Design and Usage of an IT-System for workplace management with ergonomic analysis under health protection aspects

Clemens Dubian

Volkswagenwerk Kassel
Health Care / Human Resources
clemens.dubian@volkswagen.de

Wolfgang May

Institute for Computer Science
Göttingen University
may@informatik.uni-goettingen.de

Abstract: This article describes an information system for analysis and description of workplaces under the aspects of health protection and ergonomic risks, which is currently being developed at Volkswagenwerk Kassel. The system provides an instrument for matching ergonomic risks of workplaces with work limitations of employees for an efficient assignment of employees to appropriate workplaces. It integrates data from several existing systems and collects additional data. The collection and maintenance of data is accomplished by an analysis team and by the team leaders in the factory.

Besides the functional aspects, the following two issues have been solved: minimizing the effort for the collection and maintenance of data by using a hierarchical categorization of the objects of interest and their properties. Secondly, for accomplishing the acceptance and direct benefit for the following user groups (health care, human resource management, and most of all, local supervisors), group-specific graphical user interfaces are provided.

1 Introduction

There are legal requirements that bind industrial businesses to document all work-specific hazards (German: Belastungen/Gefährdungen) including ergonomic risks. To accomplish activities for workplace design and for the identification of appropriate workplaces for employees with work limitations, it is necessary to get an overview of the ergonomic risks situation. Additionally, against the background of demographic change, the appropriate design of workplaces for older employees gets more and more important.

The project for developing an IT system to collect work-specific hazards is led by the departments for health care and human resource management with support from the work council. Besides the improvement of employee assignments, the system collects all other existing information of workplaces that is somehow associated with health care. Additionally, it is the pronounced aim of health care to use the system to get information about coincidences between working conditions and diseases.

This article is structured as follows: Chapter 2 explicates the notions of the application domain and describes the modeling. Chapter 3 describes relevant functionality and presents some GUIs. Chapter 4 concludes the paper with a short discussion including status and acceptance, transferability of the approach, and perspectives.

2 Application Domain and Modeling

2.1 Concepts of the Application Domain

The developed system combines information about different views on the company, especially its product division. The structural classification of the plant into *organizational units* is essential for user guidance and responsibilities:

In the Volkswagenwerk Kassel, the classification begins on the plant management level and leads over divisions to local teams. All workplaces in the production are grouped into teams, each of them led by foremen (more concretely, one foreman per shift; such a team is usually called "Meisterschaft"). This structure is not specific to the given use case, but is a common structure of large industrial plants. In this presentation we restrict ourselves to the production area; workplaces in e.g. logistics, administration and health care can be handled in a similar way.

Thus, large parts of the modeling are concerned with aspects of the production area. Volkswagen Kassel employs about 14,000 people at about 7,000 workplaces which include about 20,000 machines to analyze. Information is not captured and stored separately for each item, but managed in categories at different levels of abstraction. Conceptually this is modeled by *multiple inheritance* at different *dimensions*. The main dimensions are (i) the equipment ontology of machines, and (ii) the structuring of the actual working processes. To adequately formalize these coherences, the abstract concept of *categories* describes an "entity to analyze". Categories inherit from other categories and add own properties. Categories represent machine classes (e.g. milling machines), machine types (e.g. Gleason Pfauter GP90 as a special type of milling machines), tasks or any other (abstract) concept related to the workflows.

From the working process structure aspect, the focus of analyzed workplaces differentiates between tasks of one job; large assembly lines are partitioned in (abstract) components. A *workplace* includes all machines and tasks handled by one employee. The assignment of machines to workplaces is weighted by percentages, so that one machine can be assigned to several workplaces.

The ergonomic risks analysis combines both views. The basic analysis objects are concrete objects such as machines, and categories. The ergonomic risks of each workplace are then derived from its composition. Besides the analysis of machines or categories, there are hazards caused by the work location such as noise or temperature, or exposure to hazardous substances.

Furthermore workplaces themselves are aggregated to workplace packages. Thus, a group of workplaces together performing a larger working process can be associated to a group of employees who organize who is assigned to which workplace, optionally including job-rotation. Each workplace and each workplace package is associated to exactly one operating team. Therefore the view of a team's foreman is one of the main views of the workplace management system. It is used by the foremen to maintain the information about the structure and the actual assignments in their area. The functionality and the GUI are described in more detail in Section 3.

In the description above, the abstract concept of "workplace" has been used for modeling the production environment. For modeling the actual production workflows, workplaces are associated to employees. For that, one function of the workplace management system is the structural association of employees to workplaces in terms of planning and scheduling. Based on that, the actual occupation of workplaces within a shift is maintained.

For the assignment of employees to workplaces, *work limitations* of employees must be taken into account: upon medical checks, the health care department states work limitations for employees, like "no heavy lifting". German legislation requires a certain system of *preventive medical checkups* under specific circumstances; this is also organized via the system.

2.2 Existing Information Infrastructure

The workplace management system integrates different views and data, which are partially stored in other already existing information systems that are maintained autonomously. In the following the connections from the workplace management system to other information systems are described (see Figure 1). The current system is a prototype; therefore the described connections contain manual data transfer.

Structural data contains the organizational structure of Volkswagen. Organizational units are used for defining access policies. The structural data is maintained in the SAP system by the human resource management. Personnel base data is also maintained by the human resource management within the SAP system. Current data about employees who are present on the factory site (electronical check) can be obtained from the *Access Authority System* (ZUBESY), a plant security system. The actual realization of this connection is subject to privacy protection issues.

The *Hall Layout System* (HLS) contains layouts of every hall, including the positioning of the individual machines. The workplace management system uses the layouts to structure and associate workgroups, workplaces, machines and employees via a graphical user interface.

The *central file for operating equipment and machines* (ZBM) contains and maintains all data on machines and operating equipment including inventory number, its assignment to organizational units and the positioning with respect to the coordinates in the HLS.

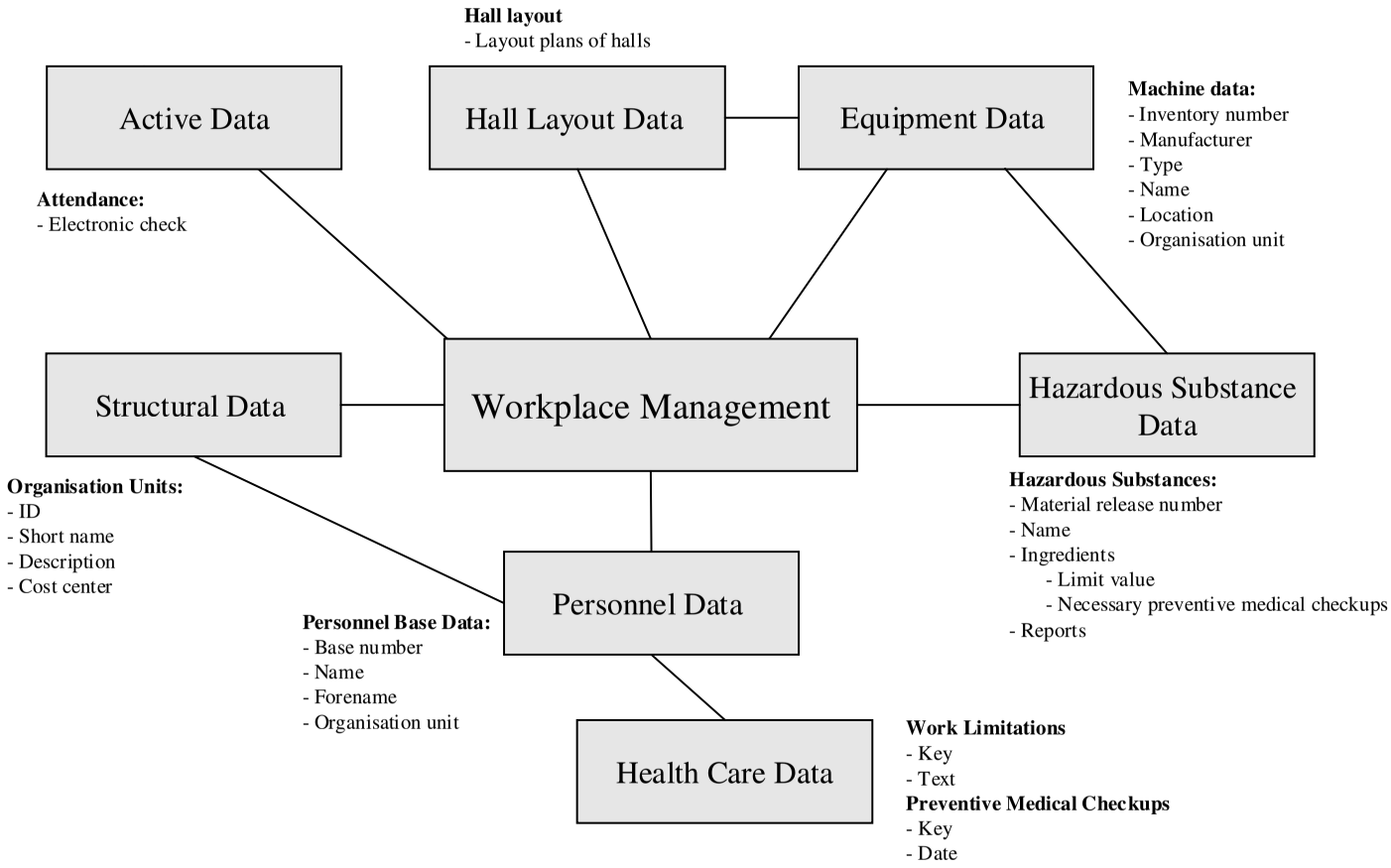


Figure 1: Connections of the workplace management system

The division for chemical safety maintains the *hazardous substances database* (APM). Hazardous substances are associated to workplaces within workplace analysis and through hazardous substance measurements.

Medical data, which is important for human resource management and team leaders, is transferred from the *Occupational Medicine Administrative System* (AMVW) of the health care division to the SAP system. The workplace management system gets the combined data through a protected interface from the SAP system.

2.3 The Conceptual Model

The conceptual model of the application area is shown in Figure 2, where concepts are grouped into individual-related information, workplace structure and working environment characteristics.

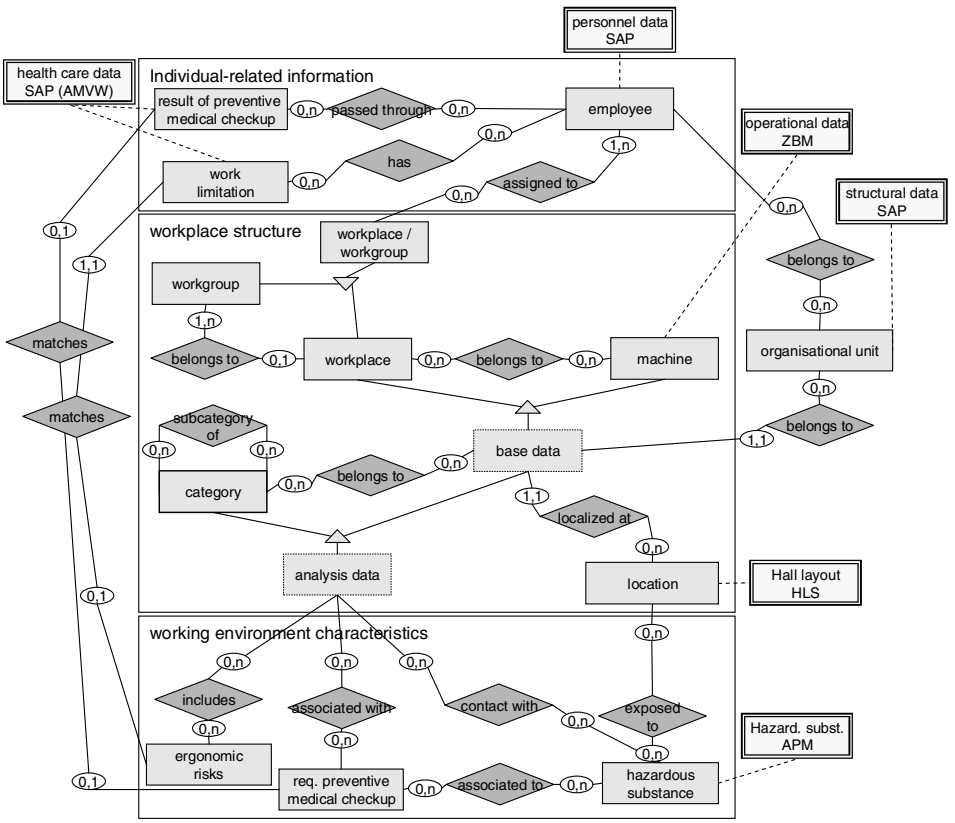


Figure 2: ER-diagram of the workplace management system

The modeling of the workplace structure mirrors the described structural aspects. *Base data* describes the combination of an instance of a category and a location inside the

plant, referring to the Hall Layout System. It combines properties of the location with properties of the category and is associated to an organizational unit (referring to the SAP system). Information about machines refers to the operational data kept in the ZBM; a more concrete example is given at the end of this section.

The analysis data about workplace environment characteristics contains ergonomic risks, exposure to hazardous substances and the required medical checkups. This information is related to each of the categories.

Personnel data and some medical data from employees are imported from the SAP system into the workplace management system. An employee can be assigned to a single workplace or to a workgroup. If an employee is associated to a workplace or workgroup, the workplace management system matches the work limitations of the employee with the ergonomic risks of the workplace and relates with preventive medical checkups.

Example. Input of initial data (such as the definition of the category hierarchy including the weighting and data about machine classes and types) is done by analysts. As shown in, a Gleason-Pfauter P90 is a milling machine (German: Fräsmaschine; 90%) as well as a deburring machine (10%) and therefore combines analysis of both categories. At a Gleason-Pfauter P90, usual millcutting (70%) and deburring (10%) are dry, more complex millcutting (20%) requires using cooling lubricant. Each instance is associated with its location. Each of the categories is associated with its analysis data, and the properties of the actual machine are obtained as a combination of that data.

2.4 Application-Specific Modeling of Risk Analysis

The core aspect of the system is the information about risk analysis and connecting it with individual-related data. *Risk analysis* is the analysis of all risks that employees are exposed to during their work time. For the given application, risk analysis consists of *ergonomic risk analysis*, which is described in more detail below, and *hazardous substance analysis.* Based on the analysis of different individual hazards of a workplace, the overall characteristics of the workplace can be summarized. For the actual assignment of employees to workplaces, these characteristics must be matched with the work limitations of the employees.

The *ergonomic risk analysis* [La04] is based on a questionnaire. The questionnaire includes general aspects of given tasks and workplaces, and complementary questions related to the kinds of potential work limitations. Risk analysis distinguishes between exposures, e.g. hazardous substances or oil, ergonomic risks related to physical strain, e.g. heavy lifting, as well as special requirements like stereoscopic vision, e.g. for driving a stacker, or work in night shift.

Risks and exposures are classified according to *how* they are characterized:

(1) A *risk or exposure without weighting* is just quantified by “yes” or “no”. It excludes employees with the corresponding work limitation. The exposure “skin contact with oil”

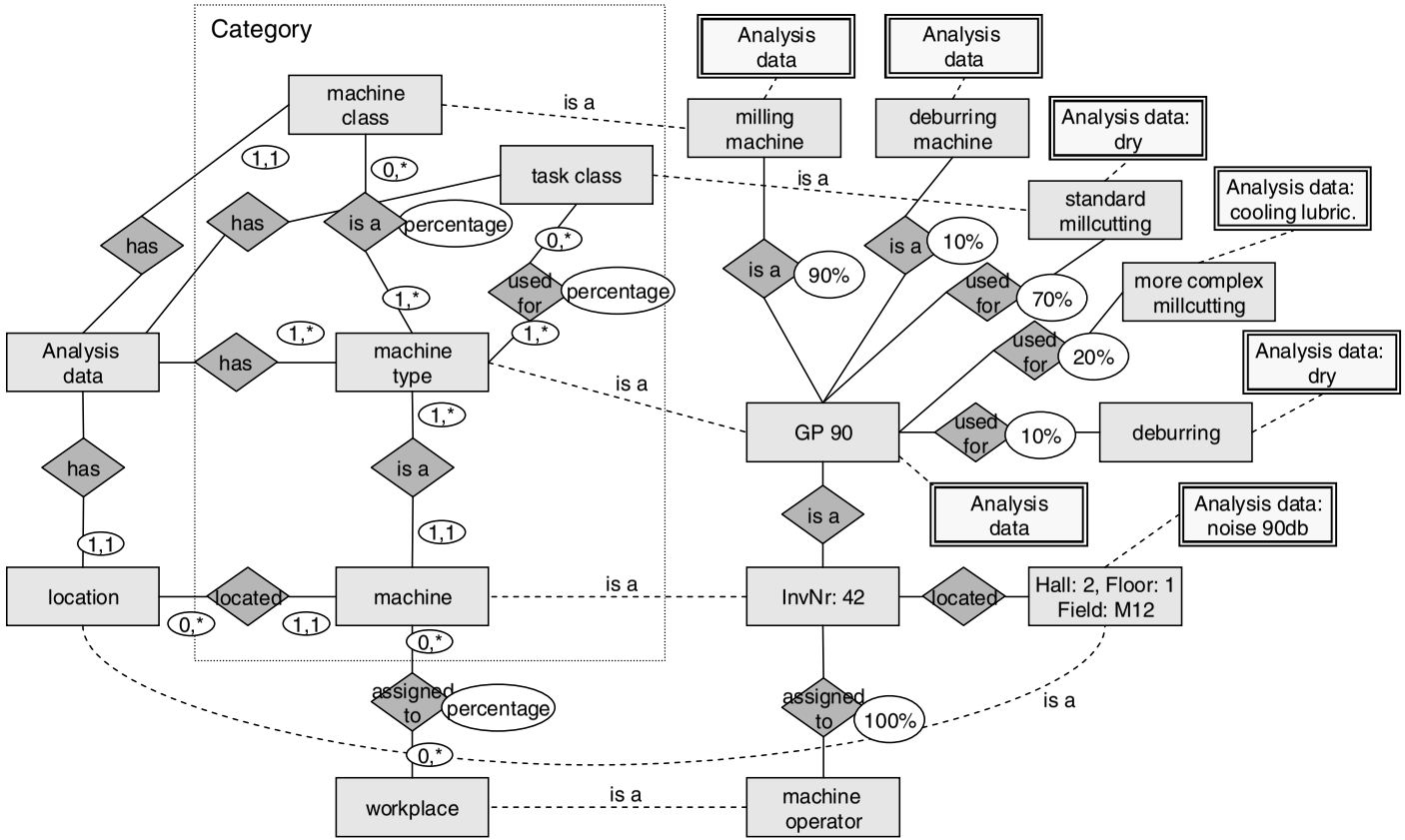


Figure 3: Example for categorization

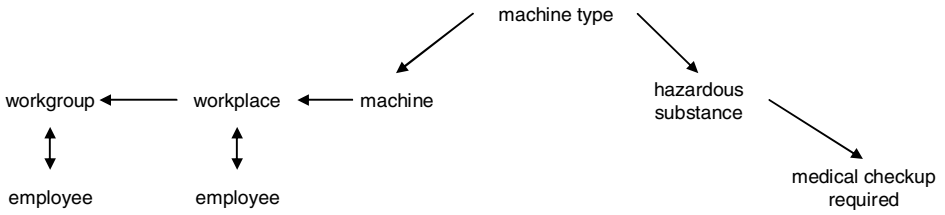
for example excludes employees who are allergic to oil no matter if the contact is for one hour or one minute.

(2) A *risk or exposure with weighting* is expressed in terms of the percentage of working time. Those hazards only exclude employees with the corresponding work limitation when they are associated for a specific duration. For example there could be one task to bend down to lift work pieces. If this task amounts to 2% of the working time it should be no problem even for an employee with the work limitation “no bending down often”. When forming a working group, the overall risk or exposure is computed according to the distribution; depending on the characteristics of the working group (e.g. frequency of job rotation), this can amount to maximum- or average-based formulas.

(3) For ergonomic risks or exposures that have more complex characteristics, there are *Key Indicator Methods* of the Federal Office for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, BAuA). With help of these Key Indicator Methods the risk or exposure can be calculated and results in a score. However multiple scores from different tasks cannot be added easily. To determine a score, the interim results must be summarized in a given manner and the Key Indicator Method must be performed again with the summarized values. The result is a structural rating with multiple attributes.

Work limitations wrt. ergonomic risks or exposures are expressed in the same way by prohibitions (“no skin contact to oil”) or threshold values (“bending down must not be more than 10% of working time").

As a consequence of the analysis, the necessity of preventive medical checkups can be derived through the category network. For instance a preventive medical checkup implied by exposition to a certain hazardous substance related to a certain machine type can be derived for employees assigned to workplaces and workgroups by the following relationships:



Categorization lowers redundancy and therefore supports consistency not only for collecting data, but especially reduces efforts for data maintenance.

3 Functionality

User groups in the workplace management system have access to different functionalities according to their requirements and their rights. A central task is to collect and

maintain the information about risk analysis and workflow structure. This is done by analysts and foremen. The actual assignment of employees to workplaces that changes daily is maintained locally by the foremen. The information system is also used by different user groups for several retrieval tasks. The Human Resource Department and the foremen use it for finding and assigning workplaces to employees with work limitations. The Health Care Department obtains background information about an employee's workplace conditions in the context of medical checkups. Additionally the scheduling of medical checkups is supported.

For each user group, a specific GUI is implemented, according to its needs. This chapter discusses the functionality and gives an impression of the target-group specific GUIs.

3.1 Maintenance of Individual-Independent Information

The initial risk analysis is performed by a team of analysts, including ergonomists, planners, representatives of chemical safety and occupational health physicians. The risk analysis information can be updated later. The initial workplace definition is also done by the analysts. Changes in workflows are usually maintained by the foremen by changing associations and attribute values (e.g. percentages). The changes of associations, both in risk analysis and workplace definitions lead automatically to a new calculation of affected categories by the system.

The task of analysts is to build categories and to enter data about analysis objects, using a tree view-based GUI for designing the category structure. The actual machine categories are populated by importing existing data about machines from the ZBM. The analysis data is then added in cooperation between ergonomic specialists from Health Care and the foremen by using a questionnaire. The original concept of the questionnaire was taken from Frieling [Fr04]. Modifications and extensions are made by suggestions from a consortium of automotive industries as well as from an ergonomic workgroup of Volkswagen and incorporated by the Health Care department.

The second stage of the initialization consists of defining workflows and workplaces. This step is also carried out by the analysts together with the foremen, using either the tree view-based interface described above, or the graphical interface of the foremen that is described in Section 3.2.

After completing the initialization, the foremen take on maintenance of workplace definitions and the actual daily assignment of employees to workplaces.

3.2 Foremen View: Definition of Workplaces and Employee Assignment

The main focus for designing this user interface was to enable foremen (i.e. people with a non-IT professional context) to handle the workplace management system without the need for long instructions and with a minimum of time for data maintenance.

At first “dot-plans” (Figure 4, right-hand side) were used to identify workplaces. These plans are abstract illustrations with rectangles as machines and dots as employees (workplaces). After further interviews with foremen it turned out, that the plans of the hall layout provide a useful complementary view as shown in Figure 4, left-hand side.

Associations can be made by drag&drop, each object has an interactive context menu and double-click and mouseOver for detail information. This GUI is used for four tasks, in which different items are shown in the graphics:

Definition of workplaces: Machines and workplaces (A) are positioned according to their location information (note that a workplace as an abstract notion gets a virtual location). Assignments of machines to workplaces are done by drag&drop and are indicated by (blue) connection lines.

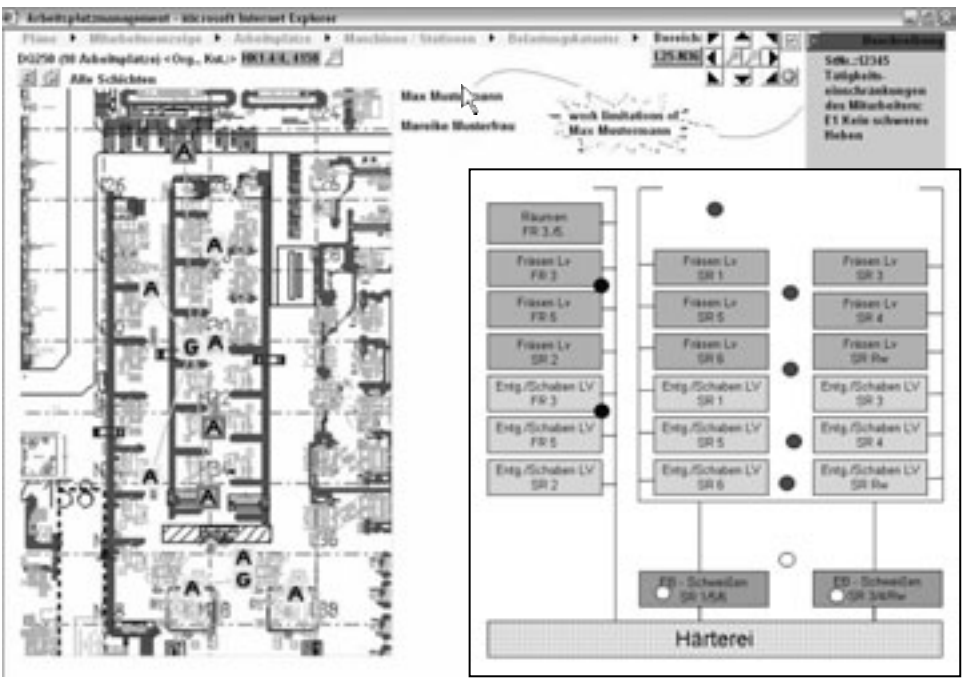


Figure 4: Foremen’s view with hall layout background

Definition of workgroups: Workplaces (A) and workgroups (G) are positioned according to their (virtual) location information. Assignments of workplaces to workgroups are done by drag&drop and are indicated by (yellow) connection lines (cf. Figure 4, left-hand side).

Assignment of employees: For each actual shift, the employees are assigned to workplaces or workgroups. The hall layout plan shows workplaces (A) and workgroups (G), and additionally all employees already present in the plant are listed to the right of the hall plan (cf. the test employee in Figure 4 where the mouse cursor points to). Moving the mouse cursor to an employee, the description area on the upper right shows work

limitations of the employee (in the above example “no heavy lifting”; in German: “Kein schweres Heben”). All workplaces and workgroups get a specific colored border according to the match between their ergonomic risks and work limitations of the employee: all workplaces are marked with green icons ( , cf. Figure 4 left-hand side), where this employee has no conflicting work limitations. In case of possibly conflicting work limitations, the workplace is marked with a yellow icon ( ; this requires a decision on a by-case-basis), and if there is a definite conflict with a work limitation, the workplace is marked with a red icon. The actual assignment is again done by the foreman by drag&drop. Pointing the mouse cursor to a workplace on the other hand, all employees in the visible area get a specific colored border according to the match.

Detailed search to assign employees with work limitations: In that view, machines, workplaces and employees are shown. By pointing to a machine or an employee, the appropriate detailed matches are shown. Through this view, light duty work can be created by setting up a workplace definition that consists only of operations of specific machines without ergonomic risks.

To minimize the latency during maintenance, the workplace management system functions mostly without full post backs. Server functionalities are initiated with JavaScript, results integrated with AJAX [Ga05]. Therefore workplace definitions and associations of employees to workplaces can be maintained fast and efficiently.

3.3 View for Human Resource Management

The human resource management is interested in finding adequate workplaces for each employee. Adequate in that case means that the employee can handle the workload without limitations. This search can be invoked for an employee, or for any combination of work limitations[1], starting at any height of the tree of organizational structure. Figure 5 illustrates such a search for the organizational unit HK1, which is gearbox production, with the work limitation “no heavy lifting” (“Kein schweres Heben”). The hall layout is used as background and the user can navigate through it.

If more than 50 workplaces are matched against an employee, they are combined in rectangles for each organizational unit below the chosen one, e.g. HK1-4/3, HK1-4/4 and HK1-4/5. Each rectangle shows included workplaces in numbers. These numbers are colored according to the match against the employee (e.g. in HK1-4/4 there are 17 adequate (green) workplaces, 14 possibly adequate (yellow) and no non-adequate (red) workplaces). By clicking on a rectangle, it is enlarged to get details of every included workplace. By further zooming in, the view gets more and more detailed, until it shows the same detailed view including individual workplaces as shown in Figure 4.

The search is e.g. needed in cases when employees cannot work at their former workplace or in their former workgroup anymore. This happens for example, when an em-

[1] Adequacy of a workplace for an employee also depends on his knowledge and abilities.

ployee had an accident or gets new work limitations for other medical reasons by an occupational health physician. Foremen and superiors can use the search with access limited to their organizational unit.

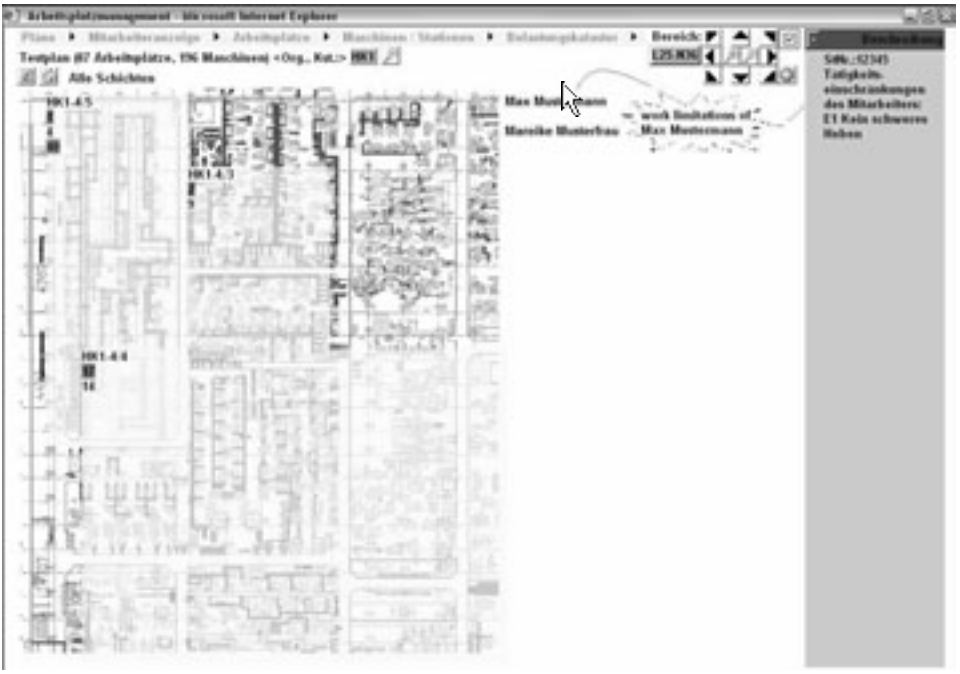


Figure 5: Search for an adequate workplace in multiple organizational units

3.4 View for the Health Care Department

Every time an employee consults the Health Care department, the physician can use the system to get an impression of the work situation of the employee within a few seconds: the workplace management system enables occupational health physicians to have a closer look at the specific workplace. *Workplace summarization* gives an overview of all medically relevant information of the workplace or the workgroup. Managed by a tree view, all associations including weightings and subtotals are listed. Photos and videos illustrate why specific ergonomic risks are associated to a workplace.

By keeping history of all associations of an employee to his workplaces, all working conditions the employee was exposed to during his working life are registered. In that way the so called *exposition record* is generated. Those records are a substantial fundament for investigating *coincidences between working conditions and diseases.*

4 Discussion

We presented a use case of enterprise modeling on a detailed level. The modeling uses a concept hierarchy for representing and structuring equipment and the actual work in the production division. The categorization is applied to capture and maintain information about ergonomic issues. In addition to the modeling and the analysis data which are captured by analysts during the project, the integration of the existing information from heterogeneous sources had to be solved on the conceptual level as shown in the diagrams, and then had to be implemented.

Relevance. The topic "risk analysis and work limitations of employees" and the corresponding additional expenses for searching adequate workplaces emerged recently due to a German law that implements European regulations for occupational health and safety, and due to the background of demographic change.

Status. The workplace management system is a prototype developed by the Health Care and Human Resource Management departments. It implements a standard three layer architecture with data layer, application layer and representation layer where the Intranet application connects to a relational database.

Acceptance. Critical for the benefit of every information system is its acceptance by all involved user groups. For that purpose the system, the modeling and especially the user interfaces have been designed in close communication with prospective users, incorporating their continuous feedback. As most of the maintenance and daily use is done by the foremen in the production, their GUI is a crucial factor to achieve ongoing success. Until now workplaces for approximately 800 employees are being analyzed and about 40 users are testing the usability.

Transferability. The described modeling of work categorization and matching possibilities is transferable to other larger industrial plants. Concerning risk analysis in particular, different environments lead to different restrictions and requirements. The model provides a framework that can be used for any matching possibility that fits into one of the three summation methods.

Related Work. Work on enterprise ontologies [Us95, Di06] usually deals with high-level aspects of enterprises like organizational structure, administration, business process models and patterns, business transactions, strategic goals etc. In contrast, our approach focuses on the modeling of the industrial production level.

Usually industrial workflows are designed and analyzed by using MTM [BL06] (Methods-Time Measurement) methods and tools. *MTM-Ergonomics* [MTMe] is a proposal based on the experiences of several companies. MTM-Ergonomics and similar approaches (for an overview see [La04]), in most cases proprietary, systems allow for workplace analysis and for the search for workplaces corresponding to given restrictions. However, none of the systems known to the authors integrates personnel data.

New Features. By integrating personnel data, the Workplace Management System allows actual matching of employees to workplaces and thus supports the daily planning and scheduling and runtime rescheduling. Another distinguishing feature is that it is based on generating an ontology in terms of a hierarchical structuring of the production. This categorization reduces maintenance efforts since work parts and machine types are analyzed separately. They allow changes in workplace definitions without the need for new analyses: if a workplace definition changes, the summarized analysis is recalculated as shown in Section 2.4.

Perspectives. The functionality of the current prototype focuses on the requirements of running the production process in the plant. Further on, more advanced usage of the information available in the system can include the following:

From an ergonomic point of view, the categorization can be used for testing transferability of improvements to similar machines. Data mining algorithms can be used to search for peculiar or similar structures and enlarge and refine categorization; activity recommendations could be derived automatically.

Up to now, the workplace management system includes import and gathering of required data and maintenance of analysis data as well as generating reports. The full historization of all maintained and all integrated data builds a large data stock. Thus, a powerful fundament for upcoming studies is build.

For health care, exposition files are very precious data for further analysis. The search for similarities between exposition records from employees who suffer of a specific disease could provide knowledge about coincidences. On a long term perspective, large studies about effects of health care actions or about effects of hazards can be developed with minimum effort. This also includes studies about contact to hazardous substances.

References

[Ga05] J.J. Garrett: Ajax: A New Approach to Web Applications. Tech. Rep. Adaptive Path, http://adaptivepath.com/publications/essays/archives/000385.php, 2005.

[Fr04] E. Frieling: DFG Schwerpunktprogramm 1184: Altersdifferenzierte Arbeitssysteme. Zeitschrift für Arbeitswissenschaft, 2006; S. 71-80.

[La04] K. Landau: Montageprozesse gestalten. ergonomia Verlag, Stuttgart, 2004.

[BL06] R. Bokranz, K. Landau: MTM-Handbuch. Schäffer-Poeschel, Stuttgart, 2006.

[MTMe] http://www.mtm.com/produkte/software/ticon_modul_ergo.php

[Di06] Jan L. G. Dietz: Enterprise Ontology: Theory and Methodology. Springer, 2006.

[UK95] M. Uschold, M. King, S. Moralee and Y. Zorgios: The Enterprise Ontology, http://www.aiai.ed.ac.uk/~entprise/enterprise/ontology.html, 1995