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SIMULATION-AIDED DESIGN AND EVALUATION OF FLEXIBLE WORKING TIMES

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ABSTRACT

The configuration of appropriate working time models can be a key factor in the success of both companies and employees. While such models can be used to adapt the available workforce to companies' specific requirements, there are also various disadvantages inherent in these models, generally for the employee. Conflicts which may arise usually have an impact on family, hobbies or honorary posts held. However, there are currently no instruments available to assess the impact a working time model may have in terms of employees' work-life-balance prior to the model's introduction. To close this gap, the simulation procedure *OSim-GAM* has been developed. This paper details the methodology for assessing working time models from an operational, financial and employee-related point of view. Furthermore, results of a pilot study are presented which uses this methodology to compare different working time models regarding employees' workloads resulting from an imbalance between professional and private life.

1 OPPORTUNITIES AND RISKS OF FLEXIBLE WORKING TIMES

The issue of flexible working times has become increasingly important in recent years. In 2010, for example, flexible working times played an instrumental role in helping the German economy to return to high rates of growth following the financial crisis. After having fallen in 2009, working time accounts increased by 3.7 hours per employee in the course of 2010; more paid overtime per employee was also worked (IAB 2011). However, "... the possibilities of companies to contribute towards economic growth through flexible working times, … are not yet exhausted" (IAB 2011, authors' translation). It is therefore to be assumed that flexible working times will become more widespread in future.

When designed in an appropriate manner, flexible working time models offer benefits both for the employer and the employee (Knauth 2002, 58 and 63; BMFSFJ 2010, 6). However, there may also be various disadvantages inherent in a model, generally to the disadvantage of the employees (Knauth 2002, 54). Currently, only 21% of Germans think that professional work and family life are well harmonised (IfD 2010, 33). Nevertheless, the conflicts that arise in this respect not only affect the family and friends but can also have an impact on, among other things, hobbies and honorary posts held.

Against this background, the configuration of appropriate working time models is a key factor in the success of both companies and employees (BMFSFJ 2010, 7). For this reason, in February 2011, the German Federal Government, business associations and the German Confederation of Trade Unions DGB launched the "Family-Friendly Working Times" initiative aimed at improving the work-life balance (BMFSFJ 2011). The first step of this initiative was to issue a guideline for the practical implementation of flexible, family-friendly working time models and then to present their actual implementation using numerous examples of good practices (BMFSFJ 2010). However, there is currently still no instrument that is able to assess the impact that working time models will have in terms of employees' work-life balance prior to their actual introduction. The problems that may arise often do not become evident until the pilot stage of the new working time model.

In light of these factors, the *ARBWOL* project (German acronym for "Working time configuration considering the work-life balance with the help of simulation") aims at closing this gap and developing a suitable simulation-aided analysis and configuration tool. The leading research hypothesis states that employees have differing social roles which may lead to typical problems in their work-life balance. Appropriate working time models may help to diminish or even avoid potential problems.

Taking this as a basis, part of the research project examines how conflicts between professional and private life may be minimized by using specific working time models. In addition to the situation in terms of workloads, when selecting a suitable working time model, various different regulations - which are already in place as a result of laws, directives, collective wage agreements or internal company agreements (Knauth 2002, 52) - need to be taken into account. Added to these are ergonomic recommendations on the configuration of working time arrangements.

Against this background, the research project applies a simulation-based approach. With the help of an appropriate simulation tool, various working time models can be compared in a specific application case and assessed in quantitative terms. Varying different influencing parameters such as customer frequency or deployment of staff should allow causal relationships to be revealed and guidelines for the configuration of working time models to be developed considering the work-life balance.

2 MODELING AND SIMULATION-BASED ASSESSMENT OF WORKING TIME MODELS

2.1 Modeling Concept For Production And Service Companies

The tool used to assess working time models is the object-oriented simulation tool *OSim-GAM* (German acronym for "Object Simulator for the Design of Working Time Models"; Bogus 2002, 160) developed at the ifab-Institute of Human and Industrial Engineering of the Karlsruhe Institute of Technology (KIT, formerly University of Karlsruhe). This tool allows for the simulation both of production and service companies and has already been used successfully in numerous simulation studies for configuring working time models (e.g., Zülch, Bogus, and Fischer 2002; Zülch, Stock, and Bogus 2003; Stock and Zülch 2005; Han, Stock, and Zülch 2005; Zülch, Stock, and Hrdina 2007, 2008a, 2008b). However, in order to configure working time models which are able to improve the work-life balance, *OSim-GAM* had to be supplemented by novel concepts for modeling and assessing conflicts between professional and private life. The *OSim-GAM* tool will be presented below and then applied in section 3 to configure the working time arrangements in a canteen kitchen.

OSim-GAM uses netgraphs to model the various work tasks related to different types of customers. They represent the customer orders or services to be provided in the logical interrelationship of the involved activities together with the needed activity times (Bogus 2002, 105). The activities constitute the nodes of the netgraph, while the arcs stand for their interrelationship. To every activity, accordingly qualified employees are to be assigned, or in case of a production system the needed machinery equipment are to be assigned. The arrival of customers in the system is controlled by so-called triggers. These triggers can be used to model either the deterministic arrival of an individual customer at a particular time or the arrival of several customers at pre-defined stochastic inter-arrival times (Bogus 2002, 109).

2.2 Modeling Concept For Working Time Models

In the extended module *OSim-GAM*, Bogus (2002, 55) developed a special modeling concept for working time models. With the help of the configuration elements specified in Table 1, not only can individual working time models be described for a company but working time systems can also be modeled, i.e., the set of all working time models which are applied at the same time within the company. Especially in a service company, a number of different working time models may be used, e.g., flexible working hours for sales employees and a rigid shift system for administrative staff (Bogus 2002, 73). In order to model employees' working times, working time corridors and the breaks therein are to be defined. These are then assigned to the modeled employees in a work roster on a daily basis.

Table 1: Modeling concept for working time models (Bogus 2002, 55; translated)

Content configuration elements	**Formal configuration elements**
Duration (chronometry): • Weekly working time in hours • Minimum possible daily working time in hours • Maximum possible daily working time in hours *Placement (chronology):* • Number of working time corridors, meaning tuples with start and end times as well as possible compensation bonuses • Cycle period in days	• Reference time frame • Implementation time frame in days, meaning the time for which the working time model is valid • Compensation time frame in days, meaning the time in which the contractually agreed upon working time must be performed • Planning time frame in days, meaning the time in which the employment times for each employee of the organizational unit are defined and binding

2.3 Modeling Concept for Social Roles and Time Conflicts

As part of the aforementioned *ARBWOL* project, *OSim-GAM* was expanded by the modeling of social roles and time conflicts so as to represent and to assess the work-life balance of the employees. In order to do this, the social roles must first be modeled. These can be characterized by their name and the time frames during which work cannot or should not be carried out in order to avoid work-life conflicts. A social role is then assigned to each employee. Each potential conflict is represented by the category of conflict as well as the start and end date. The latter are further characterized by the resulting consequences, when a conflict arises, as serious, moderate or minor.

The social roles in *OSim-GAM* therefore serve, on the one hand, as a category of strains and conflicts in terms of specific roles. On the other hand, they can be used to interpret the simulation findings with relation to specific social roles.

2.4 Assessment of Working Time Models

In order to compare different working time models in service companies, a suitable assessment concept incorporating both the company and employee as well as customer-oriented key figures is necessary. This requires a system of key figures that are independent of each other and are also standardized and non-dimensional. For this reason, the assessment concept of goal achievement degrees was used (following Wedemeyer 1989) which has proven favorable for the evaluation of simulation results. A goal achievement degree has a value between 0% and 100%, the former being the pessimistic state of a key figure, the latter the ideal one. Such key figures were already defined for the production sector (Heitz 1994, 97) and the service sector (Bogus 2002, 126). The most important operational key figures are (for details refer to Bogus 2002, 126):

Operational key figures

- The lead time is the time proposed for performing a task. The degree of goal achievement (DGA) lead time degree is the ratio of the minimal possible lead time and the actual lead time. The DGA lead time degree attains 100% if no waiting times occur at all.
- The DGA workload is the ratio of capacity used and the available capacity of a resource. In a service department, in most instances, it is the workload of the employees which is of interest.

- The DGA service degree is the ratio of the number of processed tasks and the number of initiated tasks. The DGA service degree achieves 100%, if all initiated tasks within a defined period are finished.

Financial key figure

- The DGA used capacity costs is the ratio of the used capacity costs of a resource in relation to the period costs of this resource.

Employee-related key figures

- The DGA physical stress generally summarizes the different stress factors which influence one employee during his or her working time. In the model, it is simplified as a function of time for processing tasks, whereas a break does not increase the physical stress. A DGA physical stress of 100% for one employee will be achieved if only one task was started by the employee; it achieves 0% if the employee is loaded the full period in question, e.g., a shift.
- An employee experiences time stress if there is a queue with several tasks waiting to be processed by the employee. The DGA time stress is a function of the number of waiting tasks, therefore it worsens as the number increases. If the DGA time stress reaches 100% for one employee, there was never a queue waiting in front of the employee; if it achieves 0% there was always a queue of tasks waiting.

In order to carry out a comparative assessment of the effects of working time models in a service company, the employee-related key figures are particularly useful. In addition, an assessment with regard to existing time conflicts must also be created. Any overlapping between the planned working time and a private obligation is recorded as a conflict in this regard. The number of conflicts is added together for each conflict class to be defined.

3 SIMULATION STUDY FOR THE VERIFICATION OF *OSim-GAM*

The following application example of the described approach was taken from a knowledge transfer project carried out at the *ifab*-Institute, in order to highlight the concept of simulation-based working time configuration taking social roles into consideration, and to display its potential. The initial situation, procedure and results are set out below.

3.1 Modeling of the Initial Situation

The canteen kitchen considered here prepares three meals a day for some 320 customers at a time. These meals are served in the canteen's dining hall which is only open at fixed meal times:

- Breakfast is offered as a self-service buffet between 07:15 and 09:30 hours during which time the buffet must constantly be refilled. Where necessary, tables have to be cleared and cleaned.
- Lunch is served between 11:45 and 12:45 hours. Each day, there are three menus offering a selection of different dishes and consisting of a starter, main course and dessert; one of the menus is a vegetarian menu. The various dishes are provided at a self-service counter. This too must be refilled and where necessary, the counter must be cleared and cleaned.
- The evening meal is also offered on a self-service basis between 17:30 and 18:45 hours. This consists of a main dish (e.g., salad or pie), which is served together with a selection of cheese and cold meats. The individual plates are prepared accordingly so that a customer may only choose the plate but not the individual dishes separately. Here too, the self-service counter has to be refilled and tables are cleared and cleaned.

The primary aim of the canteen kitchen staff is to provide meals on time and to prepare and regularly refill the food on display so that customers are not forced to wait. As described in section 2.1, these tasks are modeled in the form of netgraphs.

Figure 1 shows the activities which are required in order to prepare and arrange breakfast. Preparing breakfast is made up of a number of different activities, e.g., the preparation and provision of the various different ingredients. The activities involved in the node “Preparation of breakfast” are to be carried out in the kitchen and may, in principle, be performed in parallel provided there is an adequate number of staff available. In the same way, all of the activities which are assigned to the other three nodes, may also be carried out in parallel. At the same time as the activities for the “Preparation of breakfast,” the dining hall must be prepared (node “Preparation of the dining hall”), by setting out cutlery and crockery, for example. Once these steps have been completed, the prepared foods can be taken to the buffet area. Independently of this, the workplaces used in the kitchen must be cleared up. Figure 2 shows how these activities are modeled using *OSim-GAM*.

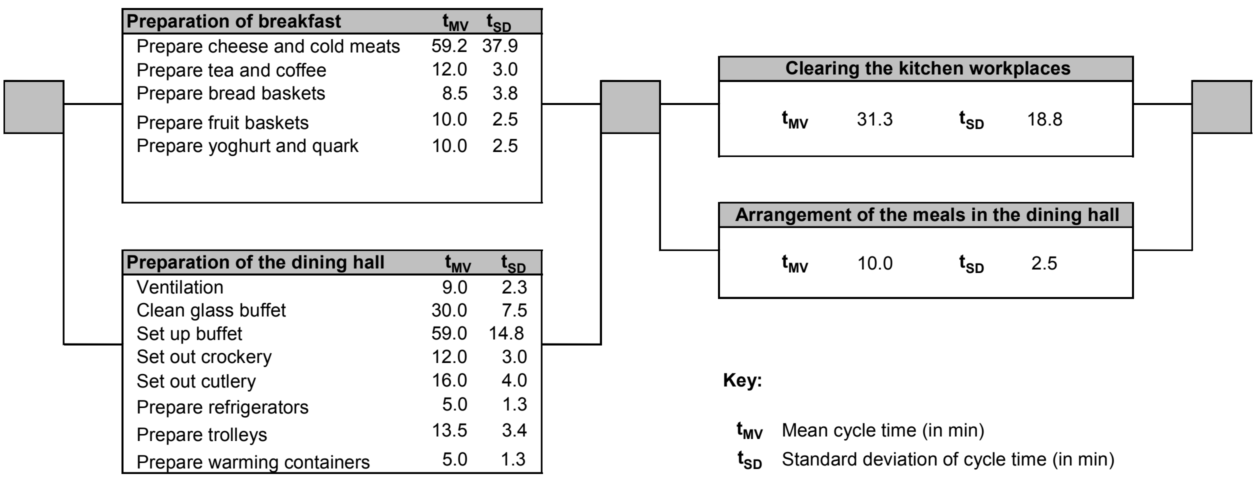

Figure 1: Activities for the preparation and arrangement of breakfast

In addition to preparing meals, there are a number of indirect activities which are not directly associated with customers. For the most part, these are measures relating to the cleaning of the kitchen and the dining hall but also include other activities, such as the ordering and receipt of goods as well as administrative activities (drawing up rosters, instructing staff). These indirect activities are also modeled as netgraphs, although these generally only consist of one activity each.

The netgraphs are started by so-called triggers that represent the instigation of the task in terms of their start. To this end, the start date of the task must be indicated. Multi-level priorities for activities are also modeled in order to ensure that only non-important duties remain uncompleted. The highest priority 1 is accorded here to activities where a client is directly involved. Moreover, some tasks may be cancelled if they have waited for too long. For example, if on one day the floor of the dining hall cannot be mopped, this task is cancelled in the evening as otherwise the floor would be mopped twice on the following day. The "service grade" key figure measures the number of such tasks that are not carried out regularly.

In the kitchen, different types of staff members can be identified. A distinction between these can be drawn on the basis of their qualification level and personnel cost rates:

- The kitchen is managed by two full-time employees (i.e., working a 38.5 hour week) who are responsible for most of the administrative activities.
- Four trained cooks work in the kitchen full-time. Only these persons may prepare warm meals.

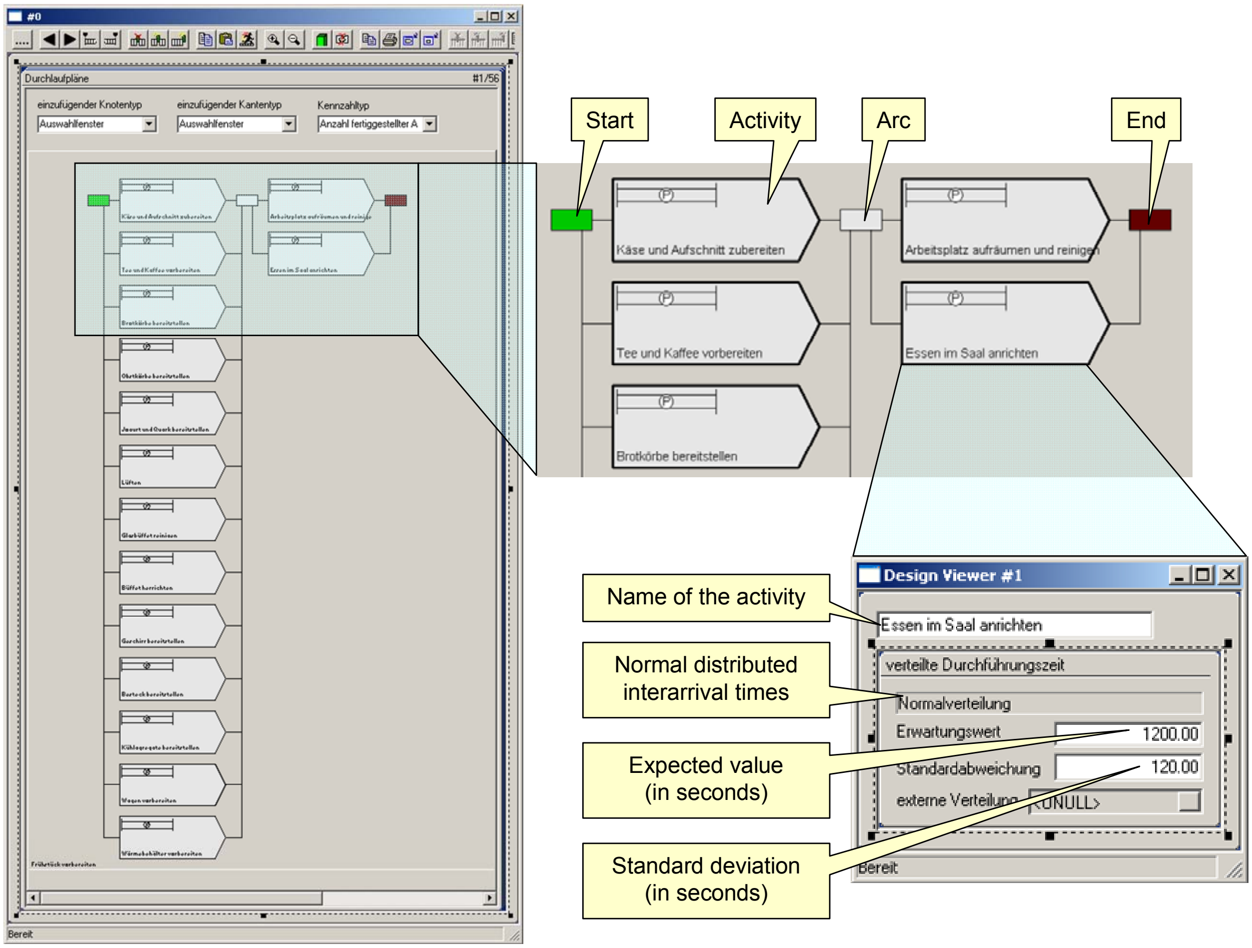

Figure 2: Flow chart for modeling activities for the preparation of breakfast

- The cooks are supported by a total of 16 assistants who help with preparation and perform cleaning tasks in the kitchen. Half of these assistants are employed on a full-time basis and half on a part-time basis, working 21 hours a week.
- A total of 12 employees are responsible for looking after the dining hall. Four are employed on a full-time basis while eight are on part-time jobs (21 hours per week). They are responsible for setting up and supervising the counter and for cleaning the dining hall.

3.2 Social Roles and Distribution of Roles

As part of the *ARBWOL* project, a written survey analyzed the strains of employees in service companies in order to gauge a more precise picture of the individual workloads as perceived by the employees. As the analysis of the survey has not been completed to the current day, the categories for the social roles are not available yet.

An existing concept of roles was therefore taken as the basis for this simulation study. Building on an empirical survey, Lüdtke (2000, 74) used a cluster analysis and thereby identified twelve lifestyles which differ from each other as regards their mentality, the resources that are available and the use of time. Accordingly, there are, for example, "Younger, male, active members of associations, with an interest in sports" (ibid, 80), "Confident persons and persons active in social services, musical, technical and educational terms" (ibid, 76), or even "Passive, isolated persons" (ibid, 81; all translations by the authors). Lüdtke specifies typical activities for each type of lifestyle.

The lifestyles defined by Lüdtke were processed for the simulation study in such a way that, below, only those activities which are restricted in terms of time (e.g., association activities, social activities, meeting friends) are considered. On the other hand, activities without any concrete time reference (e.g., reading, drawing, carrying out car repairs) were not considered further. As a result, the 12 lifestyle types are reduced to a total of 10 types which are characterized by their time-restricted activities. Time conflicts were established for these 10 types as a result of the activities, i.e., these types represent the social roles that make up the simulation model.

Using those types, five different role distribution scenarios were established. Each of the scenarios attributes one of the social roles to each of the 30 members of staff employed in the kitchen and dining hall. For each of the scenarios only the individual assignment of roles to employees was changed. The total number of employees per social role was kept the same. The absolute frequency of these social roles in the simulation model corresponds to the frequency of the social roles observed by Lüdtke (2000, 74).

3.3 Working Time Systems Studied

The aim of the simulation study was to examine whether the conflicts between professional and private lives of the employees can be reduced by configuring working times in a suitable manner. Against this background, twelve different working time systems were defined (Table 2). These differ from one another in terms of the working time model for full-time and part-time employees as well as the number of weekends to be worked during a four week period.

As a working time model, the following 2-shift model can be applied for full-time employees:

- Early shift: 06:15-14:57 hours — with a breakfast break from 09:00-09:30 hours and a lunch break from 12:00-12:30 hours
- Late shift: 10:15-18:57 hours — with a lunch break from 13:00-13:30 hours and a further break between 15:00-15:30 hours

As one alternative, the full-time staff may be employed in a block model, i.e., they work almost 10 hours a day and are given a longer period of time-off between shifts to compensate for this. In this case, there is only one shift:

- Extended shift: 06:15-16:52 hours — with a breakfast break from 09:00-09:30 hours and a lunch break from 12:00-12:30 hours

Part-time employees work a 2-shift model which is different from that worked by full-time employees in terms of the shift times:

- Early shift: 06:15-12:45 hours — with a breakfast break from 09:00-09:30 hours
- Late shift: 12:27-18:57 hours — with a break from 14:30-15:00 hours

Using the shifts available, various rosters can be developed that differ from one another in terms of the number of weekends which must be worked within a four week period. Depending on the roster, either one or two weekends must be worked within a four week period or, alternatively, one whole weekend and two half-weekends must be worked. Since many private activities take place at weekends, based on the social roles, the number of weekends that need to be worked has a considerable effect on the work-life balance of the employees.

Once the working time systems have been modeled in *OSim-GAM*, these are allocated to the individual employees in a roster across the entire simulation period. Figure 3 shows the working times for the working time system in the initial situation.

Table 2: Definition of the various different working time systems

Working time system no.	Full-time employees		Part-time employees	
	Working-time model	**Number of weekends to be worked per 4 week period**	**Working time model**	**Number of weekends to be worked per 4 week period**
1	2 shifts of 8 hours each	1	2 shifts	1 + ½ + ½
2				2
3		1 + ½ + ½	2 shifts	1 + ½ + ½
4				2
5		2	2 shifts	1 + ½ + ½
6				2
7	Block model of 10 hours each	1	2 shifts	1 + ½ + ½
8				2
9		1 + ½ + ½	2 shifts	1 + ½ + ½
10				2
11		2	2 shifts	1 + ½ + ½
12				2

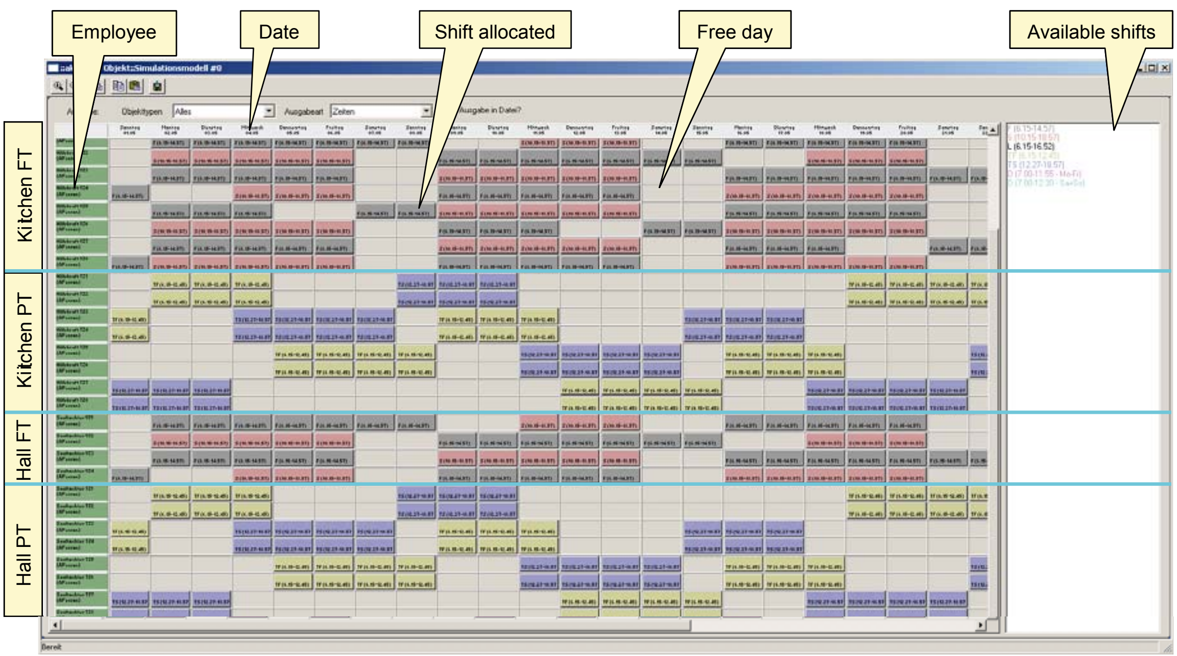

Figure 3: Modeling of working system 1 in *OSim-GAM*

3.4 Test Scenarios and Simulation Results

In order to test this approach, the five role distributions were combined with the 12 different working time systems to form a total of 60 test scenarios. To eliminate stochastic effects, each scenario was simulated 20 times using different random number seeds.

Figure 4 shows a comparison of the results of the working time systems simulated. As can be seen, lead time degrees and time stress seem to be closely correlated. The interpretation for this is that short waiting queues lead to low lead times (i.e., a higher lead time degree) as well as lower time stress (i.e., a higher goal achievement degree for time stress). Since utilization, physical stress, service degree and capacity costs change only slightly, it can be concluded that certain employee-related and operational key figures can indeed be improved without impairing other figures.

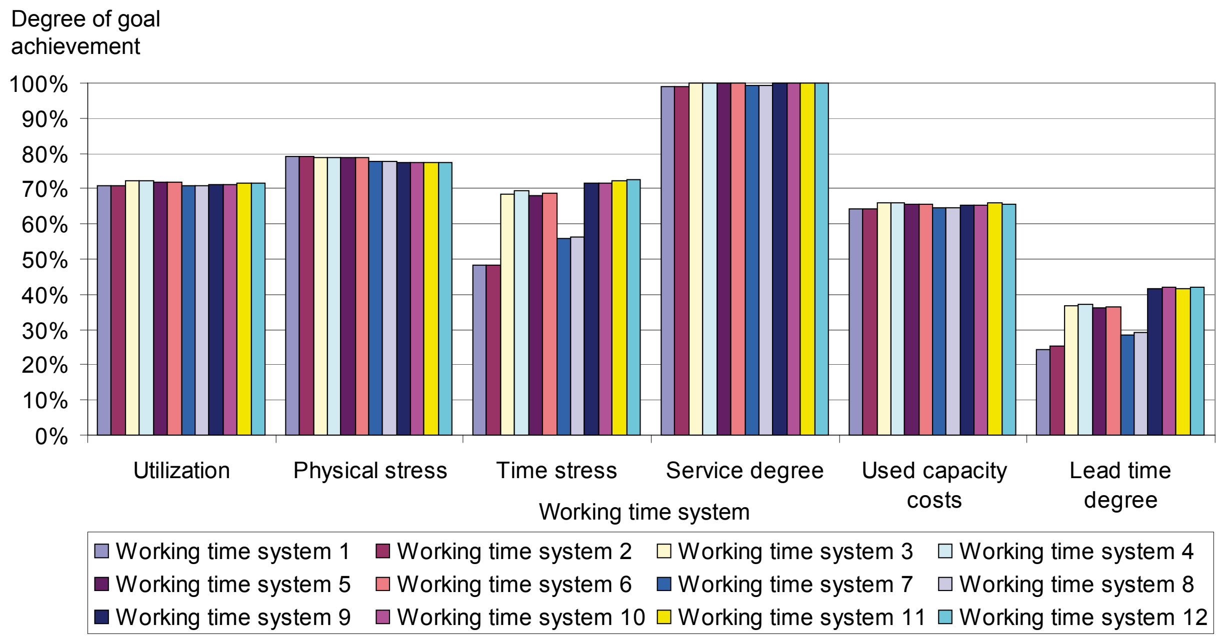

Figure 4: Comparison of working time systems regarding utilization, physical stress, time stress, service degree, used capacity costs and lead time degree

Figure 5 depicts the total number of conflicts arising in the simulated period, ranked by severity, on an ordinal scale and working time system. Only two of the five role distributions that were simulated are shown for illustration purposes. One of the differences between those two role distributions which helps to explain the deviation in the number of conflicts witnessed is that in role distribution 5 the number of roles that have a bigger number of potential conflicts and which have been assigned to full-time employees is higher than in role distribution 4.

Depending on the distribution of roles, it is apparent that different working time systems are suitable for reducing the number of conflicts which may arise. For example, working time system 8 achieves the lowest number of minor, moderate and serious conflicts for role distribution 4 whereas it results in the highest number of serious conflicts and average numbers of minor and moderate conflicts for role distribution 5.

4 SUMMARY AND OUTLOOK

The development of working time systems which improve operational as well as staff-related key figures is a complex matter. Initial studies show that it is clearly possible to improve certain key figures in both areas while not impairing others. However it is not yet possible to combine various financial, time-based and other non-financial key figures such as the number of possible conflicts in a way which enables the use of a heuristic approach for establishing a near-optimal working time system for a given number and distribution of roles among employees.

Besides investigating different preference orders to be used, the next step should be to find and define further stress-based key figures in order to rate the effects of working time models on employees' work-life-balance. An integral step to achieving this goal will be the evaluation of the aforementioned survey conducted at various service companies collaborating in the *ARBWOL* project.

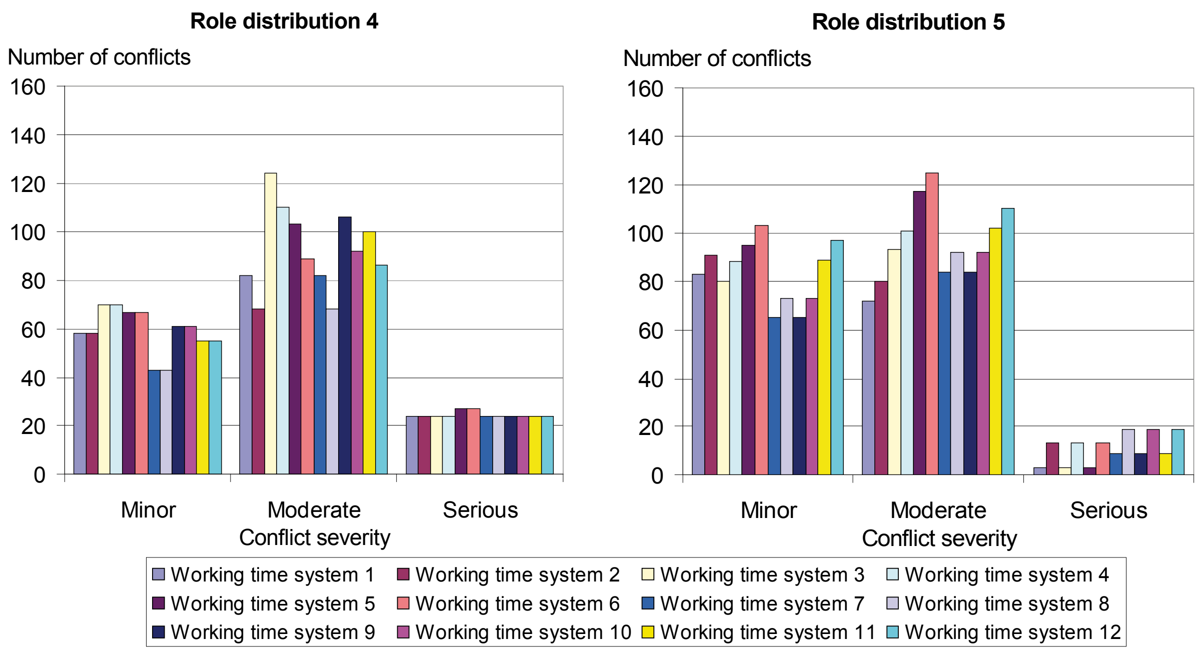

Figure 5: Number of arising conflicts for role distributions 4 and 5 by working time system

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