Analysis of real-world personnel scheduling problems

Patrick De Causmaecker, Peter Demeester, Greet Vanden Berghe, Bart Verbeke

KaHo Sint-Lieven, Information Technology
Gebroeders Desmetstraat 1, 9000 Gent, Belgium
Email :{Patrick.DeCausmaecker, Peter.Demeester, Greet.VandenBerghe, Bart.Verbeke}@kahosl.be
Tel: +3292658610, Fax: +3292256269

Abstract. This paper provides a classification of real-world personnel scheduling problems. Various companies have been examined and their way of scheduling is described according to three independent parameters: time, personnel and duties. From this classification, four different different types of the scheduling problems can be identified: permanence, mobility, fluctuation and project centred planning. We point out that all of the studied cases exhibit additional properties and complexities when compared to similar cases, previously published in literature. Additionally, the companies' current solutions and future demands for scheduling are discussed.

Keywords: Employee Timetabling, Distributed Timetabling Systems, Practical Experiences

1 Introduction

Recently we started a research project to develop prototype software for real-world distributed personnel scheduling [14]. In most of the studied cases, the central problem is to find (rightly qualified) personnel for assistance in a department that is temporarily understaffed, due to e.g. illness or leave of personnel. This kind of planning often leads to time-consuming weekly negotiation meetings. At these meetings, each head of department informs the other heads about the current attendance status of the personnel. This information helps the attendees to decide which department to temporarily award extra personnel. In none of the studied cases, there was an objective measuring instrument available to determine under- or overstaffing of a department.

Every company has its own needs and desires concerning staffing. This diversity on the one hand and the need to be generic on the other hand is most conveniently met by a framework of independent components. The aim is to classify the encountered planning problems and to generate a basic structure in which the different planning systems can be implemented.

A particular focus of the project is distribution. We found that the departmental structure within companies larger than a critical size tends to consist of islands within which fine-grained optimisation is feasible. This isolation can and should not be complete. The departments need to interact in order to avoid the limitations of local optimisation. We will consider an agent model to handle this interaction. The ultimate aim of the project is thus to develop an agent-based framework that can handle distributed personnel scheduling.

In this paper we report on the different personnel planning problems that we encountered within the companies involved. Although the number of companies is not large enough to make quan-

titative statements, we use them as a starting point for the qualitative classification of the personnel scheduling problems.

Section 2 describes the objective of this research and briefly discusses other contributions to classifying personnel scheduling problems. In Section 3, we define a set of independent parameters to describe personnel scheduling problems. We rank the studied companies according to our personnel scheduling classification in Section 4. Starting from this characterisation that is based on real-world problems, we will develop a basic model that can be applied to most situations.

2   Personnel Scheduling Problems

The objective is to classify personnel scheduling problems based on a small but representative sample of Belgian companies. We visited eleven different companies and interviewed them about their experience with personnel scheduling.

The investigated companies are:
- A small local police division (+/- 60 policemen)
- A hospital in a large city (+/- 700 employees)
- The largest Belgian health and safety board (+/- 500 employees)
- The largest Belgian home health care organisation (+/- 1100 employees for each of the five counties)
- A small warehouse for books and post cards (+/- 20 employees)
- One of the largest Belgian employment agencies (with 40000 available temporary employees)
- Two of the largest software consultancy and development organisations (with about 1000 employees each in Belgium)
- Three smaller software consultancy and development companies (number of employees ranging from 20 to 50). All of them deal with numerous problems in labour intensive companies and they are very well aware of various types of personnel scheduling problem.

In order to make the sample more representative, we added fast food restaurants and call centres to the list. Those are interesting because of certain specific short-time constraints. Including these, we consider the variety of studied problems sufficient for the purpose of this research.

Ernst et al. present an elaborate review of applications, methods and models in personnel scheduling in [7]. Ten different personnel scheduling domains are covered in the overview, of which three are considered economically much more relevant than the rest: crew scheduling, call centre scheduling and health care personnel scheduling. Crew scheduling differs from the other personnel scheduling problems in that locations play a significant role in the problem description. All aspects of transportation related problems have been widely examined over the years [3,8] but we have decided not to go into crew scheduling in this research.
Also the call centre sector has been the subject of many research papers. A review by Grossman et al. [9] describes the problems and solutions in call centers for outbond and inbound systems.
The health care sector is also well analysed throughout the literature. Especially nurse rostering in hospitals is a complex problem for which automated decision support is still not common.

Burke et al. describe various aspects of the nurse rostering problem in a recent review paper [4]. They classify models and approaches and formulate challenging directions for future research.

A simplified case on police services, with specified shift sequences, is studied by Taylor and Huxley [12]. It considers service types with 4 days of 10 hours or 5 days of 8 hours each followed by 3 consecutive days off. However, real-world problems often are much more complex (see Section 4.1). Laporte [11] describes constraints concerning rotating schedules, which differ from the constraints that we have identified in the emergency and security services (Section 4.1.1).

Tien and Kamiyama [13] present a common framework with which they classify approaches to manpower scheduling. The framework consists of five stages: temporal manpower requirements, total manpower requirement, recreation blocks, recreation/work schedule and shift schedule. Bradley and Martin [2] on the other hand distinguish three stages in the personnel planning process: staffing (long-term process of determining how many personnel must be employed by the organisation to provide a predetermined level of service), personnel scheduling (the process of converting expected daily work force requirements into precise scheduling assignments) and allocation (actual assignment of scheduled personnel to work sites). The planning horizon for the three stages ranges from years and months (in the case of staffing), over weeks (in the personnel scheduling case) to days and hours (in the allocation phase). The latter phase is the most relevant for this research.

Apart from the literature review papers, the published approaches and solutions are very domain specific [1,6]. In this paper, we aim at a generic framework to support fast development of such applications.

3   Scheduling space and constraints

Most scheduling problems have three independent variables, which we call dimensions: personnel (P), time (T) and the task or duty to be carried out (D). Personnel consist of all employees involved in the scheduling problem. They are divided in groups, according to their capabilities and their assigned tasks. A simple example is a group of employees and a manager. In more complex cases there are many different groups and departments, each having a manager. The time dimension can be subdivided according to the time period to be scheduled. In call centres the smallest time concept, for example, relates to seconds and the scheduling period stretches over a couple of minutes. In case holidays need to be assigned, the smallest time division can range from one hour to one day, while the scheduling period often is one year. The task, or required duty, can range from very specific and non-varying (answering a phone call), to more complicated, (answering a phone call about a special promotion of a mobile operator in English, French or Dutch).

In some cases, such as school timetabling involving different groups of students, classrooms, lecturers and a time division in hours, there is a fourth dimension that we will call the location (L). The groups of students correspond to the duties, the teachers are the personnel and the classrooms are the locations. We refer to [5] for a survey of practical course timetabling. We notice that in case of transportation problems the task and location are quite similar and therefore no fourth dimension is required. Each task is characterised by its starting time and location

and its finishing time and location [14]. In this classification, we will restrict the research to three dimensional cases with P (personnel), T (tasks) and D (duties).

The three independent axes (P, T and D) define a three dimensional solution space. In this space many areas that are defined by constraints, represent infeasible solutions. We distinguish two types of constraints: hard and soft constraints. Hard constraints should not be violated. An example of a hard constraint is that an employee can only answer one telephone call at a time. Soft constraints often are economically less important, but if fulfilled, the staff's satisfaction level will increase. 'Monica prefers not to work before 9 o'clock' is an example of a soft constraint.

More complicated constraints are: after working three consecutive night shifts, a rest period of at least one day is required; no night shift after a free day. Every constraint defines a relation between the three axes P, T and D. Many personnel scheduling problems are over-constrained. Infeasibility is very common but the organisations typically have ways of coping with that. The framework that we develop should provide means to implement these - often implicit - coping rules.

In the next section we will describe all the scheduling problems in terms of (P, T and D) and their mutual relationships ((D,T), (P,T) and (P,D)), as presented in Table 1.

Table 1. Parameters for the classification of personnel scheduling problems

P	Division of personnel into groups
D	Division of different tasks
(D,T)	Duty D has to be executed at time T
(P,T)	Employee P has to work at time T
(P,D)	Employee P has to perform duty D
(P,D,T)	Employee P has to perform duty D at time T (the actual schedule)

In the examples we discuss the dynamics of the axes case by case.

4   Application and classification

We interviewed all the involved companies and organisations. In this paragraph, we briefly discuss and classify the needs we encountered in this small but diverse sample of companies.

We classify the companies according to the personnel scheduling problem. Police services and hospitals face the problem of permanent assistance. The number of personnel needed is defined in advance (except for emergency cases). Their personnel scheduling problem is *permanence centred.* On the other hand, there are companies that need to schedule duties involving transportation. These companies have a *mobility centred* planning. Note that we exclude pure transportation companies. Examples considered in this paper are health and safety board and home

health care. Next to permanence and mobility centred planning, we distinguish personnel planning based on *fluctuating* demand (fluctuation centred planning). Four different examples are discussed: a warehouse or distribution centre, an employment agency, a call centre and a fast food restaurant. Finally, we discuss companies that divide the work into *projects*, to which they assign different groups of employees. They aim is to accomplish different projects with different groups and therefore we call this scheduling problem `project centred planning'. Typical examples are software development and consultancy.

4.1 Permanence centred planning

In permanence centred organisations, a minimum personnel coverage is required at all times. Personnel work in shifts (typically three, but in some cases more).

4.1.1 Security and emergency services

Belgian police is divided in zones. A zone consists of a set of adjoining cities or villages. Every zone has 3 major units: intervention, criminal investigation and traffic control. Only the intervention unit is in continuous (24/24) stand-by. In case of severe problems such as multiple collisions on the motorway, assistance can be obtained from a neighbouring zone. This does not frequently occur.

Scheduling the personnel of the intervention unit is carried out in reference periods of 2 months. In each period every individual is granted 4 weekends free. In a 'book of wishes' individuals can express their weekend preferences. The planner will first attempt to schedule the free weekends. There are also numerous legal constraints on the workload, for example:
- maximum 10 hours per day,
- maximum 50 hours per week,
- on average 38 hours per week,
- at least 11 hours of rest are required between two shifts. Intervention unit staff are therefore scheduled in cycles: on the first day of a cycle, they work an early shift; on the second day a late shift and on the third day a night shift; they rest on the fourth day,
- there are mandatory training sessions like shooting practice, truncheon exercises; individuals are also allowed to take promotion related courses,
- after 10 consecutive working days, minimum two days of rest are required,
- maximum 55 night shifts per year; maximum 10 nights per reference period (2 months).

Difficulties arise when an individual reports sick. Adaptive scheduling, which tends to consume a lot of effort, is then required. In order to guarantee permanency, some of the statutory rules sometimes need to be broken. As a consequence, most individuals work more than they are supposed to and this brings along that the police staff has to be indulgent when people ask for a leave (give and take).

Currently, the planning is still carried out manually on a large sheet of paper. The most important goal is to minimise labour costs by reducing overtime, as is presented in the analysis (see Table 2).

Table 2. Parameters for personnel scheduling in security and emergency services

P	Civilians (mainly office workers), inspectors, head inspectors, police commissioners, zone chief
D	Reception, intervention, criminal investigation, traffic control and office work
(D,T)	Intervention is permanent, other tasks are mostly carried out during day time
(P,T)	The department intervention works in different shifts, other departments generally only during day time. There are many legal constraints.
(P,D)	Civilians only do reception, inspectors and head inspectors can carry out most tasks, commissioners and zone chief have specialised duties.

4.1.2   Hospitals

In general, hospitals assign nurses to different departments at an organisational level. The number of nurses that is assigned to each department is based on the workload. Hospitals also deal with a need for permanency. As in the police case, a lot of statutory regulations need to be met. For example:
- maximum 10 hours work per day,
- maximum 9 hours for night shifts,
- minimum 36 hours rest per week,
- minimum 11 hours rest per day (with 2 exceptions per week on which 8 hours and 10 hours are sufficient),
- if working time exceeds 5.5 hours, a rest period is required: half an hour or 15 minutes twice,
- maximum 5 consecutive night shifts,
- maximum 35 night shifts per 13 weeks,
- the average over 4 weeks should be at most 50 hours per week,
- the average over 13 weeks should be at most 45 hours per week.

Each department has to be staffed at all times by a head nurse and a number of regular nurses. In case there is no head nurse available, a nurse with relevant experience can replace the head nurse. Apart from the legal regulations, there are different types of leave (extra holidays for nurses older than 45, compensation for overtime, (un)paid vacation for exceptional occasions, social service leave, maternity leave, paternity leave,...).

In order to handle absence of personnel, the studied hospital uses a 'mobile team' that supports the departments that are understaffed. At weekly meetings the staff determines which department gets an extra nurse. The particular hospital that we studied ran an experiment to determine the workload of every department in an objective manner, in order to discover the understaffed departments. Due to the resulting mass of paperwork, the experiment failed.

The hospital uses an Excel spreadsheet to roster individual nurses. The sheets are huge (about 12 MB for one month and one deparment), and awkward to handle. The primary purpose of these sheets is to organise holidays: a printed version of the sheet is put on a bulletin board that nurses can consult if they want a day off. The main goal of the personnel rostering is to minimise labour costs by reducing overtime.

Table 3. Parameters for personnel scheduling in hospitals

P	A number of nurses is required in each department: junior nurses, nurses and head nurses
D	Nursing concerns very diverse tasks (bathing, medical care,…) but details are not required in the schedules.
(D,T)	There is a permanent work schedule. The number of nurses needed is captured in weekly (or longer) periodical schemes, which are divided in different shifts.
(P,T)	There are many legal constraints on working time
(P,D)	Based on experience, qualification and individual agreements, some nurses can replace a head nurse.

Notice that since the specific tasks are not to be scheduled (see D in Table 3), the problem is rather two- than three-dimensional.

4.1.3 Common characteristics
In general, permanency is guaranteed by cyclical schedules, but the cycles are very often disrupted due to absence of personnel. Shift moves are thus unavoidable.

4.2 Mobility centred planning

When mobility is involved, the main focus of personnel scheduling is on reorganising employees' assignments during daytime. Delays cannot be avoided and they regularly occur. Consequently, assignments depend on the progression of work and transport. This is particularly valid in pure transport cases. In the health and safety board case the coach that is used to examine people on-site, must be booked by one of the local divisions. In the case of the home health care, the mobile nurses can independently plan their route provided that they visit all the patients.

4.2.1 Health and safety board
Health and safety organisations deal with medical examination, prevention and protection on the work floor. Their clients are companies (without a medical board) for which they perform medical inspections in-house. Other subjects handled by these boards are violence, stress, safety,... investigations.

The sample organisation has approximately 500 employees (doctors, nurses, engineers, computer scientists,...) divided in nine local departments, which serve about 40.000 companies. Companies are visited a few days per year. In large companies, the health and safety organisation has a permanent office. There are eight coaches available, equipped with medical instruments. Each company has special demands like available days and hours for examination, whether they want the same team as the previous year or not, local facilities for examination, average time needed for an examination,... All employees have to be examined and this is not always easy to organise. The schedule changes regularly because of unforeseen delays or accelerations. Different departments of the health and safety board support each other when there is

local overpressure. In this case as well, there is need for an objective, agreed upon, measurement of the workload.

The visited health and safety board currently uses a Java application for personnel scheduling. There is no automated decision support involved. The goal is to facilitate the work of the planners, since at present approximately 10% of the people are involved in drawing up the personnel schedule. Table 4 presents the classification of the health and safety board sector.

Table 4. Parameters for personnel scheduling in health and safety board

P	Doctors, nurses, engineers, computer scientists
D	Examinations, driving from A to B, reporting
(D,T)	Continuous rescheduling of duties
(P,T)	Normal day schedule for everybody, with holidays
(P,D)	Continuous rescheduling and reassignment of duties

4.2.2 Home health care

Home health care organisations employ nurses who visit the patients at home. Most patients are visited on a regular basis, ranging from three times a day to once a week. The central office assigns the nurses to a department and to a district. A district can be a number of streets or a small village. There are two nurses for each district and for every three adjoining districts, an extra nurse is assigned. This extra nurse can replace one of the six regular nurses in case of leave, illness…

Most nurses work four hours in the morning and four hours in the afternoon; other nurses work from 6 pm till 10 pm on weekdays, and in the weekends during the morning and the evening. The maximum allowed work time is nine hours per day and 50 hours per week. The central office has a team to guarantee permanency at noon (when the regular nurses have a lunch break), in the evening and at night. The pool consists of seven people, two which always have to be stand-by. There is a mobile team and a pool of temporary nurses to assist departments in case of understaffing. Neighbouring departments can step in after a phone call. Notice that nurses and patients get attached to each other, implying that changes are in general not appreciated. The schedule is generated by the central office. According to the contract, each nurse gets a standard schedule that is repeated every two weeks.

The schedule is manually constructed with an Excel spreadsheet, but the organisation recently started to automate the process. The goal is to reduce overtime and thus minimise labour costs, as is presented in Table 5.

4.2.3 Common characteristics

The studied organisations are arranged in local departments that are reluctant to exchange personnel. Although we classified these two organisations as mobility centred, we experienced, to our surprise, that mobility was not a major issue. In the the home health care organisation, the nurses are allowed to define their own route.

Table 5. Parameters for personnel scheduling in home health care

P	Nurses, assistant nurses, dieticians and office workers
D	Nursing, helping to get dressed,...
(D,T)	Most tasks are a periodic, but there can be emergencies
(P,T)	Many different work schedules, many people work half-time
(P,D)	Nurses are allowed to carry out most tasks, assistant nurses have more restricted duties (washing and clothing people)

4.3 Fluctuation centred planning

The required number of personnel and/or the assignment of tasks depends on a continuously changing demand. Most companies with fluctuating demands, maintain a history record for demand forecasting.

4.3.1 Distribution/Warehouse

Individuals working in warehouses are qualified for a variety of tasks. Some warehouses organise job rotation: each individual has another task every month (for which he/she is qualified) in order to maintain skills. The most common tasks are: handling incoming goods, putting them at a location, picking up goods, and preparing for shipment. In order to guarantee a flexible assignment of tasks, at least three qualified people are required for each task. For some important tasks, there are only three of these people available, which can hamper the scheduling. Certain posts in the warehouse need to be permanently manned during working hours in order to guarantee a sound operation. The amount of work in the warehouse depends heavily on fluctuating demand. By experience, the planner can predict more or less which periods of the year will be busy. When the workload is too high, temporary employees are hired. About one week of training is required before new people can start on the job. Therefore, the planner needs to decide in advance when to hire temporary employees.

The visited company sets the personnel schedule up manually. It makes use of a 'polyvalency' table that keeps track of each employee's capabilities and experience. The goal of scheduling is to reduce overtime and the number of temporary workers (see Table 6 for a classification).

Table 6. Parameters for personnel scheduling in warehouses

P	Staff is extended with temporary employees who need training in advance
D	Goods coming in, classification, taking orders, picking, goods going out, administration,...
(D,T)	Incoming goods and incoming orders determine the (re)organisation of tasks. Some duties are always required, others are less urgent
(P,T)	The required number of employees is derived from previous information about the same time of the year.
(P,D)	Some people can carry out many tasks, others are restricted to certain activities.

4.3.2 Employment agency

Employment agencies try to find jobs for people and to find qualified people for jobs. The visited agency consists of about 80 national offices. These have about 40.000 temporary workers available, of which, 10.000 are employed every day.

Companies offering jobs have selection criteria for the workers. This means that the agency has to keep many parameters for each person. Examples are experience, seniority, transport facilities, physical condition, driving license, availability,...

Jobs frequently require training in advance. Most companies that recruit work forces from the agency, prefer to hire temporary workers who have worked for them before. Some companies only want to work with a pool of people, specifically trained on the spot.

Each office tries to supply the local demand. When a local office is in need of more workers, it contacts the neighbouring offices.

There is a need for a well-structured database with distributed facilities and planning tools to optimise the delivery of work forces.

At the visited agency, the local offices work independently. The goal is to maximise the client satisfaction (see Table 7 for a classification).

Table 7. Parameters for personnel scheduling in employment agencies

P	Temporary workers that can be summoned
D	Delivery of temporary workers
(D,T)	Demand for short or long periods and known a short or long time in advance
(P,T)	Available hours/days are different for each person
(P,D)	Workers have personal demands and qualifications

4.3.3 Fast food

The scheduling problem of fast food centres is in the name: when a customer orders a meal, delivery is expected within a very short time interval. Depending on the time and the day of the week, there is a different number of customers and a different demand. Fast food centres maintain history records on an hourly basis. This allows them to calculate the average demand at each moment and to start preparing meals in advance. The tasks are almost scheduled per minute (e.g. prepare 20 hamburgers by 11h53), according to the predicted patterns. Personnel demand is based upon this pattern.

The fast food companies have developed their own software programs for personnel scheduling. The goal is to serve food as quickly as possible (maximising customer's satisfaction) with a minimum number of personnel. The characteristics are listed in Table 8.

4.3.4 Call centres

Call centres are hyperactive organisations where lots of phone calls have to be answered (e.g. mobile phone operators, power companies,…). Before a call reaches a human operator, an automatic operator asks questions concerning the preferred language, the topic of the call,... According to these data, the phone call is diverted to a human operator, who is able to answer it

in the appropriate language. Each employee has a computer screen that shows how many phone calls are in the operator's queue. Some call centres strive to answer every phone call within 3 minutes. All incoming calls are more or less equally divided among the employees and are rescheduled according to the time it takes to answer a call. Some calls are labelled more urgent since they come from privileged or impatient clients: there is an unwritten rule that impatient clients need to be helped as soon as possible.

Table 8. Characteristics for personnel scheduling in fast food restaurants

P	Employees and local manager
D	Cleaning, cooking, serving
(D,T)	Varying, with local peaks
(P,T)	The number of people employed depends on the history of similar days and hours. This changes at every possible time step (e.g. half an hour) using different regimes and working schedules for everybody
(P,D)	Most people can perform all the tasks

Important call centres have programs that deal with the problem described above. The goal is to answer all the phone calls in time and to minimise the labour costs since call centres are not profitable (see Table 9).

Table 9. Characteristics for personnel scheduling in call centres

P	Operators and local manager
D	The task is to answer incoming phone calls. Each phone call is distributed according to language, topic, ...
(D,T)	The number of phone calls is changing all the time. Each phone call should be answered within 3 minutes
(P,T)	The number of people employed depends on the history of similar days and hours. It changes at every possible time interval (e.g. half an hour) using many different regimes and working schedules
(P,D)	Each employee speaks specific languages and knows specific topics

4.3.5 Common characteristics
A general feature of these problems is the importance of accurate forecasting.

4.4 Project centred planning

A project can have different groups of employees assigned to it. Each group can work on different projects at a time. According to the demand, the groups and assigned projects are rescheduled.

4.4.1 Consulting and software development companies

In many consulting and software engineering companies, the activities are organised in projects. The consulting company makes a proposal and if it gets accepted, the contract has to be executed in a certain time window. The execution is normally carried out in a team consisting of a project leader and some programmers. After visiting the client and interpreting the problem, the development cycle (analysis, design, implementation,…) starts. A provisional version of the software is demonstrated to the customer. The appearance of extra information, the participation of clients who did not attend the initial meetings, etc. may cause delays and pressure on other projects (e.g. by transferring people from other projects). In one of the software development companies studied, each project team contributes to 3 projects: a project that is in its starting phase, one in its final state and another one that is fully running. If one of these projects is running out of time, it involves rescheduling the other 2 projects.

Currently, the planning is a manual process on a white board. The goal of this type of personnel scheduling problem is to improve the project management (see Table 10 for a classification.)

Table 10. Characteristics for personnel scheduling in consultancy companies

D	Consult, build (develop) and run (support) for different clients
P	In small groups, each group has clients to work for. A development group consist of a project leader and programmers
(D,T)	For each client: consult, build and run in respective order
(P,T)	No shifts, work by day (9-5)
(P,D)	Specific qualifications for all the team members

4.4.2 Common characteristics

Project centred planning looks quite similar to fluctuation centred planning, but we opted to make a distinction since the projects are executed in teams. Forecasting could be helpful but it seems very difficult to realise because every project has its own needs (and a different grouping of personnel).

5 Conclusions

An overview of the studied personnel planning for the end users is presented in Table 11. The personnel scheduling in all the studied organisations and companies happens to be still a manual process. Some use software tools (e.g. Excel in the hospital), however, none of the packages support automatic planning. They are just a more or less elegant way to present the roster to the employees. In some cases these tools are only used as a holiday organiser: employees can first check the roster to find out if a leave is appropriate. The documents used in the hospital are so huge that they are impractical: they contain so many rules and data that the limits of Excel's capabilities are reached.

In most organisations, much effort and time is spent on creating personnel rosters. Even more time is spent when the roster has to be changed due to illness or holidays. We have anecdotal evidence from hospitals and police divisions for this statement. In the case of the health and safety board, the personnel scheduling involves almost 10% of the organisation's personnel.

Another striking point is that people expect the manual planner to know everything: how the company is organised, how certain tasks are executed, the capabilities of each employee, the interrelationships between the employees, the contracts of each employee,... Thus, the general responsibility puts considerable pressure on the planner.

When comparing the goals of every organisation, we detect some commonalities. One of the largest costs in Belgian production is the labour cost. Most organisations therefore want to minimise the labour costs by reducing overtime or by reducing the number of temporary workers.

Some of the visited software companies pretend to sell personnel planning software. But, when asked if they schedule their own personnel automatically the answer was negative. However, many commercial tools exist and obviously some companies use them. Still, it was very difficult to obtain demonstrations and the few that we have seen were not fit for flexibly solving different problems.

Although distribution was a particular focus of the study, it was difficult to detect in the visited organisations. Exchange of personnel requires mutual empathy, which is not always obvious. There is lack of objective measures to determine work (over)load in the departments. Another reason is probably that distribution is not easy to organise in the case of manual scheduling. Consequently, the planners are not aware of the possibilities that distribution of personnel can offer.

During the visits, we identified the following important parameters for the personnel planning problem:
- the number of available employees,
- the amount of overtime,
- fixed or fluctuating demands,
- the work contracts (full time, part time,...),
- the robustness of the planning,
- the possibility of employees to mutually swap tasks,
- the flexibility of the schedule.

In order to determine the criteria and quality measures of a good schedule, the following parameters can be helpful: the quality of the schedule for the individuals, the quality of the schedule for the organisation, the difference between schedule and execution, the incorporation of personnel preferences, the impact of a change, the cost of executing a schedule,...

From a company policy's point of view, it is interesting to know how many people are required to satisfy certain needs, how long in advance a schedule can be fixed and if the customers are satisfied. There was a recurring request for a simulation tool in nearly every visited organisation. It should allow to experiment with the number of required personnel and with holiday periods.

We conclude with one last remark. In general there is no wish for a fully automated planning. Instead, support will be strongly appreciated. Most planners prefer evaluation tools that indicate possibilities and that warn for mistakes such as double bookings. Furthermore, people always prefer to be able to make schedules that ignore certain predefined constraints.

References

[1] U. Aickelin, K. Dowsland: Exploiting problem structure in a genetic algorithm approach to a nurse rostering problem, Journal of Scheduling, Vol. 3, No. 3, (2000), 139-153

[2] D.J. Bradley, J.B. Martin: Continuous personnel scheduling algorithms: a literature review, Journal of the Society for Health Systems, Vol. 2, No.2, (1990), 8-23

[3] H.-J. Bürckert, K. Fischer, G. Vierke: Transportation scheduling with holonic MAS - the TeleTruck approach, Proceedings of the Third International Conference on Practical Applications of Intelligent Agents and Multiagents (PAAM'98), (1998), 577-590

[4] E.K. Burke, P. De Causmaecker, G. Vanden Berghe, H. Van Landeghem: The State of the Art of Nurse Rostering, to appear in Journal of Scheduling, (2004)

[5] M.W. Carter, G. Laporte: Recent Developments in Practical Course Timetabling. In: E. Burke, M. Carter (Eds.): Practice and Theory of Automated Timetabling II, LNCS 1408, (1998), 3-19

[6] P. Cowling, G. Kendall, E. Soubeiga: A Hyperheuristic Approach to Scheduling a Sales Summit, In E. Burke and W. Erben (Eds.), Selected Papers of the Third International Conference on the Practice And Theory of Automated Timetabling PATAT2000, LNCS 2079, (2001), 176–190

[7] A.T. Ernst, H. Jiang, M. Krishnamoorthy, D. Sier: Staff scheduling and rostering: A review of applications, methods and models, European Journal of Operational Research 153 (2004), 3-27

[8] M. Gamache, F. Soumis: A method for optimally solving the rostering problem. In: G. Yu (Ed.): OR in the Airline Indystry, Kluwer (1998), 124-157

[9] T. Grossman, D. Samuelson, S. Oh, T. Rohleder: Call centres, In: S. I. Gass and C. M. Harris (Eds.): Encyclopedia of Operations Research and Management Science, 2nd Edition (2001), 73-76

[10] J. Hueter, W. Swart: An integrated labor-management system for taco bell, Interfaces, 28(1) (1998), 75–91

[11] G. Laporte: The art and science of designing rotating schedules, Journal of the Operational Research Society 50 (1999), 1011-1017

[12] P. Taylor, S. Huxley: A break from tradition for the San Francisco police: Patrol officer scheduling using an optimization-based decision support system, Interfaces 19 (1) (1989), 4–24

[13] J.M. Tien, A. Kamiyama: On Manpower Scheduling Algorithms, SIAM Review, Vol. 24, No. 3, (1982), 257-287

[14] http://ingenieur.kahosl.be/projecten/DINGO/

Table 11. Schematic overview of personnel scheduling problems in companies and organisations

Type of personnel planning	Dimensions of the problem	Hard con-straints	Distributed?	Extra	Minimise/ maximise?
Police	Agents (+qualifications), shifts	Minimum coverage + qualifica-tion	Different divisions (intervention alternated with criminal investiga-tion,…)	Very rigid legal regulations (in theory)	Minimise overtime
Ware-house	Employees (+qualifications)	Minimum coverage + qualifica-tion	Individuals (personnel can carry out different tasks)		Minimise overtime and tempo-rary em-ployees
Hospital	Nurses (+qualifications), shifts	Minimum occupa-tion + coverage of nurses	Mobile teams (departments)	Very rigid legal regulations (in theory)	Minimise labour cost
Employ-ment agency	Temporary em-ployees (+qualifications)	Availabil-ity of the temporary employ-ees + qualifica-tion	Different pools of em-ployees from which to choose	Large database	Maximise customer satisfaction
Health and safety board	Personnel (+qualifications)	qualifica-tion + minimum coverage	Occupation of the coach (teams are not fixed) + in space	Satisfy the wishes of the customers to the highest possible extent + taking legal constraints into account	Reduce the work of human planners
Home health care	Nurses (+qualifications), shifts	qualifica-tion + coverage	Teams of nurses		Minimise labour cost