Barbara Deml · Patricia Stock
Ralph Bruder · Christopher Marc Schlick *Eds.*

Advances in Ergonomic Design of Systems, Products and Processes

Proceedings of the Annual Meeting of GfA 2015

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Editors
Barbara Deml
ifab-Institute of Human and Industrial Engineering
Karlsruhe Institute of Technology (KIT)
Karlsruhe, Germany

Patricia Stock
REFA-Institut e.V.
Dortmund, Germany

Ralph Bruder
Institut für Arbeitswissenschaft
Technische Universität Darmstadt
Darmstadt, Germany

Christopher Marc Schlick
Institute of Industrial Engineering and Ergonomics
RWTH Aachen University
Aachen, Germany

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Editorial

These proceedings include a selection of papers presented at the 2015 Annual Meeting of the German Gesellschaft für Arbeitswissenschaft, held at Karlsruhe Institute of Technology (KIT) from February 26 to 28. The conference featured more than 160 presentations and 30 posters reflecting the diversity of subject matter in the field of ergonomics, human factors and industrial engineering.

The first part of the book deals with the *design of work systems* against the background of current socio-technical challenges. The contributions take up relevant research topics caused by the demographic change (Jungmann et al.; Wassmann et al.), important issues concerning occupational health (Bockelmann et al.; Hillebrecht et al.; Penzkofer et al.; Rivkin and Schmidt; Rücker and Brombach) and current changes in working time (Stock; Tegtmeier et al.). Furthermore, the effect on outcome variables, such as motivation (Kassirra and Rausch), quality (Sattler et al.) or efficiency/effectiveness (Tackenberg et al.) is regarded.

Within the second part of the book the *design of products* is considered. Here, too, the contributions cover a wide spectrum addressing the assessment of both cognitive (Arenius et al., Schneider and Deml) and physiological user states (Bürkle and Schmauder; Franzke and Walther; König and Jaschinski; Jaschinski et al.), the design of both input (Meyer et al.) and output (Knott et al.; Nelles et al.; Strenge et al.) processes in the field of human–machine interaction as well as new approaches for measuring working environment variables (Spitzhirn et al.).

Finally, in the third part of the book the *design of processes* is taken into account. Again it is current socio-technical developments that are reflected by the research papers. The contributions address topics such as flexible-mobile working (Gisin et al.), interdisciplinary collaboration (Brandtstädter and Sonntag), age-appropriate working processes (Büttner et al.; Kugler et al.), complex project planning (Terstegen et al.) or ecological aspects (Lüderitz et al.).

Considering the wide range of topics covered and the variety of scientific methods applied, it is apparent that advances in ergonomics may only be achieved by a multidisciplinary approach. Thus, these proceedings address human factors and safety specialists, industrial engineers, work and organizational psychologists, specialists in occupational medicine as well as production planners and design engineers.

Karlsruhe, Germany Barbara Deml
Dortmund, Germany Patricia Stock
Darmstadt, Germany Ralf Bruder
Aachen, Germany Christopher M. Schlick

Contents

Part I

Design of Work Systems

Assessment of the Individual Work Organization During a Service Provision

Sven Tackenberg, Sönke Duckwitz, Julia Seibold, and Christopher M. Schlick

Abstract

Employees of knowledge-intensive service companies organize their work individually. Therefore, an inadequate coordination of people may lead to an exceeding of service time and costs. In order to avoid this, a method-based work analysis provides an appropriate, but also time-consuming procedure to evaluate the efficiency and effectiveness of operations at an individual employee level. In this paper, we introduce a new approach for the assessment of an individual work organization during a service provision. To achieve this objective, a performance measurement system and a software tool for tablets and smartphones are presented. The software tool will be introduced, and tested by a verification study in a service company.

Keywords

Work organization • Service management • Self assessment tool

1 Introduction

For the most part, service research-to-date contains a variety of generic models to describe service productivity [2, 11, 23]. All these models have in common that they focus on the sales department, human resource management, the design of work processes, and the application of technologies [11]. But, knowledge-intensive services are based on service provisions that mainly rely on the expertise of individuals. Therefore, the processes contain a high degree of individualization and interaction between persons, as well as high uncertainty with regard to the performance potential and the work results. Hence, those service productivity

S. Tackenberg • S. Duckwitz (✉) • J. Seibold • C.M. Schlick
Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Aachen, Germany
e-mail: s.duckwitz@iaw.rwth-aachen.de; c.schlick@iaw.rwth-aachen.de

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models are of limited suitability in practice. According to this understanding, the work processes of a service provision as well as the individual work organization of the involved working persons determine the success of sustainable services.

In this paper, we have interpreted the measurement of service productivity from the perspective of the individual work organization of an employee. Yet, there are only very few studies about individual planning and knowledge-intensive activities [3, 17, 21], which investigated the relationship between the individual work organizations of employees and service productivity. This is surprising, as the studies were able to show that an individual work organization and the working conditions influence the required time, strain, and the work outcome. Based on the results of [10], service productivity can be defined as the result of the invested time, the quality of results, and of the individual work organization. Therefore, we interpret a service as productive, if there is an efficient and effective collaboration of persons with an optimal individual work organization. Accordingly, it raises the question, which performance indicators of an individual work organization exist, and how is it possible to measure and control them.

2 Work Analysis: State of Research

2.1 Conceptual Classification

Work analysis is often characterized as the initial starting point for almost any other effort to measure and improve work. Thereby, work analysis methodology is the foundation of work analysis [28]. For the most part, work analysis focuses on a systematic structuring of tasks and activities, which are processed by an employee of a work system [26]. Such a work system is a regulatory model to systematically describe a workplace using various elements, such as employees, requirements and tasks [27]. To perform a work analysis, various methods, procedures and instruments are available to capture, process, and interpret information about tasks, the organizational-technical working conditions, the required work equipment, as well as their impact on the involved employees [27]. The different methodological approaches can be applied to a theoretical issue or to specific elements of a work system. Therefore, a work analysis proceeds not just analytically, but also for evaluation and design purposes [14]. In particular, a distinction must be drawn between the psychological and the task-centered work analysis [5, 6]. The former is restricted to the effect of working conditions and the requirements imposed on the employee [5], whereas a task-centered work analysis gather data about the work content and the target oriented processing of tasks [6].

In our approach of a performance measurement system we provide a conceptual framework for the assessment of an individual work organization by focusing on processes that exhibit two critical characteristics: knowledge-intensive and weakly-structured:

- Knowledge-intensive: Such processes are characterized by a heavy reliance on employees and significant incidents of problem solving as well as non-standardized production [1]. These employees are the primary sources of information and knowledge which are used to produce intermediary services for the customer.
- Weakly-structured: Such workflows represent task sequences which are not strict and predetermined [27]. Due to missing standards and incomplete information, an employee has to identify and to choose the best strategy to solve and schedule the assigned tasks.

2.2 Background: Work Analysis

In the last 50 years in fields as task scheduling, organizational behavior, and management science, many studies have been conducted in order to understand how employees distribute their working time [10]. Most studies have focused on the role of managers, to identify the characteristic of their tasks and to analyze their simultaneous management of activities [17, 19, 20]. In the field of service research the focus was solely laid on the relations between actors and communication processes [11]. In real service provision, the employees communicate asynchronously, i.e., via email, messenger, and document postings in a cloud. Therefore, the sender of a message may not know exactly how long a response will take. Due to the lack of information the person might switch to another task and reorganize his/her work plan. Rubinstein et al. examined the effects of task switching depending on the familiarity and complexity of tasks [25]. Their results indicate that employees create a delay before they start working effectively on another task. Furthermore, they could show that each task switch causes a time loss. There is even more time loss, when switching from a familiar to an unfamiliar task and from a simple to a complex one.

An external interruption of work is defined as a synchronous interaction, which is unscheduled and not initiated by the employee of the considered work system. Such an interruption results in a discontinuing of the current activity of the recipient [4, 24]. For improving the productivity of an employee it is essential to know whether and when interruptions constitute disruptions and which kinds of interruptions have negative or positive effects on task performance. Therefore, in the field of interruption research, efficiency and effectiveness are measured based on the work conditions [9, 21, 22].

In the late 1960's, Horne and Lupton found that middle managers spend most of their work time in managing various activities, but very little time for reflection and decision-making [13]. To obtain the relevant data, managers recorded their own activities on a specific form, which contained several terms, the "*Managers Activity Record*". If one of the terms was appropriate for describing the work day, the manager had to mark it.

Mintzberg proposed that the best way to describe and evaluate the work of managers is to focus on the managers' activities [17–19]. He conducted a 5-day long observational analysis, during which he recorded the type, the purpose and the duration of each activity of the observed managers. Based on the data of five chief executive officers he developed his role theory. Thereby, Mintzberg [17] concluded that managers perform a set of ten, basic roles, which describe behaviors belonging to an identifiable office or position.

In a quasi-field experiment, Perlow [22] investigated how team members of a software engineering team use their work time, what kind of tasks they choose and if their planning is time-optimal for them or their work groups. Thereby, the group's collective use of time perpetuated each individual as "time famine", a feeling of having too many tasks and not enough time to properly work on them. Due to interrupting each other, the observed engineers had difficulties to get their individual work done. To reduce the quantity of interruptions, Perlow [22] initiated the implementation of a "*quiet time*". Such a "*quiet time*" is an agreement among coworkers to not interrupt a colleague during the defined designated hours. A result of the "*quiet time*" was a higher percentage of task completion due to a longer processing time.

During a fieldwork observation Gonzáles and Mark [10] discovered that employees (analysts, software developers, and manager) have a high level of discontinuity during the execution of their activities. Thereby, the average to work on a task was about 3 min. If the employee had to use an electronic tool or paper document the period before a further task switch was not longer than 2 min. To enlarge the working period, the authors introduced the concept of "*working spheres*" to conceptualize and organize the work [10]. The result was that the employees worked on average in ten different working spheres for a period of about 12 min.

Other interruption and communication characteristics, including the particular time and the length, the demands of the service process and the initiator, as well as the recipient moderate the efficiency and the stress of project managers [3]. In an observational study of project managers Beuscher-Mackay et al. were able to show that the fragmentation of a work day has an impact on the subjectively perceived productivity [3]. In addition, Cutrell et al. [4] found that the timing of such interruptions has an impact on the performance of an employee. The earlier such an interruption occurs during the completion of a task, the more disruptive is the effect [4].

For the most part, research-to-date focuses on identifying the timing or the frequency of task types of managers and on the characteristics of individual interruptions [24]. While studies indicate that various interruptions decline the performance of an individual, there is no concept to measure the individual work organization. Furthermore, we did not identify a software solution, which can automatically identify and support people's continuous switching between tasks and interruptions.

3 Method for Evaluating Individual Work Organization

3.1 Individual Work Organization

The term work organization is often used in the context of planning and executing actions to solve work tasks. Thereby, the content of a work organization relates to various contexts. For instance, Schlick et al. [27] define a work organization as the planning and the design of separate work systems with a specific focus on division of labor and cooperation. Other definitions focus on the individual's work behavior, which differs in terms of decision-making and the strategies to solve a task [12]. Both aspects are prerequisites for an employee to carry out the necessary actions to fulfill the assigned task. Therefore, a definition and demarcation of the term work organization are necessary.

The individual work organization of an employee comprises in particular the identification of options for decision-making in regard to perform certain acts for solving the assigned tasks to maximize the potential benefits. Thereby, existing restrictions and degrees of freedom have to be considered by the employee. Applying this definition to the systematic of labor organization, as defined by Hacker [12], an individual work organization is only the third step after the distribution of functions between employees and work equipment, and the distribution of work tasks between different employees (Fig. 1).

Hence, there are two perspectives from which an individual work organization can be assessed. Here, the work system determines if there are any degrees of freedom and uncertainty for processing work tasks. Also, the input of the work system as well as the characteristic of the elements of the observed work system can cause the occurrence of interruptions. Furthermore, the data quality is important, because an evaluation of an individual work organization can only be achieved if a baseline measurement is available that can be used as a reference. Consequently, the evaluation and improvement of the individual work organization depend on the design of the work system and the decision-making of the employee. Therefore, the evaluation of a given, unchangeable work system differs from a system, which allows the partitioning of functions between the employee and the work equipment, as well as between different persons.

3.2 Assessment of the Individual Work Organization

To provide an adequate database, a workshop with the knowledge-intensive employees of a service company was carried out to identify the central factors influencing the quality of an individual work organization, and to describe the characteristics of a work system. Only one worker can be assigned to such a work system. Therefore, cooperative activities between several workers have to be described by a corresponding number of work systems. To analyze the individual work organization of an employee, as well as the performance of a service provision, the terms "*effectiveness*" and "*efficiency*" are particularly suitable for

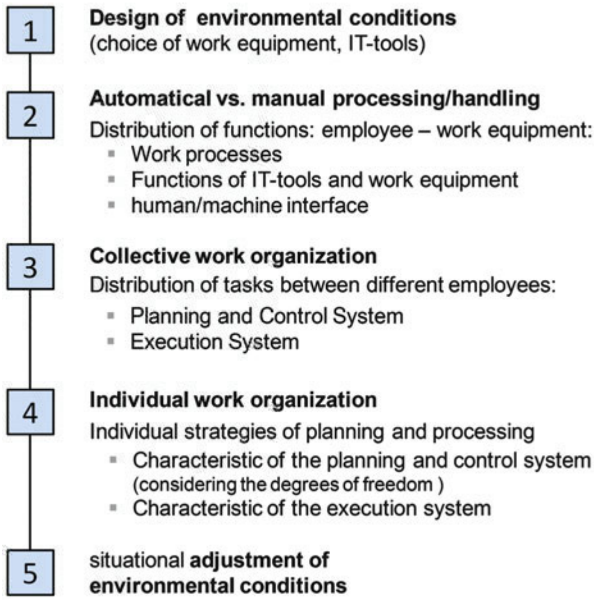

Fig. 1 Classification for designing a work organization

describing the corresponding actions. Thus, identifying and scheduling tasks in connection with the optimal characteristics of a work system can be deliberately focused on an efficient and effective task processing. Moreover, the employee is empowered to understand and analyze the individual productivity as a result of their decisions and actions.

Based on the process of a service provision the essential influential factors were consolidated to latent variables. These variables shall contribute to the endogenous latent construct "*service productivity*". The productivity of a process is related to how effectively input resources of a service process are transformed into economic results for the service provider and value for its customers [11]. In the following sections we refer to the concept of service productivity developed by Lasshof [16] and the results of the empirical study of v. Garrel et al. [8]. They have linked service productivity to the aspect of planning and task execution, measured in terms of efficiency, effectiveness and quality. All of the constructs have the advantage that they can be used for the assessment of the individual planning as well as the action of employees [29].

A work organization is considered effective if the expected output of the work system is achieved [15]. However, a work organization is efficient, if the required quantity or quality of the output is achieved with a minimum number of input factors (e.g. working hours), while the product quantities remain constant [7]. Thereby, the specification of the minimal input factors has to reach a balance between a human-oriented structuring of work, and the productivity of a service provision. Yet, in practice such an equality of economic and human criteria is often not achieved due to considerable private economic interests [29].

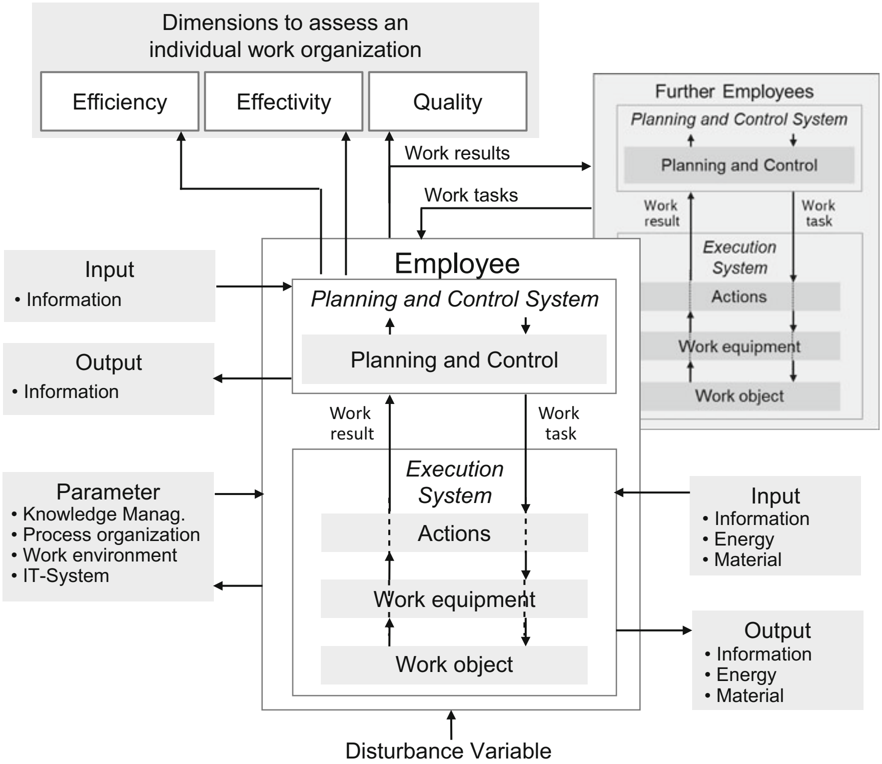

Fig. 2 Work system for assessing the individual work plan

The basic model of a work system [27] was expanded to include three evaluation dimensions for the individual planning of work. Whereas, the efficiency and the effectiveness are a result of the "*planning and control system*" of an employee, the quality of work is determined by the interaction between the "*planning and control system*" and the "*execution system*" of a work system (Fig. 2). Therefore, the key figures of effectiveness and efficiency evaluate the identification and scheduling of tasks. While the indices for the term "*quality*" refer to the work results of the work system.

3.3 Performance Figures for the Individual Work Organization

The following section is based on the work of several previous studies [3, 4, 10, 17–19, 21]. A performance measurement system will be presented, which argues that it is possible to evaluate the individual work organization of employees during a knowledge-intensive service provision. Thereby, we refer to the terms "*effectiveness*" and "*efficiency*" because both are typically used to indicate the desired and the unintended consequences within a work system.

3.3.1 Efficiency of the Individual Work Organization

The result of a knowledge-intensive service provision is based on a strict division of labor and a task-allocation to several decentralized employees. In the field of manufacturing, productivity is a concept related to the efficiency of producing goods [11]. However, the problem about providing an efficient service process is that productivity and perceived service quality are inseparably connected. In contrast to the manufacturing sector there are no methods to calculate standard times for a task execution due to the dependence on the individual problem solving. Therefore, based on the introduced understanding of the terms "*efficiency*" we defined the figures "*work efficiency*", "*perceived work efficiency*" and "*process continuity*". All three figures are indicators for the latent superordinate construct of "*efficiency*" to evaluate the work organization of an individual.

Definition "*expenditure of human labor*"

The measured expenditure of time $ET^{m}_{i,w}$ of a task i is the sum of all time points t (time: 1 min), a task is processed by person w:

$$ET^{m}_{i,w} = \sum_{t \in T} a_{i,w,t}, \tag{1}$$

$$\begin{matrix} a_{i,w,t} = 1 & if & task\ i\ is\ processed\ at\ time\ point\ t\ by\ individual\ w \\ a_{i,w,t} = 0 & else & \end{matrix}. \tag{2}$$

Figure "*work efficiency*" *(WE)*

The figure "*work efficiency*" (*WE*) is based on the comparison of the expenditure of human labor $ET^{m}_{i,w}$ needed for a complete processing of a task (current value), and the initial estimated workload $ET^{p}_{i,w}$ (planned value). To determine the value of "*work efficiency*" for a given period, the mean value WE_{ges} across all completely processed tasks is calculated:

$$WE_{i,w} = \frac{ET^{m}_{i,w}}{ET^{p}_{i,w}}, \tag{3}$$

$$WE_{ges} = \frac{1}{\sum_{t=t_{min}}^{t_{max}} y_{i,t}} \sum_{t=t_{min}}^{t_{max}} y_{i,t} WE_{i,w},\ \forall i \in A, \tag{4}$$

$$\begin{matrix} y_{i,t} = 1 & if & task\ i\ is\ completely\ processed\ at\ time\ point\ t \\ y_{i,t} = 0 & else & \end{matrix}. \tag{5}$$

The information provided by the figure "*work efficiency*" has to be questioned in particular when the observed employee w defines the planned value $ET^{p}_{i,w}$. In that case, the demand of minimizing $WE_{i,w}$'s value, may lead to the definition of time buffers to maximize the robustness of the individual work organization. Yet, such a behavior would be contrary to the objectives of improving the scheduling and processing of tasks.

We consider that an efficient individual work organization exists if $ET^{p}_{i,w} = ET^{m}_{i,w}$. If $ET^{m}_{i,w}$ clearly exceeds $ET^{p}_{i,w}$, the risk of an outrun of the planned duration and costs may exists. However, an overestimated expenditure of human resources indicates an inefficient individual work organization. Because these time buffers cause idle periods, or they are often used to generate a not necessary outcome. Both kinds of deviations can trigger a situation-based adjustment of the individual work organization. But studies have shown that compared to the initial planning, employees are often not able to use interruptions or time buffers, arriving in the short term, efficiently [18]. Therefore, it should be an aim to minimize any deviation: $\Delta ET = ET^{p}_{i,w} - ET^{m}_{i,w}$. Consequently, a learning assistance system can propose a value for $ET^{p}_{i,w}$. Alternatively, based on historical values the input of the user $ET^{p}_{i,w}$ can be adjusted.

Definition *"Processing phase"*
A processing phase of a task *i* is defined as the period of connected points in time at which this specific task is processed. A processing phase ends if an interruption or a task switch occurs.

Figure "*Perceived work efficiency*" (*PE*)
The figure "*perceived work efficiency*" can consider the contribution of the task content as well as of the working conditions to the efficiency of an individual work organization. Both factors are necessary for setting the performance baseline. The "*perceived work efficiency*" is defined as the proportion of the value ($V_{i,n,w}$), perceived by the employee *w* for processing phase *n* of task *i*, to the measured duration of phase *n*. As an input the subjective evaluation of the value $V_{i,n,w}$ has to be measured after each of the phases. In fact, we define that a unit of labor (1 min) represents one unit of a currency. The usage of these time and monetary units should generate a value for the employee of the work system. Later on, the ratio of the perceived benefit of the invested time is compared to the measured time of task processing d_n:

$$PE_{i,n} = \frac{V_{i,n,w}}{d_n}. \tag{6}$$

The key figure value of all finished task shall be calculated as follows:

$$PE_{ges.} = \frac{1}{\sum_{t=t_{min}}^{t_{max}} y_{i,t}} \sum_{t=t_{min}}^{t_{max}} y_{i,t} PE_{i,n,w}, \ \forall i \in A. \tag{7}$$

Figure "*process continuity*" (*PC*)
In real world contexts, processing tasks is often interrupted by rotation of tasks, information delays, interruptions and non-working periods. From the efficiency

perspective, the fragmentation of processing a specific task i has to be evaluated in the context of the measured expenditure of human labor $ET^m_{i,w}$. To determine the respective period, a differentiation between working hours and unavailability can be included or neglected. The basic calculation of the figure $PC_{i,w}$ is based on the quotient of the measured workload and the duration to complete the task i:

$$PC_{i,w} = \frac{ET^m_{i,w}}{t_{i,max} - t_{i,min}}, \tag{8}$$

$$t_{i,\max} = \max\{t\, x_{i,t} : t \in T\}, \tag{9}$$

$$t_{i,\min} = \min\{t\, x_{i,t} : t \in T\}, \tag{10}$$

$$\begin{array}{ll} x_{i,t} = 1 & \textit{if} \quad \textit{task i is processed at time point t} \\ x_{i,t} = 0 & \textit{else} \end{array}. \tag{11}$$

3.3.2 Effectiveness of the Individual Work Organization

A conceptual differentiation of effectiveness from the term efficiency in the context of individual work organization cannot be presented selectively. Finally, we have defined that the execution of the right tasks to reach the expected outcome is recorded through the figure "*work efficiency*". This is mainly due to the fact that counterproductive operations lead to a higher workload compared to the initial planning. Within a work organization context, the term "*effectiveness*" refers to the rework of an initial completed task. An iteration may be necessary for the following reasons: It is the repetition of initially completed work outcomes due to the availability of new and modified information, or an upstream task need to be repeated when the downstream task discovers some sort of error or incompatibility. Yet, a modification of a task by another person of a different work system can cause iteration, too.

Definition "*Rework*"

Rework of a task is said to occur when the current work results have to be modified that beforehand were regarded as "*finished*", and transferred as an input to the same or a different work system. A possible reason of rework could be a faulty or incomplete output due to missing information or erroneous actions or erroneous transmission of information.

In contrast to a manufacturing process, the quality of content and methodology cannot be compared to a reference value due to the heavy reliance on individuals and on non-standardized production. Nevertheless, in order to enable an assessment, we differentiate the investigated tasks and interruptions by the addressees and the generated results. If a result is the input and the output of the same work system, we imagine that the "*planning and control system*" of the system only considers a result as completed if it has a sufficient quality. In contrast, if the result is handed over to another work system, the external "*planning and control system*" assesses the content and methodology of the result. Afterwards, the previous result is again transferred to the observed work system and the information regarding the results may get revised. Therefore, we focus on the assessment of results, which are handed over to an external work system.

To ensure the consistency of indicators, we are making use of the currency concept. When a result is handed over to another employee, the person of the work system has to estimate the time (earned value) still required to reach an adequate result for the recipient. In case of a response, the required time for rework of the results is an indicator for the genuine quality of the content and the methodology of the previous outcome. In this respect, the relative proportion of time, which is based on a modified or an enlarged task, has to be separated for calculating the figure.

Figure "*effectivity of task processing*" (*EP*)
The figure relates exclusively to tasks for which the output is transferred to another work system and a verification of the results is expected—"*task for resubmission*". As an input, at the date of handover $n = 1$, the expenditure of human labor $ET_{i,w}^{m(1)}$ and the anticipated rework $ET_{i,w}^{n,p}$ is measured. Following a feedback, the required time for rework $ET_{i,w}^{n,m}$ minus the time $ET_{i,w}^{n,a}$ which is caused by a modified or enlarged task, must be identified and are included in the calculation of $EP_{i,w}$:

$$EP_{i,w} = \frac{\sum_{n \in N} ET_{i,w}^{n,m} - ET_{i,w}^{n,a}}{ET_{i,w}^{m(1)} + \sum_{n \in N} ET_{i,w}^{n,p}}. \tag{12}$$

The consolidated key figure value of all finished task shall be calculated as follows:

$$EP_{ges.} = \frac{1}{\sum_{t=t_{min}}^{t_{max}} y_{i,t}} \sum_{t=t_{min}}^{t_{max}} y_{i,t} EP_{i,w}, \ \forall i \in A. \tag{13}$$

Figure "*Relative adherence to schedule*" (*RT*)
An important subsidiary aspect of the quality of an individual work organization is the period between the planned and actually realized date of completion. The former value is imposed by the "*planning and control system*" of the observed or the external work system. Both times describe the robustness of the individual work system. The time units after the scheduled time represent penalty minutes. We consider these time units as an indicator of an ineffective individual work organization, or an unrealistic definition of the planned date of completion. The calculation of the figure $RT_{i,w}$ for the completed task i is based on the quotient of the measured workload $ET_{i,w}^{m}$ and the period between the planned t_i^p and measured date t_i^m of completion:

$$RT_{i,w} = \frac{t_i^p - \sum_{t=t_{min}}^{t_{max}} y_{i,t} t}{ET_{i,w}^m} = \frac{t_i^p - t_i^m}{ET_{i,w}^m}. \quad (14)$$

The consolidated key figure value of all finished task shall be calculated as follows:

$$RT_{ges.} = \frac{1}{\sum_{t=t_{min}}^{t_{max}} y_{i,t}} \sum_{t=t_{min}}^{t_{max}} y_{i,t}\, EQ_{i,w}, \ \forall i \in A. \quad (15)$$

4 Conception and Implementation of the Software

The calculation of the defined key performance indicators (*KPI*) requires a data basis, provided by a measuring tool. Existing tools, *such as ORTIM time, REFA time, Getting Things Done* and *Every Task*, do not allow an assessment of the individual work organization if the work processes are weakly-structured. Furthermore, a second person is required to use the tools. Also, the defined *KPI*s have not been implemented to date. Therefore, a new software framework will be presented and verified in the following sections.

4.1 Software-Framework

The application is structured according to three defined variants. These differ in terms of time, required for data entry and the informative value of the *KPI*s as well as the deducible directives. The specific functions of the software build upon one another and their combination results in three separately usable software versions. By that, the user can select the so-called "*basic version*", "*evaluation version*" or "*expert version*":

– The "*basic version*" offers the possibility of a continuous task analysis. Here, the tasks processed during a work day are recorded with their particular time of operation. In addition to the tasks of the service projects and the day-to-day business, self-initiated and external-initiated interruptions are documented. Therefore, the generated database contains information regarding the dates and the frequency of task-processing and interruptions as well as the characteristic of the observed rotation of tasks. Based on these data, the deducted *KPI* "*work efficiency*" assesses the deviation between the planned and required expenditure of time for each task. Furthermore, the proportion of the defined task categories as well as the fragmentation of a working day is captured.
– The "e*valuation version*" is an enhanced version of the "*basic version*". In particular, it allows the calculation of the *KPI* "*perceived work efficiency*" which can be determined for an individual task as well as for the whole of the completely processed tasks.

– The application of the "*expert version*" leads to the calculation of all *KPI*s, defined in Sect. 3.3. In addition to the evaluation of the planned and measured date of completion, the required time for an iterative task processing is recorded. Furthermore, this version includes an assistance system which proposes the user a probable expenditure of time for a specific task processing. Such a value is calculated based on historical data.

4.2 Software Application

The software-framework was implemented for the Android operating system—a so-called application (*APP*). In order to graphically optimize the user interaction and the dialogs, we focus on tablets and smartphones with a screen size of at least 4 inches. For each type of device, we developed a specific layout, in regard to the orientation—vertical vs. horizontal—and the screen size of the used device.

4.2.1 Dialog Boxes for Interaction

The "*main screen*" of the software comprises four areas: "*task pool*", "*task collection and interruptions*", "*workbench*" and "*menu bar*". Thereby, the "*main screen*" is the starting point of any user interaction. If a tablet is used, these areas are arranged on the right side of the screen while the application- or situation-specific dialog boxes are situated on the left side. An overview of the Human-Machine-Interface is depicted in Fig. 3:

– The area "*task-pool*" includes all tasks which have to be processed by the employee of the work system. Thus, it represents the current status of his or her work basket. Besides the name and the importance of a task, the required time for a complete processing as well as the already consumed time exposure are displayed. To ensure a concise presentation, the current tasks can be filtered regarding their assignment to a project or the day-to-day business.
– The "*workbench*" comprises the currently processed task or interruption. Therefore, its content indicates the status of the employee (user of the *APP*). Besides the task-specific information—name, importance, required finishing time—the consumed expenditure of time is presented up to the respective point in time. This value is depicted in minutes and shown as a bar diagram. The bar has at the beginning a green color and the bar height increases during task processing. If the consumed effort exceeds the planned value, the bar is removed and a new bar with a red color appears. This bar increases also proportionally to the consumed time during the further task processing.
– The "*pool of standard tasks*" contains the buttons for tasks, which are often chosen by the user during a work day. Standard tasks can be defined and sequenced individually in this area.
– The button for indicating the occurrence of an "*interruption*" is arranged next to the "*workbench*".

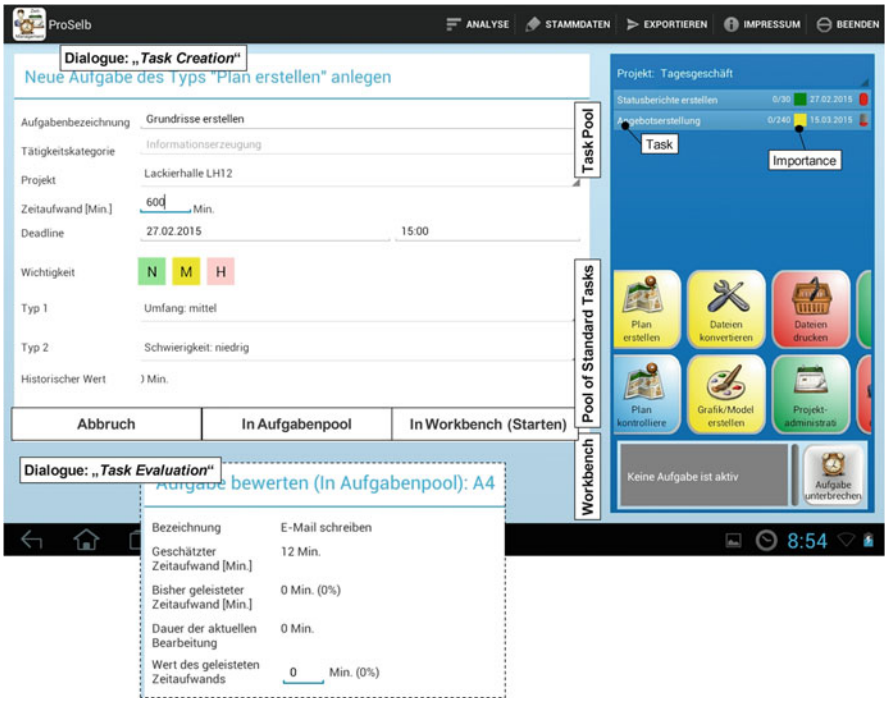

Fig. 3 Structure of the application's user interface

– The "*menu bar*" includes the functions for switching to further dialog boxes. These boxes enable the user to analyze the recorded working day and the calculated *KPIs*. Furthermore, a function allows the termination of a working day.

4.2.2 Software Functions for Data Collection

The software-framework is based on a so called "*project/task – workbench*". This means that in the case of the initial use of the *APP*, the current service projects of the employee as well as the category "*day-to-day business*" have to be generated. For this purpose, the user must select the button "*new project*" in the "*menu bar*". Thereby, it is possible to edit the entries or to create additional projects at a later point in time.

Furthermore, so-called "*standard tasks*" can be defined. Such a "*standard task*" represents a task category or an action, which occurs several times during a regular working day of the user. Due to the individual definition of "*standard tasks*" it takes up much less time to create a new task during the process of data collection. For example, an employee in a service company for factory planning will define a standard task for "*Writing an email*" or "*Submitting a building permission*".

Subsequent to the initial start of the *APP* and the definition of projects and "*standard tasks*", the user has to create his or her current tasks and to assign them to a project or the category "*day-to-day business*". To create such a new task, the user can select one of the buttons representing a "*standard task*" or he/she may use the button "*user-defined task*". In both cases a dialog box appears to enter the relevant information of the task (Fig. 3).

Based on the selected software version (*basic*, *evaluation* or *expert*), a variable number of user inputs is required. After entering the information, the user must decide, whether the task has to be assigned to the "*task pool*" or the "*workbench*". The latter means, that the user will process the new task subsequently to its creation. During the phase of processing, the task will appear in the "*workbench*". Each minute of such a processing leads to a proportional rise of the expenditure of time. If a new task has to be set up, the user is able to select at any time a task from the "*pool of standard tasks*" or can choose the button "*user-defined task*".

If the user wants to interrupt the current task processing to start working on another task, he or she can choose a task from the "*task pool*" or can create a new task. With such an action, the dialog box for the assessment of the past processing phase appears (Fig. 3 – "*expert version*" of the *APP* is shown). The information to be entered in the box provides the basis for the calculation of the *KPI*s (Sect. 3.3).

Besides the evaluation of the current processing phase, the user has to indicate whether: 1) the task is completely processed, 2) the task has to be processed further at a later point in time (reassignment to the *task pool*) or 3) the task has to be indicated for a later resubmission. The latter describes a transfer of the outcome of the task processing to another employee (outside the observed work system), and the expectation of feedback and rework. Task with the status "*resubmission*" are differently colored in the "*task pool*" and can be hidden from the display if necessary.

In case of an externally or self initiated interruption, the user has to select the button "*interruption*". Following this selection, a specification of the type of the current interruption is necessary. Afterwards, the interruption appears in the "*workbench*" and the last processing phase has to be evaluated by the user. Hereby, the previous processed task is automatically moved to the "*task pool*". If the user selects the button "*task restart*", the interruption is terminated and the previous task is reassigned to the "*workbench*". In analogy to a task switch, the dialog box for the assessment of the interruption appears.

The operating philosophy of the *APP* ensures that subsequent to the start of the *APP* and the initial selection of a task, a task or an interruption is always assigned to the "*workbench*". Only if the user selects the function "*termination of the work day*" from the "*menu bar*", the data collection is terminated and the task is removed from the "*workbench*". This guarantees a continuous assignment of all minutes of a working day to a specific task or interruption.

4.2.3 Software Functions for Data Analysis

The screen "*daily overview*" (Fig. 4) presents the tasks and the interruptions which are processed by the user on a working day. If the user selects the menu item "*analysis*" and subsequently the section "*daily overview/schedule*", a daily overview of a single working day occurs on the screen. Thereby, the tasks and

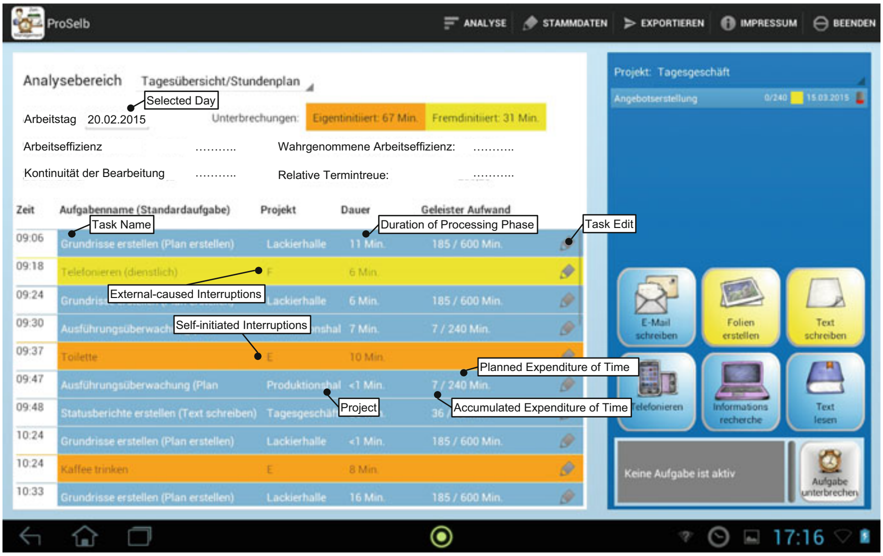

Fig. 4 Depiction of the daily overview and the central KPI

interruptions are chronologically assigned to the presented timeline. Therefore, a task can be listed several times, due to task switches and interruptions. For each processing phase of a task, both the planned as well as the cumulated expenditure of time are presented.

The button "*pencil*" (edit) enables the user to edit a recorded processing phase of a task or an interruption. Besides the adjustment of the duration, the user can remove or insert a processing phase.

Furthermore, the overview of the selected day provides a summary of the central *KPIs*. Thereby, the *KPIs* "*working efficiency*" and "*perceived working efficiency*" are only calculated for completely processed tasks. In addition, the expenditures of time for the self-initiated breaks and the external caused interruptions are displayed.

A detailed reporting of the *KPIs* for a processing phase, a single task or a working day are displayed in the sections "*task overview*" and "*KPI overview*". In these sections, all introduced *KPIs* (Sect. 3.3) are presented to the user for a single task, a single working day or a freely configurable period of time.

5 Field Study

With regard to the absence of empirical research about the individual work methods of an employee during a service provision, this paper addresses the following research question: Which *KPI*s for the assessment of an individual work organization exist, and how do communication delays and interruptions affect the quality of task scheduling and processing? Specifically, we focus on the intended effect of the individual work organization on the productivity of a service. Due to the fact that we were not able to investigate all stakeholders of a knowledge-intensive service provision, we have drawn on, and synthesized prior research on the documentation of the tasks and the interruptions of one employee, as well as the *KPI*s for the individual work organization. We believe that only a field study can further improve our collective understanding of the complexity of using an *APP* to measure and analyze the individual work organization. In order to use such a tool in a company, we present the outcome of a small verification study for the software concept as well as data of a service company.

5.1 Data Sources and Methods of Data Collection

The validation study for the developed software concept was based on two main ethnographic techniques [10]: participant observation and use of short interviews. The level of detail required for the individual calculation of the introduced *KPI*s demanded the capturing of tasks to be performed by the employee of the work system. We decided that a direct observation technique such as "shadowing" observation technique, similar to the methods used in previous studies of [3, 10], would be disruptive and inaccurate. Thus, we asked the employees of the work systems to keep diaries to generate the information needed for the verification of our concept. In our case, each employee of a work system tracked his or her activities during each observed work day and participated in a short follow-up interview. Whenever the employee got a new task or performed an action such as making a phone call or writing an email, he or she had to write down the time and other details regarding the task. Whenever the documentation of an individual work organization was unclear, we asked the observed subject at the end of the day. Inspired by Beuscher-Mackay's [3] structured observation method, we designed a tracking log where we transcribed the generated data (e.g. time stamps, event type, types of cooperation) of activities and interruptions. A total of 9.575 min was recorded in the observation at the field site.

Over a period of three consecutive days, eight people aged between 27 and 36 years (28, 20 years, $SD = 3.53$) were investigated. Each employee documented his/her individual work organization for the whole day. Before the data collection started, a further day was used to introduce the concept of the survey. For the next three following days, a formal data collection was done and the average time of formal observation for each individual was 6:39 h ($SD = 1{:}13$ h).

All eight employees worked in offices; two had an office with two fully-employed persons. Each workplace had a computer with internet connection, phone and resources such as books, binders, stationary, etc. The printer and copier were located at the end of an aisle. Due to the fact, that in general the doors were left open, the employees were able to easily communicate with other colleagues.

5.2 Results

Within the investigation period, the number of tasks processed by all employees was 106. Moreover, 192 interruptions were caused by employees of external work systems or were self-initiated breaks. The employees spent an average of less than 25 min (SD = 5 min) on a task before they switched to another task, or were interrupted. The data collected also indicates, that in fact, the effort required to completely process a task was in average approximately 70 min (*SD* = 10 min). Thereby, a single interruption took quite long (combined mean = 11 min, *SD* = 5 min). But, the most surprising fact was that a person easily spent over 9 min for an informal communication with a colleague before he or she chooses another task.

Taking into account the findings of previous research [3, 10, 17], we structured our data into eight main groups of tasks in order to compare our results with those of earlier studies. Therefore, analogous to Beuscher-Mackay the category "desk work" was defined as the time during which employees were sitting at a desk and worked with a computer or other physical artifacts [3]. Compared to earlier studies [13, 17] with non IT-based work systems our results reveal that more time was spend in deskwork, but that the findings are very similar to the results of Gonzáles and Mark [10]. Yet, the time spent on unscheduled meetings (e.g. going and entering to other offices, meeting at the coffee machine or the copier) was substantially lower (combined mean = 21 min., *SD* = 6 min.) than the level identified by Gonzáles and Mark [10] (98 min). This is not surprising, as the investigated employees mostly worked in their own single office, and not in cubicles (open space office). Therefore, it was not easy to interact and communicate with colleagues without moving. On the other hand, the results for the time spent on planned meetings (7, 8 % of all task categories) confirm the previously identified relationship between a higher hierarchical position, and more time spent in meetings [10].

The task categories are divided as outlined in Fig. 5, with a focus on the relative quantity as well as the proportion of time spent on each category. Looking more closely at the distribution of time across the categories, we can clearly see that also an average short-term duration of a task category (e.g. emails, telephone calls) can causes a greater proportion of work time. A major reason is the high frequency of new tasks (writing emails or telephone calls), which occur unannounced.

The individual work organization can result in a planned or unplanned task switch as well as the occurrence of an interruption. If an interruption occurs, in almost 60 % of the cases employees resume the disturbed sequence. The duration of a non self-initiated interruption can range from 2 min up to 25 min. In Fig. 6 and Table 1 the distribution of the interruptions among the observed employees is shown.

In fact, the large number of interruptions for w_4 resulted from the location of his office within the building—close to the copier—and the occupancy of the room with two fully-employed employees and one temporarily present assistant. This leads to interruptions caused by colleagues within the room and employees who worked at the copier. However, the good values for "*work efficiency*" and