does the shift schedule match your skills?

C) How do you feel about the social relationships you have been assigned for this week?

D) How do you feel when you think about the jobs you have been assigned?

E) Does the percentage of preferences met meet your desired value?

Figure 5 shows the corresponding results for the questions. All workers took part in the feedback loop.

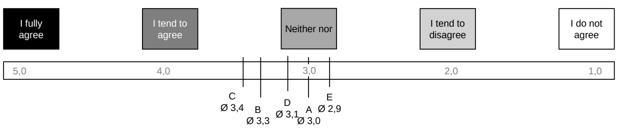

Figure 5. Feedback from the workers on the resulting schedule

The analysis of the results shows that the mean values of the answers for all questions are in the middle of the possible answers. The workers' responses to all five questions are spread across the entire response scale, which shows that employees have very different opinions on the shift schedules. A comparison of the preference points achieved and the feedback from employees shows that, with an average of 78.5 preference points out of 100 possible preference points, a high level of preference fulfilment was achieved. However, this is not reflected in the very mixed feedback from employees. Answers between lot of enthusiasm for AI-based scheduling to large scepticism were given. The insufficient rotation in the algorithmically created shift schedule was criticized. This feedback could be considered when creating further shift plans. Ideally, no employee should be assigned the same workstation twice a week, except for the dispatcher, the storing task and the loading task - here, such frequent rotation is not possible due to the employees' lack of qualifications. In general, employee feedback shows that with further, small adjustments the allocation could be improved and used on a weekly base for creating schedules.

4.2 USE CASE 2: HOSPITAL

The human-centered scheduling system was tested in the second use case as part of this work at the hospital MRI in Munich. The department of visceral surgery was selected from various groups of doctors and nursing staff for our use case. 32 doctors were working in that department at the time of the study. Further scheduling problems such as the planning of the nursing team on the ward, surgery planning or other groups of doctors in the hospital were not considered in this study. In addition to adapting the shift planner, the study included obtaining preferences for shifts and a subsequent evaluation of the results with some of the doctors.

4.2.1 RECORD DATA (STEP 1-5)

The shift plan has so far been drawn up monthly by one of the doctors. A digital tool is used to enter the data and create the shift schedule, but it only offers a few functions. The shift planner therefore uses Excel to carry out preliminary calculations or to count and save data. In contrast to production logistics, the doctors all have the same workplace, but it depends on who works in which shift and with what experience. Doctors can give preferences for shifts per month. Schedules must be communicated six weeks before start of the schedule, as regulated in the German collective agreement for medical work (Marburger Bund). Changing shifts with colleagues is possible in personal conversation.

The visceral surgery doctors at the MRI work in five different shifts. There is no rotating pattern for individual doctors. The doctors can make requests for certain shifts or days off, but these do not all have to be fulfilled. Doctors with certain qualifications must be present on each shift: one specialist and two assistant doctors at each of the four wards. Three shifts must be scheduled during the week: dayshift, on-call-shift and stand-by-shift. Two different shifts must be planned for weekends and public holidays: on-call-shift and stand-by-shift. On-call-shift is assumed to be four hours; doctors do not have to be present during on-call-shifts and only the actual hours worked are billed. Doctors must be present during stand-by-shifts and the entire time is counted as working time.

The doctor's preferences were surveyed using a digital tool, where everyone had access. We used an ID-code to ensure pseudonymization and data protection of the employees. In addition, the doctor's availabilities were queried and entered. The sample month for this use case was June 2023. The aim of the algorithm is to maximize the preference score, that is the fulfilment of the doctors' preferences for days off and certain shifts.

4.2.2 RESULTS OF SHIFT PLAN (STEP 6)

Finally, the code is run, and the shift plan is created. Two different shift schedules are created. The first shift plan based on up to four doctors' preferences for shifts - this was the specification for the study. Not all doctors adhered to this requirement and in some cases submitted more preferences. In addition, the shift plan was created manually by the doctor responsible and distributed to all employees. In a second run, the same number of on-call-shifts as in the manually created schedule were scheduled for everyone, to avoid that someone favours our shift plan due to less work than in the manually created. Work was carried out according to the manually created shift plan in June 2023.

In the manually created shift plan, the doctor was able to fulfil 65 of 69 requests (94%) for days off and 15 of 26 requests (58%) for shifts. In total, doctors were assigned to work below their highest qualification level in 17 shifts. This affects a total of eight different doctors.

In the algorithmically created shift plan, considering a maximum of four on-call/stand-by-shifts per employee, 69 out of 69 preferences (100 %) for days off and 22 out of 26 preferences (85 %) for specific shifts were fulfilled. The four shift preferences that couldn’t be considered were distributed among three doctors. Compared to the manually created shift plan, more preferences were fulfilled for six doctors and fewer for none. For all other doctors, there was neither an improvement nor a deterioration compared to the manually created shift plan. With the algorithmic solution, however, 13 doctors were scheduled below their qualification level a total of 21 times. This is because the minimization of the deviation of the required qualification in the assigned shift from the highest qualification level per doctor was not considered in the optimization. If a corresponding term would be added in the code, the allocation according to the appropriate qualification level could be improved. The percentage of preference fulfilment of the manual and algorithmic planning is shown in figure 6.

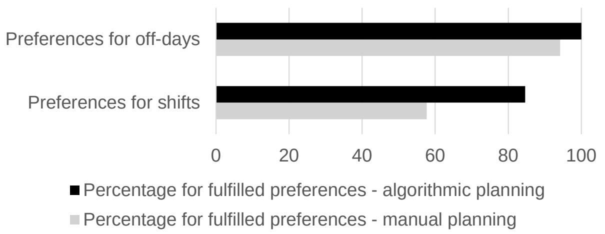

Figure 6. Preference fulfillment in use case 2

4.2.3 FEEDBACK OF DOCTORS (STEP 7)

In the final step of the use case, feedback on the shift schedule was recorded from the assigned doctors. 15 of the 32 doctors participating in the study completed the following questions on the shift plan:

1. How satisfied are you in general with the algorithmic schedule compared to your actual schedule?
2. How satisfied are you with the algorithmic schedule in terms of your personal professional skill? (Note: If, for example, you as ’A1’ are assigned as ’A2’.)
3. How satisfied are you with the algorithmic schedule regarding the fulfillment of your off-day preferences?
4. How satisfied are you with the algorithmic schedule regarding the fulfillment of your job preferences?

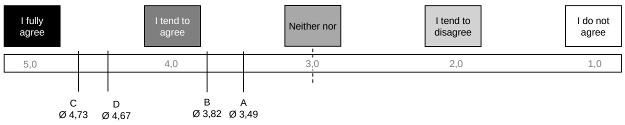

Figure 7. Feedback from the doctors for the resulting schedule

The analysis of the results (see figure 7) shows doctors tend to be rather satisfied with their algorithmic schedule in general and tend to be in between a neutral position and rather satisfied regarding the consideration of their personal professional skill. Further, the doctors tend to be very satisfied both with the fulfillment of their off-days as well as their job preferences. A more detailed analysis of questions A and B shows that some of the doctors surveyed selected "rather dissatisfied" for various reasons. In one case, a doctor deliberately wanted to work two weekends in a row to have the other two weekends of the month free. The doctor planning the shifts knew this, but the algorithm did not, as it tries to distribute the weekends off as evenly as possible throughout the month. However, it would be possible to program this in a second run. In another case, the algorithmic planner assigned specialists below their qualification level. As a result, the algorithmically generated shift plan was rated lower. Here, stricter boundary conditions could be introduced as well to prevent this case. The algorithmic shift plan was rated very highly for the fulfilment of preferences, the maximization of which is the optimization goal of the algorithm.

4.3 CONCLUSION OF THE USE CASES

The use case in logistics was selected to evaluate the model and its applicability in the environment it was developed for, logistics. During the use case a high interest of the company was shown in the study and results are promising to use the model and the corresponding code regularly. However, a permanent use of the model was not part of this study. To evaluate the transferability of the model to other sectors, we performed the study in a similar way, but with other constraints in a hospital. Here, the interest for algorithmic scheduling was even higher and results show the high applicability and easy transferability of the model to the hospital sector. We assume the same transferability to further sectors such as production lines, police departments, fire workers or restaurants.

Nevertheless, there are still a few challenges for the long-term use of the system. These are addressed in chapter five.

5 DISCUSSION

This section discusses aspects that became noticeable in the development of the human-centered shift planning. They are derived from the application examples and from discussions with experts.

5.1 SIMPLIFICATIONS

Shift planning of a work group can become very complex due to various influencing factors. The number of employees and workstations as well as the criteria considered in planning have an exponential effect on the complexity of the planning problem. In application, it is therefore useful to adopt simplifications and divide large working groups. The structuring of the code provided helps to assume simplifications for the input data and the boundary conditions. Simplifications can also help to reduce the historically grown complexity in the shift planning of companies.

5.2 MISSING DATA

Errors can arise during the input data query due to inaccurate work or unawareness. In one of the use cases an employee only entered one preference instead of four. In another case, no preferences were entered at all. Therefore, assumptions had to be made for both cases, which can only be an approximation and do not reflect the employee's actual preference. Working with approximations is useful in the absence of data, but the assumptions should be checked carefully and ideally replaced with real data as soon as possible.

5.3 FAIRNESS

Fairness can be understood in different ways. Barredo Arrieta et al. separate individual fairness as the difference between the subject and the rest of the population from group fairness, i.e. fairness from the perspective of all individuals [14]. Fairness considerations should be made before, during and after the introduction of a shift planning system. In preference-based shift planning the maximum preference fulfilment of an individual person can be optimized at the expense of the preference fulfilment of other employees. On the other hand, the preferences of all employees can be optimized on average, so that in the end all employees have fulfilled as many preferences as possible. Situations, in which the preferences of some employees are met in full and those of other employees are not met at all, should be avoided.

5.4 SOCIAL RELATIONSHIPS IN SHIFT GROUPS

The human-centered shift planning developed here considers preferences, competencies and ergonomic factors at the workplace. Social relationships are respected to the extent that "teamwork" and "individual work" can be preference attributes. Preferences for working together with one or more specific people were not considered. As some of the employees in production logistics come from different cultural backgrounds with conflicting interests, cooperation should be approached with caution in individual cases. A human planner can take such conflicts into account through personal knowledge and should check this when selecting from alternative shift plans after the shift plan has been created. It would also be possible to include preferences or dislikes for working with individuals in the algorithm, but this is countered by the question of whether regular collaboration between conflicting parties - or indeed collaboration with regularly changing partners - does more good than harm to the team structure. The regular change of colleagues in direct collaboration can also be modeled as a boundary condition in the algorithm.

5.5 ECONOMIC EFFICIENCY

The clear focus of this work was the employee-oriented approach through human-centered shift planning regarding satisfaction with the assignment of workstations. The assumption was that an increase in satisfaction can also have a positive influence on employee health and the length of employment in the company. However, this could not be proven due to a lack of long-term observation. Both aspects have an influence on the economic view of the system, as the absenteeism rate due to illness and the rate of employees who leave a company at their own request can be reduced. Nevertheless, the efficiency of shift planning is increased, as algorithmic shift planning takes significantly less time than manual planning. Changing from manual to algorithmic shift planning requires capacity to be invested in adapting and introducing the system and, in the case of a commercial system, in procurement. How much effort is required in relation to the potential benefit must be investigated further in each individual case.

5.6 GENERAL VALIDITY

The methodology for human-centered shift planning was developed specifically for logistics and the shift and workplace models commonly used there. The modular structure of the code makes it possible to adapt the system to other areas. With a few modifications, for example, it was possible to represent the monthly shift planning for doctors in a hospital. Transferability to other areas working in shifts is therefore possible. Applications are conceivable in production or manufacturing, in the public sector, on the railroads, in catering businesses or other areas of society that work shifts.

6 Summary and Outlook

This paper presents a human-centered approach to shift planning in logistics. This method can be used to allocate jobs as well as tasks and shifts to employees, whereby the preferences of employees are of central importance. The allocation is carried out using a CP-based algorithm and is not intended to replace human activity, but to support it. The existing shift planner can therefore create shift plans faster, consider workers preferences and find a solution to complex problems quickly. Rescheduling in the event of sickness absence is also possible easier. The application in two real cases, logistics and a hospital, has shown that this method can be used in logistics and can be transferred to other sectors with simple adjustments as well.

Nevertheless, there are still challenges when using this human-centered approach. Fairness is a topic that is viewed very individually by workers and is therefore difficult to process objectively in an algorithm without making the specifications too complex and the results incomprehensible. If data is missing or if employees refuse to provide data, a way must be found to use adequate replacements. Regarding the hypothesis of enlarging profitability of companies in the long-term, the work presented here only carried out short-term studies. We still see a high advantage in using human-centered scheduling for companies to stand out from competitors. Concluding, human-centered shift planning is an approach that can be used to increase employee loyalty to a company, empower employees and increase their motivation for work.

Charlotte Haid, M.Sc., studied Mechanical Engineering at Technical University of Munich (TUM). Since 2020, her research at the Chair of Material Handling, Material Flow, Logistics focuses on using AI in a human-centered way for logistics as well as robotics and sustainability in logistics.

Oliver Berchtel, M.Sc., graduated in mechanical engineering at the Technical University of Munich (TUM). After his studies, he began his professional career at a hinge factorer in Austria and is now working in the field of passenger transport by cable cars.

Natalie Wagner, M.Sc. holds a B.Sc. in Mechanical Engineering and a M.Sc. in Medical Engineering and Assistance Systems from the Technical University of Munich. Following her graduation, she is currently working in the field of regulatory affairs for medical devices.

Prof. Dr.-Ing. Johannes Fottner, born in 1971, has been Professor of Technical Logistics at fml since 2016. He teaches at TUM School of Engineering and Design and conducts research in the fields of logistics planning, AMR in intralogistics and Circular Economy. After receiving his doctorate from fml in 2002, he rose through the ranks of various management positions at Swisslog before becoming CEO of MIAS Group in 2008. Furthermore, he has been chairman of the Bavarian division of the Association of German Engineers (VDI) and deputy chairman of VDI's subdivision Production and Logistics since 2015.

Address: fml – Lehrstuhl für Fördertechnik Materialfluss Logistik, Technische Universität München, Boltzmannstraße 15, 85748 Garching bei München, Germany, Phone: +49 89 289 15938 E-Mail: charlotte.haid@tum.de

1 Literatur

[1] H. Kagermann und W. Wahlster, "Ten Years of Industrie 4.0", *Sci*, Jg. 4, Nr. 3, S. 26, 2022, doi: 10.3390/sci4030026.

[2] S. Feldhorst, S. Aniol und M. ten Hompel, "Human Activity Recognition in der Kommissionierung – Charakterisierung des Kommissionierprozesses als Ausgangsbasis für die Methodenentwicklung", 2016.

[3] M. Breque, L. de Nul und A. Petridis, "Industry 5.0: Towards a sustainable, human-centric and resilient European industry", European Commission, Brüssel, 2021. [Online]. Verfügbar unter: https://op.europa.eu/en/publication-detail/-/publication/468a892a-5097-11eb-b59f-01aa75ed71a1/. Zugriff am: 25. September 2023.

[4] A.-L. Ladier, G. Alpan und B. Penz, "Joint employee weekly timetabling and daily rostering: A decision-support tool for a logistics platform", *European Journal of Operational Research*, Jg. 234, Nr. 1, S. 278–291, 2014, doi: 10.1016/j.ejor.2013.10.023.

[5] J. Hochdörffer, M. Hedler und G. Lanza, "Staff scheduling in job rotation environments considering ergonomic aspects and preservation of qualifications", *Journal of Manufacturing Systems*, Jg. 46, S. 103–114, 2018, doi: 10.1016/j.jmsy.2017.11.005.

[6] A. J. Ruiz-Torres, J. H. Ablanedo-Rosas, S. Mukhopadhyay und G. Paletta, "Scheduling workers: A multi-criteria model considering their satisfaction", *Computers & Industrial Engineering*, Jg. 128, S. 747–754, 2019, doi: 10.1016/j.cie.2018.12.070.

[7] M. Günther und V. Nissen, "A comparison of three heuristics on a practical case of sub-daily staff scheduling", *Ann Oper Res*, Jg. 218, Nr. 1, S. 201–219, 2014, doi: 10.1007/s10479-012-1259-2.

[8] Z. Wang, H. Hu und J. Gong, "Modeling Worker Competence to Advance Precast Production Scheduling Optimization", *J. Constr. Eng. Manage.*, Jg. 144, Nr. 11, 2018, Art. no. 04018098, doi: 10.1061/(ASCE)CO.1943-7862.0001556.

[9] Ö. Kaçmaz, H. M. Alakaş und T. Eren, "Shift Scheduling with the Goal Programming Method: A Case Study in the Glass Industry", *Mathematics*, Jg. 7, Nr. 6, S. 561, 2019, doi: 10.3390/math7060561.

[10] B. Tropschuh, J. Cegarra und O. Battaïa, "Integrating physiological and mental aspects in employee scheduling: an overview for practitioners in produc-

tion management", *International Journal of Production Research*, S. 1–14, 2023, doi: 10.1080/00207543.2023.2217278.
[11] C. Haid, C. Unruh, I. Pröger, J. Fottner und T. Büthe, "Personaleinsatzplanung in der Logistik", *Zeitschrift für wirtschaftlichen Fabrikbetrieb*, Jg. 116, Nr. 12, S. 908–912, 2021, doi: 10.1515/zwf-2021-0160.
[12] C. Haid, S. Stohrer, C. Unruh, T. Büthe und J. Fottner, "Accommodating Employee Preferences in Algorithmic Worker-Workplace Allocation" in *13th International Conference on Applied Human Factors and Ergonomics (AHFE 2022)*, 2022, doi: 10.54941/ahfe1002235.
[13] fml - Lehrstuhl für Fördertechnik, Materialfluss, Logistik, *github repository des tum-fml.* [Online]. Verfügbar unter: https://github.com/tum-fml/ (Zugriff am: 31. Januar 2024).
[14] A. Barredo Arrieta *et al.*, "Explainable Artificial Intelligence (XAI): Concepts, taxonomies, opportunities and challenges toward responsible AI", *Information Fusion*, Jg. 58, S. 82–115, 2020, doi: 10.1016/j.inffus.2019.12.012.