

Health Scores for Generating Health-Respecting Shift Plans by Means of an Expert System from the Perspective of Care Organisations

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Abstract: The care section is an essential part of our society as well as our everyday life. It is also a section which suffers from staff shortage. Even though the job itself is not the problem, the shortage is related to shift-related below-average working conditions. This work focuses on health-related aspects of shift planning in order to provide insights which can assist in improving the situation of care workers. To this end, a literature and law analysis was followed by interviews to collect, aggregate and extend health-related rules for the shift planning process. A list of derived rules from practice is presented in addition to a discussion of previous insights from literature. Based on these rules, a publicly available software demonstrator was implemented for sensitisation and to show how a health-focused shift plan generation could look like. The basis for shift plan evaluation is a health score definition, which takes into account the number of shifts and weighted rule violations. The demonstrator was also used on shift plan data covering several years, resulting in insights about rule violations from practice.

1 INTRODUCTION

In the discussion about the shortage of skilled care workers and the ensuring nursing care in Germany, the stressful working conditions in the care sector are coming to the fore. High physical and psychological demands, high work density combined with too little time for nursing activities, frequent overtime and changes in shift plans as well as little room for manoeuvre at work characterise the everyday life of the care staff. This resulted in a high rate of sick leave, high fluctuation in the care staff and reductions of working hours. The low attractiveness of the care sector is not the result of dissatisfaction with the job itself, but rather the demotivating working conditions (Rohwer et al., 2021; Rothgang et al., 2020).

The BKK Health Report of 2022 shows that employees in elderly care were absent due to illness for an average of 33.2 days. On average, this is 15 days more than the average of all employees in Germany with 18.2 sick days per employee (Knieps and Pfaff, 2022).

Other studies, such as the AOK-Bundesverband (AOK-Bundesverband, 2023) or the Technikerkrankenkasse (TK Die Techniker, 2023), confirm this trend. This vicious circle of high sickness rates and increasing staff shortages resulted in increasing workload for the remaining care staff. The recovery phase during the non-working time is often interrupted because care workers have to step in for colleagues at short notice (Herrmann and Woodruff, 2019).

According to the BKK study mentioned above, 44.2 percent of geriatric care workers said that they are currently only partially or not at all able to cope with the higher demands of their job. This proportion is almost twice as high as in other professions, where it is 24.6 percent. One out of four care employees are considering changing employers within the next two years. More than one in five people are thinking about giving up their profession completely (Knieps and Pfaff, 2022). To break this vicious cycle, strategic measures are required that aim to improve working conditions as well as to support employees through health-respecting shift plans.

According to the DGB Good Work Index of 2018, 69 percent of care staff work in shifts, 82 percent on weekends, 17 percent in the night shift and 54 percent

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in the evening shift (Schmucker, 2019). Studies show that shift work can be stressful for both health and social life (Hirschwald et al., 2020; Jacobs et al., 2019; Strauß et al., 2021).

Shift planning in care facilities is a tool for scheduling staff. It has a significant impact on the quality of patient care, the job satisfaction of care staff and the efficiency of the facility. In addition, the shift plans document compliance with laws, accident prevention regulations and collective agreements, etc. (Birkenfeld, 2000). The challenge for those persons creating shift plans lies in taking into account the interests of residents and the employees of the facility itself. Residents demand a consistent quality of care as well as flexibility in the provision of care.

Software applications have supported the design of shift plans for many years. Today's software for shift planning is usually integrated into a software suite used in the care domain. For care work, digital support is particularly important for documentation as well as planning of resources (Daum, 2022). A recent study found out, that the majority (89 percent) of the surveyed care organisations stated that care scheduling/shift planning is predominantly performed digitally (Daum, 2022). One major challenge with shift planning is the volatility of the work - a challenge which can be reduced with software supported solutions. These systems can offer a spontaneous visualisation of the consequences of a planning decision by showing time accounts, staffing information and information regarding rest times and other legal or ergonomic criteria. Shift planning can be supported to a lesser or greater automation extent (Kubek et al., 2020), whereat the software usually offers the option for managing profiles for each employee/care staff member that stores availability and personal preferences.

Planning software is usually able to show violation of relevant rules, usually predominantly law-based rules. Due to the fact, that the systems already stores huge sets of data regarding personnel and their shift plans, this data could be used to extract information regarding the "quality" of a shift plan seen as a whole as well as on employee level. The quality can be measured with different aspects in mind. This work focuses on health-related quality measures, taking into account rules derived from law, science and interviews.

The contributions of this work are as follows: health-related rules for shift planning are presented and discussed in three categories, extending law-based and established rules by recommendations derived from interviews. In addition, a health score is introduced as a health-based measurement for shift

plans. Last, but not least, a demonstrator is presented which shows an implementation of the discussed concepts, emphasising the importance of visualisation of relevant aspects. This demonstrator was also used on data coming from practice covering several years of shift plans providing useful insights.

The remainder of this work is structured as follows: section 2 describes the methodology of this paper. section 3 presents the professional basis of health-related aspects which are used for the technical demonstrator described in section 4. Finally, section 5 comes with a conclusion and future work.

2 METHODOLOGY

The underlying research questions of the presented work are the following two:

1. What health-related factors are relevant for the preparation of shift plans?
2. How can the health-related factors for shift plans be utilised (by technical means) to improve the well-being of the care staff in care organisations?

A mixed-method approach was chosen, which included literature research, qualitative surveys and elements from prototyping. The literature study according to the method vom Brocke (vom Brocke et al., 2009) started with a research on the applicable legal regulations in the field of shift plans. Relevant national and international labour laws and regulations that deal with health aspects in relation to shift plans were examined. In parallel, occupational science sources and recommendations were evaluated in order to create a comprehensive basis for the further research steps.

Following this literature review, a qualitative approach was chosen to systematically answer the research questions. The research method is made up of the following steps:

1. Semi-standardised interviews were conducted to determine the approach the persons responsible for shift scheduling were taking and to identify the requirements for shift planning from the staff. This allowed for comprehensive data collection and inclusion of the practice perspective.
2. The interviews also included questions about current technical support for service planning. This helped to understand existing software solutions and their use in the context of the care sector.
3. A detailed analysis of non-digital shift plans from practice provided by care organisations was carried out to identify further criteria for shift plan-

ning and fulfilment of the health aspects mentioned by the interview partners.

4. The findings were reflected with the interviewees to ensure that the requirements and factors identified meet the needs of the practice.
5. A set of rules was formulated based on the findings from the interviews, from the review of non-digital shift plans and from the legal regulations found in the literature review. These rule sets were to serve as a basis for the development of the software demonstrator that can transparently present the health aspects in shift plans.
6. Common shift plan applications were examined and discussions were held with manufacturers of shift plan software in order to get to know relevant functions and find out to what extent shift plan design is already supported by automation and the use of artificial intelligence (AI).
7. Criteria, requirements, rules and minimum functionality for a demonstrator were fixed.
8. Based on this, a prototype demonstrator was then specified and developed according to the prototyping method by Pomberger (Pomberger and Weinreich, 1994).
9. The result is a software demonstrator as a proof of concept for sensitisation and motivation, which analyses the aspects of healthy working within shift plans and displays rule violations both in a detailed and summarised manner as a global "health score".
10. For a qualitative evaluation, V1.0 of the demonstrator was presented to care experts, care organisations and software manufacturers in online appointments and feedback was received.
11. Based on the feedback, V2.0 of the demonstrator was developed and deployed as a public available online tool for dissemination of the results.

3 HEALTH-RESPECTING PERSPECTIVES

As already described, employees demand reliability, a fair workload, individualisation and personal flexibility. The facility itself expects compliance with the personnel budget, economical use of working hours, quality management and minimum legal requirements, as well as minimal planning effort (Herrmann and Woodruff, 2019). Due to the importance of duty scheduling in terms of keeping employees healthy and in the care context additional of shift

work, framework conditions are recommended and in some cases regulated by law. The most relevant aspects are presented in the following subsections. They provide the basis for health-respecting shift plans and are utilised by the technical implementation in section 4.

3.1 Rules Derived from Laws

The legal framework for the organisation of working time is of great importance for the protection of employees' working conditions and for ensuring a balanced relationship between work and rest. German law is the focus of this subsection due to the fact, that the context of our work is the German care sector and that all of our interview partners and data providers are from Germany. The most important law in this respect is the Working Time Act (Arbeitszeitgesetz - ArbZG) (Bundesministerium der Justiz, 2020). According to § 1 the purpose of the law is to ensure the safety and health protection of workers. It limits working time in Germany to eight hours per working day. An extension to up to ten hours is permitted under certain conditions. Employees may work a maximum of 48 hours per week. However, a 30-minute rest break must be granted after six hours of work at the latest, unless the total working time is less than nine hours. If the working time exceeds nine hours, it is 45 minutes. The rest break can be divided into sections of at least 15 minutes each. In addition to rest breaks, the law provides for a daily rest period of eleven hours. This means that there must be at least eleven hours between two work assignments. Special provisions apply to night work. Night work within the meaning of the Act is work that is predominantly performed between 23.00 and 6.00 o'clock.

With regard to a limit on consecutive working days, the German law does not provide for an explicit maximum limit. The limit is set by other provisions, such as Sundays off, and was limited by the European Court of Justice to a maximum of 12 consecutive working days (Court of Justice of the European Union, 2017).

Working time arrangements in the care sector are particularly affected by exemptions in the law. Collective agreements may go even further. For example, it is possible to reduce the rest period to ten hours.

The laws in Germany and the other member states of the EU are directly influenced by the European Parliament and Council. In the Council Directive 2003/88/EC (European Union, 2003), the EU defines minimum requirements for the organisation of working time, including minimum periods of daily rest, weekly rest and annual leave, breaks, maximum

weekly working time, and certain aspects of night work, shift work, and patterns of work. Regarding rest time the directive states that every worker is entitled to a minimum daily rest period of 11 consecutive hours per 24-hour period. A maximum average working time of 48 hours per week, including overtime is also specified. The directives remain unspecific regarding breaks and refers to agreements between the employers and employees or by national legislation.

In the USA, the Fair Labor Standards Act (FLSA) is the federal law that regulates working hours (U.S. Department of Labor, nd). According to the FLSA, employees must receive at least the minimum wage and may not be employed for more than 40 hours in a week without receiving at least one and a half times their regular pay rate for any hours worked over 40. There is no federal or state law on limits to the length of the working week, but the FLSA creates a financial disincentive to longer working hours by requiring time and a half pay for employees working more than 40 hours in a week.

3.2 Rules Derived from Official Recommendations from Authorities

In addition to the various legal requirements, there are other scientifically based recommendations for working and rest times, breaks and shift work coming from official authorities. In Germany, it is stipulated by law that reliable scientific findings must be taken into account when dealing with working hours (§ 6 (1) ArbZG) (Bundesministerium der Justiz, 2020).

With regard to working hours, a working time of 8 hours is generally recommended (BAuA, 2016). However, splitting shifts into two separated, shorter shifts with a long break, which is usually not spent at the workplace, between the two shifts, should also be avoided (Beermann et al., 2019). Consecutive working days should also be limited, and a rest day should be planned after 5 days (Beermann et al., 2019), whereby individual interspersed rest days should be avoided (BAuA, 2021) to ensure recovery (Wong et al., 2019).

With regard to the shift work required in caring, labour science recommends a forward respective clockwise rotating shift sequence. This means that a phase of early shifts should be followed by a phase of late shifts, then night shifts and finally days off, whereby the number of night shifts should be a maximum of 3 nights (Burgess, 2007; BAuA, 2016).

Other recommendations do not directly address working time and shift planning, but concern the handling of the shift plans or the organisation of available staff. Occupational science findings emphasise

the design of a better shift work. In addition to recommendations on the lengths of shifts, the rotation from early to late and night shifts as well as the shift sequence, the regularity and predictability of working hours are emphasised (Knauth and Hornberger, 1997; DGAUM, 2020; BGW, 2006). Especially the plans should be predictable and plannable in order to improve the work-life balance (Beermann et al., 2019). Insufficient predictability of work and leisure time leads to increased subjective health complaints and increased dissatisfaction with own working time arrangements (Engel et al., 2014). In this context, a health-promoting shift plan plays an important role. A shift plan that is based on science recommendations and putting the needs of the employees can have a positive impact in their satisfaction, mental and physical health, and the quality of care. A very important aspect is the absence of changes at short notice, which also has been confirmed to be a success criterion when recruiting and retaining employees (Gaugisch et al., 2017). There is no uniform opinion on the appropriate lead time a shift plan should be developed and provided to the staff. Guidelines in other countries were only found in isolated cases; the Formula Retail Employee Rights Ordinances in San Francisco, for example, stipulate a binding two week advance notice of work performance for certain companies (City and County of San Francisco, 2015).

3.3 Rules Derived from Other Sources and Interviews

In addition to the legal framework and official recommendations, there is further literature on guidelines for the design of shift plans.

A shift plan is used to regulate both the staffing requirements and the actual deployment of staff in care facilities. It is intended to ensure that the workflow is efficient, of high quality and satisfactory for both the persons being cared for and the care worker (Birkenfeld, 2000). Care workers have clear expectations of an effective shift plan, which can be classified into the categories of reliability and planning security, fairness, individualisation and personal flexibility (Herrmann and Woodruff, 2019). In terms of reliability and planning security, they expect, for example, punctual closing time, regular weekends off every 14 days and an early announcement of the shift plan. A well-designed shift plan should also be able to accommodate staff absences without people having to fill in for sick colleagues at short notice or having to work on non-working days.

In a study by the German Professional Association for Nursing Professions (DBfK, 2019) the staff

also demand sufficient staff to adequately cover the workload and that it should be binding at least four weeks in advance.

In addition, the integration of buffers for short-term staff absences is important in order to maintain the quality of patient care. The reliability of the shift plan is crucial and it is desirable to take individual preferences into account.

In a collection of good practices (BGW, 2006), measures were identified that elderly care facilities implement with regard to labour logistics. With reference to duty scheduling, the establishment of a pool of temporary staff is mentioned in order to ensure the aforementioned reliability of the shift plan and to reduce the need to call staff in from off duty. Here too, early provision of the plan (4 weeks) is discussed, although in the interviews conducted as part of the project, organisations even aim for 6 weeks in advance. In terms of shift planning, the facilities are aiming to reduce work peaks and avoid split shifts.

In order to supplement these aspects from literature, interviews with shift planners were conducted as part of this work. In the interviews, it was frequently mentioned that employees' wishes are considered when planning shifts. It has been confirmed that this leads to greater acceptance of the schedules and increases satisfaction. There is limited academic research specifically on the impact of considering employee wishes in shift planning on employee health. However, there is research that suggests that flexible work arrangements, which can include shift scheduling, can have positive impacts on employee well-being and health. For example, a comprehensive review of shift working nurses concluded that factors including control over shift patterns are crucial factors in achieving work-life balance (Dall'Ora and Dahlgren, 2020). Care workers want that the shift plan takes their individual time needs into consideration, for example a shift plan that can be integrated into their rhythm of life (Herrmann and Woodruff, 2019; Kubek et al., 2019; Schmucker, 2019).

Some of these aspects were simply confirmed by the conducted interview of us, but there were also additional aspects and also relevant conflicts arise. Of such conflict is that some employees' wishes contradict official recommendations or even legal requirements. For example, employees occurred in the interviews who work more than 3 days in a row at night in order to have more time off afterwards. Others prefer to work longer shifts (e. g. 10 hours) in order to have more time off afterwards. This creates a conflict, at least between the finding that taking wishes into account increases satisfaction, but according to current findings the work is more stressful as a result.

In the interviews, various groups of people in their organisations were identified for whom special conditions and facilities apply. Employees with children get more flexibility in the start and end times of their shifts, which are adapted to school and childcare times. For employees whose partners also work shifts, their own working hours are adapted to their partner's so that working hours are as similar as possible and free time can be spent together. Older employees are offered shorter shifts or, if their working time account allows, more consecutive days off.

In terms of other organisational aspects, full-time employees tend to be given longer shifts to ensure days off. For this reason, full-time employees are often scheduled first in the shift plan. Part-time employees are therefore often given slightly shorter shifts. A special feature applies to the planning of holidays: an attempt is made to schedule either an early shift before a desired holiday, or a late shift after the holiday, or even a whole day off is scheduled to extend the holiday.

The full list of health-related rules based on employee-wishes for shift planning derived from the conducted interviews is given in the following:

- Early duty should be preferred on last working days before holidays, if possible.
- Late shifts should be preferred on first working days after holidays, if possible.
- Part-time workers have shorter shifts.
- Full-time workers have longer shifts.
- Free days are appended to holidays, if possible.
- Shift plans of partners should be respected.
- Times of day care centres and schools are respected for care workers with (small) children.
- Older care workers have shorter shifts.
- Older care workers have preference consecutive free days.
- Shift plans should plan with net time, i. e. their working time minus holiday times, training times, and other predictable peculiarities.
- Holiday planning can be finalised in December of the last year.
- A certain amount of wishes is respected per month, if possible (e. g. two per month).
- Individual needs are respected such as certain times to bring children to their sport locations.
- Wishes about night shifts are respected in particular.
- Wishes can be registered until the 15th of the previous month.

In practice, it usually is not possible to respect all rules, especially when considering a multitude of individual living conditions and wishes. But trying to respect the needs of the care workers as good as possible is both, expected and valued by the concerned care workers.

In terms of reliability, the planners have paid particular attention to outage management. For example, one organisation has a buffer of day workers who are willing to cover night shifts. In addition to pools of temporary staff, there are also resource services that can be called upon at short notice. And finally: Standing in is usually rewarded with attractive compensation, such as an extra weekend off. The full list of outage rules derived from our interviews is as follows:

- Part-time workers are preferred for standing in.
- Care workers which stand in often get a fair compensation, e. g. additional free weekends.
- There should be a reasonable amount of buffer care workers for night shifts.
- When organising buffers, the level of training should be taken into account.
- A resource service should be used for structured outage management, i. e. care workers which check whether they are needed or not at the beginning of the day. If not, they get a compensation for staying ready, e. g. one hour of work time noted.

3.4 Stakeholders and Their Interests

After investigating the health-related factors of shift planning (research question 1, cf. section 2), the question arises how these insights can be utilised (research question 2). With already numerous law-based rules, it is unrealistic that planners can respect the multitude of health-related rules manually in a reasonable amount of time. Therefore, the target is a software support in form of an extension of the already used planning tools. To this end, a software demonstrator was implemented (cf. section 4) for sensitisation of the main stakeholders, i. e. care workers as the most affected group of persons, planners as those having to create the shift plans with various requirements, employee representative committees as those, caring for the fulfilment of many requirements to shift plans, and last, but not least, software providers as those which have the basis to implement the means to bring the insights of this work to practice.

This last subsection is about the two stakeholder groups which are most probably the main users of the potential software support, i. e. planners during generation and employee representative committees (such

as work councils) as verifying instances. The demonstrator was designed having these two user groups in mind.

The works councils have a right of co-determination with regard to duty scheduling in Germany (Bundesministerium der Justiz, 2022). They pursue various interests with regard to duty scheduling, with the aim of creating a balanced and fair working environment. A central concern is to promote the work-life balance of employees by carefully organising working hours. In doing so, the representative office emphasises compliance with working time laws and collectively agreed provisions. Another focus is on protecting the health of employees. Duty scheduling should be designed in such a way that sufficient breaks and appropriate rest periods are taken into account in order to avoid overwork. At the same time, the employee representatives are committed to involving employees in the duty scheduling process in order to better take their needs and preferences into account. Representation also aims to distribute the workload fairly and ensure that employees' qualifications and competences are appropriately taken into account. This is not just about avoiding overwork, but also about promoting efficient work performance. The employee representatives are in favour of flexibility in duty scheduling to make it easier to combine work and family life. The introduction of flexible working time models plays a key role here. Transparency and open communication between employer and employees are further key concerns in order to recognise and resolve potential problems at an early stage. Overall, the employee representatives strive for balanced duty scheduling that not only fulfils operational requirements but also focuses on the needs of employees.

Planning shifts is a major challenge for the middle care management, as it requires them to take into account individual wishes, staffing requirements and compliance with legal, collective bargaining and ergonomic standards. In the "Game of Roster" project (GamOR), a digital collaborative shift planning system was developed for care workers that motivates employees to participate in the shift planning process (Kubek et al., 2020). In the requirements analysis, shift planners complained above all about the amount of time it takes to create shift plans. Those responsible for duty scheduling are regularly confronted with several conflicting objectives when it comes to taking into account legal and economic requirements, ergonomic findings and individual wishes. In addition, economic requirements to plan shifts with only a minimum number of staff and the high sickness rate of employees lead to time-consuming shift plan changes

at short notice (Kubek et al., 2019). Therefore, it is helpful for the shift planner to be provided with all information in a clear and transparent manner. This includes information on where legal requirements or requirements found in scientific sources on healthy working. The plan could then be adapted and the updated result could be showed immediately.

Another added value for the planners is, that with a tool support for rules and wishes, they have concrete data about the care workers which can not only be used to ensure fairness, but also to communicate on a solid basis.

With these use cases and target groups in mind, a technical software demonstrator was developed, which is the subject of the following section.

4 DEMONSTRATOR FOR HEALTH-RESPECTING SHIFT PLANNING

The sheer number of different rules makes it extremely difficult to respect them all as a human planner during shift plan generation. Even though shift plan generation by means of a planning software has become standard (cf. section 1) over the last years, the majority of such tools provide assistance, but hardly any automation to their users (Petrovic, 2019). Given the assisted process of shift plan generation, transparent visualisation of rules and their compliance becomes an important feature of these assisting systems, since otherwise their users have to care about rule compliance, manually check them during the generation process, or check in the end and adapt an already finished shift plan again when compliance problems are found.

Unfortunately, existing tools only provide assistance regarding a small amount of the rules described in section 3. Usually, the rules given by law are mainly covered, the others not. This may be because software in this area rarely profits from developed models and methods (Petrovic, 2019).

With the goal of sensitisation by showing what can be done and how it can be implemented, a technical software demonstrator was developed. This section presents this demonstrator to show how health-related rules beyond laws could be implemented and visualised during the process of shift plan generation. The demonstrator is freely available in the internet (Kutzias et al., 2022).

4.1 Rule Violations and Health Score

When going beyond the law-based rules, it becomes unrealistic to always fulfil all different rules all the time for all care workers. This has been confirmed by the conducted interviews, the literature (cf. section 1) and the analysed data from practice. In such a situation, a measure of quality for evaluation and comparison of different shift plan time intervals can help the responsible persons to keep track of the quality of their shift plans during generation.

Different rules can differ heavily in relevance. Therefore, a simple count of rule violations, which cannot grasp such differences, is not the best measure. In addition, some rules can conflict and also their relevance can be based on individual preferences. Parents, for example, might optimise their time together with their children at the cost of ignoring other health-related aspects. Time with the children can also be a health-relevant factor, which can also heavily affect the well-being of a human (Milkie et al., 2010).

Whereas a total count of (weighted) rule violations is interesting information, the relation of violations and the amount of work might be even more helpful. Even on a per-person level, this might be very important, e. g. for part-time care workers. Based on these considerations, the following requirements for such a measure were derived:

1. Violations should be relative to the amount of work performed.
2. Rules should have a configurable relevance.
3. Individual preferences should be respected.
4. The measure should be intuitively understandable and comparable.

A concrete measure - namely "health score" - is proposed to be able to compare shift plans regarding their health-related quality based on the four requirements mentioned above. The basis is the number of shifts defining the maximum number of quality points which is achievable (Requirement 1). For all occurring violations, the penalty points are summed up respecting possible differences depending on the care worker for which the violations occur (Requirement 2 and Requirement 3). Based on these two values, a ratio is used to calculate a value between 0 and 100 to indicate the quality of the shift plans (Requirement 4). In the following, a more detailed and formal definition of this value, the health score, is given.

Definition 1 (Health Score). Let S be the set of shifts in the corresponding shift plan, C the set of available care workers and V the set of violations with $c_v \in C$ the corresponding care worker for each violation $v \in V$ and $p : V \times C \rightarrow \mathbb{N}_0$ the function assign-

ing the penalty to a violation in combination with a concrete care worker. w is a constant weight for the shifts, which can be fixed for application. Then the health score HS is defined as:

$$HS = \max\left(0, 100 \cdot \frac{|S| \cdot w - \sum_{v \in V} P(v, c_v)}{|S| \cdot w}\right)$$

Since the penalty points are flexible, it is no restriction to fix a constant weight of points per shift. This constant weight value should simply be chosen high enough for the desired possible relation of the different rules (as long as staying with integers) and granularity of the violation point definition. Since the sum of penalties can exceed the number of maximum points, a minimum of 0 is set by using the maximum function, so that the desired interval of $[0, 100]$ is achieved.

4.2 Technical Implementation

To show how health-respecting shift plan generation can look like, a technical demonstrator was developed. It consists of the following main functionalities: a calendar for shift plan generation, care worker management with master data, a configurable rule set for health score calculation, a measurement engine for shift plan evaluation and health score calculation, and a visualisation of rule violations and the health score. This subsection gives a concise description of the demonstrator and its implementation of the previously mentioned aspects.

Web technologies were used to provide an easy Internet access: the server back-end was implemented using Node.js with express as the webserver. On the front-end side, jQuery and jQuery UI were the main frameworks for implementation.

Since it is meant to be a demonstrator, not a software product for sale, some restrictions were made:

- Only a subset of identified rules were implemented.
- Only single source violations were visualised directly in the calendar.
- Due to data protection reasons, fictional data was used for public show cases.
- For simplicity, rule configuration is made on shift plan instead of care worker level.

The health score was implemented with $w = 15$ resulting in a maximum number of 15 times the number of shifts. Due to the rule configuration handling, violation penalties are calculated per rule type.

For the available care workers, master data is respected such as date of birth, hours per week, level

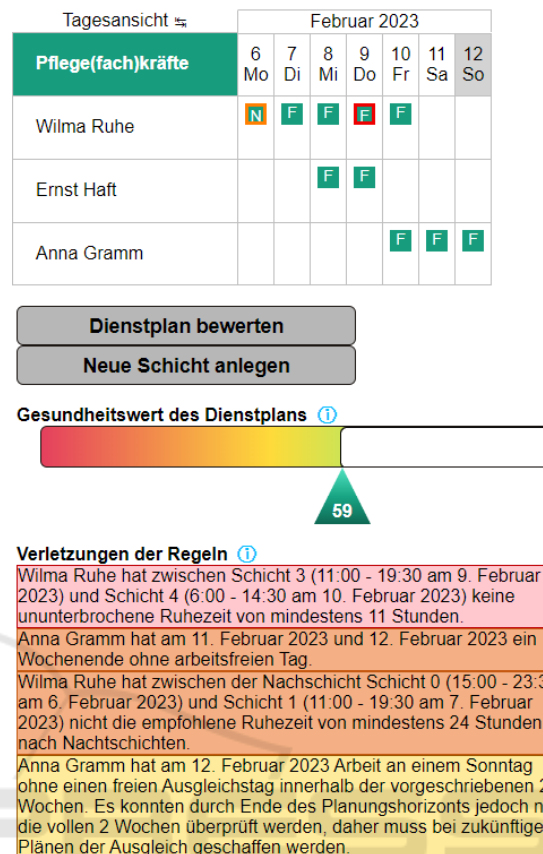


Figure 1: A small sample shift plan in the demonstrator for one week with several rule violations. Red is used for law rule violations, orange is used for official recommendation rule violations and yellow for unofficial rule violations. This sample sums up to a health score of 59, indicated by both, by the number under the bar and the filling of the bar.

of training, several pregnancy-related data, and law-based special permissions for youth work. For performance reasons, rule checking is not done automatically on each and every change in the shift plan, but on button click: the shift plan is sent to the server which calculates rule violations and sends them back. These rule violations are then visualised in the calendar, in a percentage-based filled bar with the health score and a list of all violations given beneath the bar. A sample of the demonstrator with an already checked shift plan with three care workers and a time interval of one week can be seen in Figure 1.

In addition to the online functionalities, a module was implemented for automatic processing of larger data sets for analysing real data. This module is not part of the online demonstrator to avoid contract data processing issues. It was used for analysing data covering several years coming from practice using the same rule set and code as the online demonstrator uses.

4.3 Rules and Violation Visualisation

When rules are implemented in software, questions about the user interface and the presentation arise. Immediate visual feedback is only possible by live evaluation and presentation. In addition, it is advisable to visualise rule violations as close as possible to the shifts and care workers related to the violations, to enable planners to efficiently locate violations and react to it.

To be able to visualise rule violations inside a planning tool with a calendar, different rules were grouped by their relevant time intervals in the following way:

- **Single Source Violations:** Violations caused within a single work shift are the most simple class and can be visualised by highlighting the related shift or day. An example for this can be seen in Figure 2.
- **Multi Source Violations:** Violations caused across several shifts or days can, for example, be visualised by overarching visual elements for consecutive elements such as a coloured overlay bar for a few days or by simply highlighting all single elements, presenting their unity by changing the highlighting of all of them on hovering over one of them.
- **Long Interval Violations:** Violations which are related to days and shifts with large time differences are hard to visualise in a calendar. One possibility, for example, would be by highlighting the care worker or some kind of list next to the planning area.

A concrete delimitation between multi source violations and long interval violations was intentionally not defined, since the meaningfulness of such a definition might depend on the concrete use case and software. It could be meaningful to define it simply by consecutiveness, a number of days between the earliest and the latest (e. g. seven), or count everything exceeding the boundaries of the current month as a long interval violation. The last definition would be meaningful, since many enterprises generate their shift plans in a monthly fashion according to the gathered shift plan data and the conducted interviews. This results in calendar views showing single months in many planning tools.

4.4 Analysis of Historical Shift Plan Data

According to the methodology described in section 2, the demonstrator was used for sensitisation and col-



Figure 2: An example for the visualisation of a single source violation. The leftmost cell represents a single day with a shift without any violations, the second left represents a day with a shift with a single source violation and on the right the same cell is shown with a hovering effect. A block in a cell representing a day with an "F" denotes an early shift that day.

lecting feedback from providers of shift planning software and users from care organisations. Especially, the the care organisations which assisted as providers of shift planning data from practice received a demonstration in conjunction within the last interview-session.

A data set covering several years was evaluated for investigating trends over several years using the example of one care organisation. Four years of shift plan data (September 2018 to October 2022) was received. Data from planned as well as actual shifts from 53 care workers was analysed using the demonstrator. Surprisingly, the differences between planned and actual shifts showed a comparably small amount of differences in rule violations. However, there was a relevant amount of rule violations overall. On the positive side, it was shown that the health score was trending upwards, i. e. the overall amount of rule violations decreased over time, starting with round about 40 going up and staying around 90 over the last two years. On the other hand, several health-related rules had an upwards trend in the amount of related violations as described in the following:

- Required free compensation days for work on Sundays within the following two weeks had an upwards trend in violations ending with roughly 0.36 violations per care worker per month.
- The recommendation that at least one day should be free of work on weekends was often violated with an upwards trend ending at 2.32 violations per care worker per month.
- The recommendation that not more than five days per week should be used for work had an upwards trend in violations ending with 1.53 violations per care worker per month.

When analysing the average rule violations per care worker per month, it was observed that individual care workers had up to a factor of five times as many violations as the average of all care workers. Even though the cause is not confirmed, it may be due to the "yes-person" character of those care workers.

These insights affirmed what has been stated in

the literature several times: the working conditions in the care sector have much room for improvement. The care organisations were surprised by several of the numbers and trends in the feedback discussions, especially about the individual persons with drastic violation peaks.

The analysis of data from practice gave insights about possible reasons for problems of the health sector such as the sickness rate and dissatisfaction of many care workers. These insights in combination with the used techniques (health-related rules, health score, visualisation during shift plan generation) could be utilised by commercial software tools to balance the health related aspects in practice to achieve more fair and healthy work conditions.

5 CONCLUSION AND FUTURE WORK

Shift planning was analysed regarding health-related aspects. In addition to existing law-based rules and official recommendations, further recommendations were derived from interviews with care workers. The majority of different rules is far from being respected in practice and often there are large balancing issues between different care workers, as both, the interviews and the analysis of several years of shift plan data show. To be able to measure shift plans with respect to these health-related rules, a health score was formally defined.

In order to prepare the next step by sensitising and showing how it can be done, a software demonstrator was developed as a publicly available web-tool, which implements many of the discussed rules and shows how they could be utilised by or being integrated into software planning tools. The demonstrator received a lot good feedback during the feedback sessions with the interview partners, showing the need of the planners in practice. Software providers were more reserved, but also interested.

Besides bringing the health-related rules to software planning tools and making the shift planning process more fair and transparent, further interesting research and development steps were considered.

Given the challenge of shift planning with a multitude of different (health-related) rules to consider, a next logical step would be to (partially) automate the process of shift plan generation. Since the general problem of generating optimal shift plans with given restrictions is too hard to reliably compute optimal solutions, at least with the current state-of-the-art (it is an NP-hard problem (Aickelin and Dowsland, 2000)), approximations are the main way to solve the prob-

lem. AI can be utilised to calculate such approximations. For this step to be done, a large amount of historical data is likely to be required. Given the amount of rule violations in practice, current data should not be used in an unlabelled way if the health-related aspect is to be respected, i. e., for given shift plans, a quality measure either as a number or clear category is needed. Such data is hard to acquire, since usually, hardly anyone cares about rating past shift plans. The proposed health score presented in this work is a quality measure which could be used for providing such a rating by automatically processing past shift plans, but it depends on making the decisions about the configurable weights in a generic manner. Further research on this end could help to automate the shift plan generation process.

Additionally, more simple local automation steps could be implemented such as searching for possible local swaps and offering them to the planners, but this limited approach cannot guarantee to provide valid local solutions, if none exists. Nevertheless, using such an approach with comparison of local swaps (for example, using the health score), a suggestion system can be implemented to assist in doing fast adaptations. Such a system would especially be meaningful for required short-term-adaptions, possibly caused by sicknesses of care workers.

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