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Optimizing Assignment of Knowledge Workers to Office Space Using Knowledge Management Criteria

The Flexible Office Case

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Abstract: Even though knowledge management has been around for more than a decade, so far concrete instruments that can be systematically deployed are still rare. This paper presents an optimization solution targeted at flexible management of office space considering knowledge management criteria in order to enhance knowledge work productivity. The paper presents the Flexible Office conceptual model and optimization solution. It discusses the theoretical foundation, assumptions and reasoning. A corresponding prototype was field-tested, successfully introduced, evaluated with the help of a series of interviews with users and improved according to their requirements. The paper also reflects on the organizational impact and lessons learned from field test and practical experience.

Keywords: flexibility, hypertext organization, knowledge management, knowledge work, office space, optimization
Categories: G.2.3, H.1.2, H.4.1 H.5.3, K.4.3, M.5

1 Introduction

Knowledge management (KM) has been around for about twenty years since its inception by [Sveiby 87] and [Wiig 88] and a number of KM instruments have been developed which can be applied for systematic interventions into the way an organization handles knowledge [Maier 07, 195]. Examples are communities and knowledge networks, competence management, lessons learned, best practices or semantic content management. Many organizations have built an organizational and a technical infrastructure in order to support KM-oriented tasks, such as creating, sharing, applying and retaining knowledge. The organizational infrastructure involves establishing new roles, such as subject matter expert, or fostering informal groups, such as communities [Brown 91], [Lave 91]. The technical infrastructure comprises

information and communication technologies (ICT) that provide advanced discovery, publication, collaboration and learning services for a knowledge worker's (KW) work place, sometimes called semantic desktop [Sauermann 05].

However advanced these infrastructures are, many of the more human-oriented KM protagonists (e.g., [Wiig 04]) keep stressing the importance of face-to-face meetings for exchanging the most relevant knowledge which is a combination of implicit and explicit knowledge that can only be handed on in a process of socialization. In this context [Espinosa 02] found that coordination and performance of project teams is positively influenced by team mental models. Since project teams often work locally dispersed, face-to-face meetings that are ensured by a systematic assignment of employees might help to build such models and increase performance. Consequently, it seems promising to apply KM-oriented criteria to flexibly assign office space to KWs in order to provide them with opportunities to meet those co-workers who are currently engaged in the same processes or projects, who work on the same themes or who advance the same competences. Building on an existing KM infrastructure that provides easily accessible data on KM-relevant criteria such as KWs' skill levels, organizational affiliation, projects or themes, this paper presents the Flexible Office solution, which has been developed with and implemented at GISA, a medium-sized IT company.

Section 2 discusses the main reasons motivating the solution. Section 3 presents the Flexible Office concept and the optimization solution. Section 4 gives details on implementation and reports on practical experiences and feedback given by KWs affected by the solution. Section 5 finally concludes the paper.

2 Motivation and point of departure

Interventions into handling knowledge in organizations, also called KM initiatives, attempt at creating an environment that supports the handling of knowledge and ultimately lead to increased organizational effectiveness. Figure 1 breaks down KM initiatives into a strategic, a design and an operational management level and gives an overview of four main pillars for such interventions. Generally, the model starts on the strategic level with a KM strategy. This strategy is in turn designed and implemented to create a supportive environment for the knowledge-oriented activities on the operational level [Maier 07].

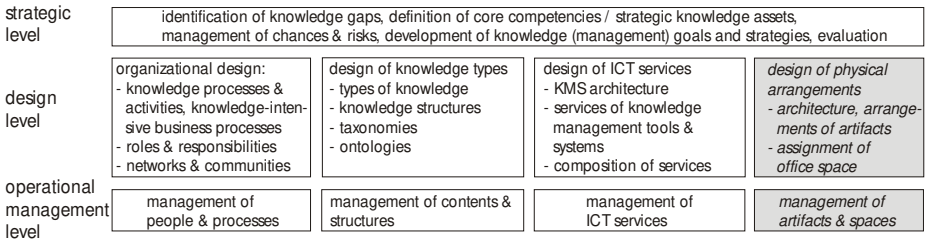

Figure 1: Strategy, design and operational management of KM initiatives (based on [Maier 07 154])

Starting point is the identification of knowledge gaps or knowledge-related problems in an organization [Zack 99]. A strategic KM initiative can also analyze the (core) competencies [Prahalad 90] and strategic knowledge assets [Teece 98] of an organization, discuss the chances and risks that come with these assets, particularly on the level of operational processes [Bayer 07], before strategic knowledge (management) goals are defined and corresponding knowledge (management) strategies are developed that aim at achieving these goals or at developing, improving or applying (core) competencies [Zack 99a].

On the design level, interventions can be basically divided into four distinct areas: design and implementation of (1) organizational and people-oriented instruments, (2) knowledge types and structure, (3) ICT resources that are viewed as services and (4) physical arrangements.

On the operational management level, the effects of the implementation of the four groups of instruments are constantly evaluated based on the operative knowledge goals derived from the strategic knowledge goals: (1) **processes**: management of people and processes, (2) **types**: management of contents and structures, (3) **services**: management of ICT services as well as (4) **locations**: management of artifacts and spaces. Processes, types and services can be seen as intertwined when designing organizational and ICT infrastructures that support handling of knowledge [Maier 07, 624].

The fourth pillar, however, includes architecture and design of physical arrangements of objects that e.g., convey meaning and represent manifestations of the organizational culture, offer spaces for knowledge sharing, minimize distances between employees who frequently have to communicate face-to-face or provide for happen-stance encounters that foster knowledge sharing. Many positive practical case examples of efficient knowledge sharing praise informal interaction of employees. Informal face-to-face interactions take place, e.g., on hallways, in coffee kitchens, lounges or at lunch. An effective (physical) space management represents the required knowledge transfer and arranges work spaces of those people close to each other who regularly work together [Probst 98, 226]. Space management can be highly effective and even prove more useful than the most advanced ICT system as good social relationships often are positively correlated with personal encounters. Examples for objects of space management are [North 98, 264], [Roehl 00, 179]: the size and sequence of offices, position of secretaries' offices, width and length of hallways, the design of office space and the arrangement of meeting space and meeting rooms. Recently, the virtualization of work spaces has changed requirements for architecture substantially as mobile knowledge workers demand to have a work environment as complete as possible wherever they are. These new requirements lead to new office forms such as nomadic offices, market offices, festival offices, just-in-time offices, non-territorial offices, project offices or so-called business clubs (e.g., [Lippert 97]).

The Flexible Office project described here concentrated on this fourth pillar, called locations. More specifically, the focus is on the effective use of existing physical offices by assigning employees to office space according to KM criteria. From a practical perspective as identified in a first workshop at GISA, the Flexible Office project was motivated by the following main observations:

Mobility: KWs increasingly work outside their offices, e.g., at their customers' offices, on the road or at home. In the Flexible Office project, the average percentages

of time spent outside the company were determined for all organizational units. It turned out that in one unit, KWs spent on average almost 30% of their working time outside the company with a minimum of 14% and a maximum of 55%. If one additionally considers the time spent in meeting rooms or offices of colleagues, these quotas are substantially higher. This organizational unit was therefore chosen for the pilot study of the Flexible Office project. Economically, the high portion of time spent outside the company leads to many empty offices and thus to inefficiencies in usage of office space. More efficient use of office space could allow for growth without the need to rent additional office space. From a KM perspective, distribution of KWs over a number of offices inside and outside the company leads to inefficiencies in communication and knowledge sharing.

Project orientation: Office structures at the company reflect the traditional organizational structure and thus are arranged according to the organizational units established in the business system. Typical for an IT company, projects play an important role and therefore they need to be carefully considered. GISA is characterized by a multitude of projects that span organizational units and employees working on a number of projects at the same time. Both, project managers and project team members suffer from the team being spread over a number of offices and would profit from the possibility to reserve a room for team members for a certain amount of time, e.g., for a project kick-off, for preparation of a milestone result or report, for finalizing a project or for documenting lessons learned.

Knowledge management: The increasing velocity, with which new products and services are created, in this case standard and individualized software products as well as consulting services, leads to an also increasing importance of knowledge [Bonora 93], [Grant 96], [vonKrogh 96]. This means that KWs improve their competencies, are engaged in learning activities and co-develop themes that span organizational units and project teams [Alvesson 04]. Flexible offices systematically take into account the themes which KWs develop that can hopefully be turned into successful projects in the future. As a consequence, work place learning, knowledge transfer between KWs working on the same theme as well as training of KWs new to the job or the theme might be improved with such a solution.

The three observations can be merged by the model of the hypertext organization developed by [Nonaka 94]. In this perspective, the well-known metaphor of a hypertext document is used to denote the synthesis of traditional hierarchical organizational structures with non-hierarchical, self-organizing structures in order to combine efficiency and stability of the hierarchy with dynamism and flexibility of cross-functional task forces. The hypertext organization consists of three layers:

- **business system layer:** performs business processes and routine operations typically organized in a traditional hierarchy,
- **project team layer:** comprises self-organizing project teams pursuing time- and resource-constrained goals,
- **knowledge base layer:** comprises knowledge resources, themes and competences embedded in people, procedures, documents and the organizational culture.

These three layers form a hyper-linked network. In this view, KWs are engaged in the business systems layer and handle topics as well as use competencies from the

knowledge base layer. Furthermore, nearly all KWs are engaged in projects. The close relationship between the project team and knowledge base layer is also supported by the work of [Schindler 03] who focuses on various methods to capture knowledge that is created in projects. Office space is typically assigned to KWs using only one of these dimensions, mostly the business system dimension. However, KWs are engaged in the three layers in parallel and shift their attention flexibly between these layers.

The analysis of current practice performed at the beginning of the project was structured along these three layers. Consequently, various documentations as floor plans and organizational charts were used to analyze the business system layer. The KWs are organized in three business units that are subdivided into seven units and spread over four floors in the company. The business units concern the main themes IT consulting, hosting of applications and a data processing centre. The first business unit, IT consulting, is of particular relevance, since this group of KWs is characterized by a comparably high degree of mobile work. Moreover, the company employs a comparably high number of external freelancers who work temporarily in projects and also have to be integrated into the structural organization for this time.

The analysis of the project team layer was predominantly supported by self reporting of time spent on various projects and in various locations, e.g., at office, at colleague's office, at meeting, at customer, performed by five employees and personal interviews to detail the self reporting. This data was collected in order to get an impression about the day to day project business. Consequently, the share of project work is 77% of the entire work time. The employees participate in between two and six projects concurrently with an average of app. four projects per employee. Moreover, the need for project communication, e.g., meetings, coordination, requires app. 19.4 hours per week and employee.

Concerning the knowledge base layer, GISA had already implemented a number of knowledge management measures. Although GISA had not implemented a systematic initiative for knowledge management, a number of fragmentary projects had been initiated that contributed to a better handling of knowledge, such as document management, skill management and employee portal. The analysis showed that the skill management initiative was promising for the assignment of office space, since this approach is based on a detailed taxonomy of skills. The top level of this taxonomy comprises e.g., consulting, product, programming and project management skills, whereas for each employee the corresponding skill levels are available. These levels range from beginner over experienced to expert knowledge. Moreover, the knowledge exchange and personnel development are important values at GISA. Concerning flexibility, the employee portal not only draws together a number of contents and services from heterogeneous systems, but also allows access to these from outside the company, an important prerequisite for true flexibility of office arrangements.

A list of business travels as well as self reporting and the interviews were used in order to identify which work places should be included in the pilot study and in order to determine the sharing ratio. The absence ratios of the selected business unit IT consulting are about 32%. Moreover, the employees state that they use their stationary work place only for 35% of the work time and spend about 28% of their work time in meeting rooms or offices of colleagues. Mobile work places are used in 5% of the work time.

The following figure summarizes the relationships between the three layers of the hypertext organization and also includes some main results of the analysis that was also guided by this structure.

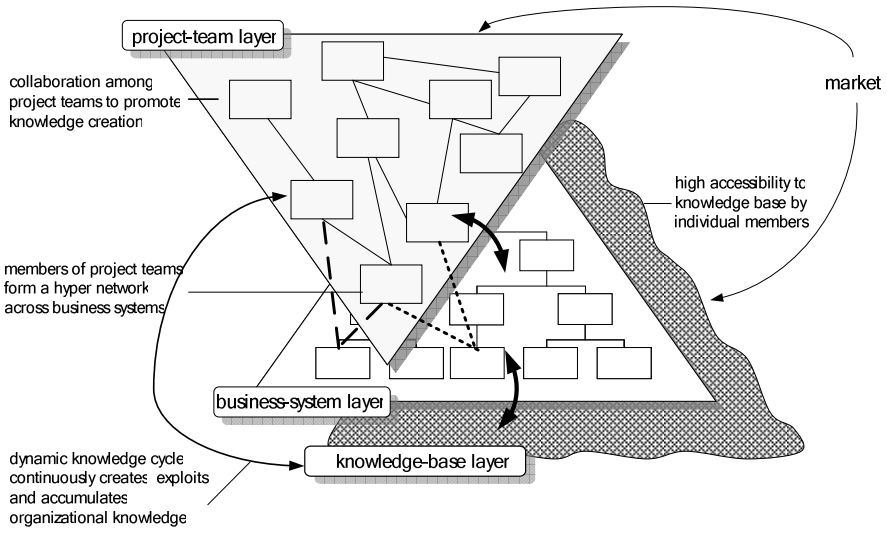

Figure 2: Hypertext organization (based on [Nonaka 94])

Based on this data and supported by the analysis of case studies of other companies that have flexible offices in place, e.g., Siemens, Accenture or Brose, the initial sharing ratio was set at 1.18 meaning that 28 work places were provided for 33 employees. This limitation of work places should assure an economic usage of office space and avoid vacancies. However, in addition to economic aspects, this approach focuses on increasing knowledge work productivity. In particular, a flexible assignment of office space should improve e.g., knowledge exchange and networking between employees as well as an effective integration of newly hired employees, which is especially of relevancy for a fast growing company like GISA.

All in all, the Flexible Office solution considers the three dimensions of the hypertext organization for the assignment of office space and thus for the provision of opportunities for interaction for KWs with the help of a set of optimization variables. Especially the data collected via self reporting and interviews with employees, project, team and business unit leaders supported the development of criteria that match with the requirements and characteristics of the company.

3 Flexible Office Concept

The Flexible Office conceptual solution consists of a technical and an organizational component. *Organizational issues* concern selecting employees, designing office space, analyzing requirements concerning equipment, defining rules as well as

assigning roles. The selection of employees who participate in the Flexible Office solution and thus share their work places is limited by absence quotas and by factors such as sensitivity of the tasks, e.g., daily use of HR records. Also, willingness to participate had to be ensured. This was supported by several meetings communicating the benefits of the approach and identifying prejudices, fears and expected barriers. A pilot group consisting of KWs, project managers and external consultants was set up to test a flexible arrangement of work places. This group also specified the requirements concerning office space, equipment, organizational rules and roles.

The required office space was selected and designed according to the preferences of the pilot group. This included furniture and specific office equipment, e.g., beamers and whiteboards, supporting communicative tasks. Concerning technical equipment, Flexible Office members were set up with mobile phones, blackberries, UMTS network access for laptops as well as a remote access solution and a virtual private network for home office or customer office access to company servers.

Moreover, organizational rules were defined that specify for example the timeframe and deadline in which rooms or single work places can be booked, mechanisms for escalation of urgent bookings or conflicts between projects, requirements concerning distribution of mail and organization of central project repositories. Additionally, a clean desk policy was established demanding that no personal items are left on the work place in order to ensure unhindered usage by several employees. In order to ensure compliance to the rules, a separate role "Flexible Office manager" was introduced to resolve minor questions and problems, forward problems and escalate conflicts and claims of the participating employees.

The *technical component* is a hotelling software that considers the three main areas of requirements mobility, project orientation and knowledge management described in section 2. Differentials to standard hotelling software are that assignments of work places consider KM-oriented criteria such as project and theme overlappings between KWs, their preferences and reservations by project managers. These criteria supposedly lead to improved communication and coordination in projects, decreased search time, improved knowledge transfer, work place learning and improved handover of projects between project teams and organizational units responsible for operation and maintenance of the resulting application systems. The hotelling solution was integrated into the B2E (Business to Employee) information infrastructure in the form of an employee self service portal. The software solution consisted of

- user interface for project managers to reserve office space for their projects,
- user interface for KWs to submit their preferences, to apply for home office days and for those work spaces that have not been assigned automatically,
- the core optimization component for the assignment of rooms,
- output components for visualizing the solution in the B2E portal and for notifying KWs per email about the booked rooms.

In the following, the core optimization component is described in some detail. The booking process determines the optimal assignment of work spaces according to the predefined criteria for one work week. Reservations and preferences have to be submitted until Thursday evening in the week preceding the booking week. The results are forwarded to KWs on Friday noon.

Criteria have been quantified and the optimization problem has been formalized with the help of standard operations research methods. The utility function (score) that is optimized consists of a number of weighted factors (described below).

Factors regarding the project team layer

Reservations by project managers: project managers can reserve a room for one or more KWs of a certain project. In case of two competing reservations, the demanded room will be assigned to the project with the higher priority. Due to hierarchical legitimation, reservations by project managers are treated separately as a kind of "K.O."-criterion.

Attractive rooms for important projects: rooms are valued according to the attractiveness estimated by KWs on a scale from one, i.e. very unattractive, to ten, i.e. very attractive. A project score consists of a project category reflecting the importance of the project and its customer as well as a time-variant score dependent on the state of activity of the project. These two parts give a project score between 1, i.e. less important project in standard mode, and 9, i.e. very important project in a "hot" phase. Multiplying both leads to results in which attractive rooms are assigned to important, currently highly active projects.

$$po_{ab} = \alpha * pao_{ab} + \beta * ppo_{ab}$$

$$pao_{ab} = \left(\frac{\sum_{i \in P} pa_{ai}{}^{*} pa_{bi}}{\sum_{i \in P} pa_{ai}} + \frac{\sum_{i \in P} pa_{ai}{}^{*} pa_{bi}}{\sum_{i \in P} pa_{bi}} \right) / 2 \quad for \sum_{i \in P} pa_{ai} \neq 0 \quad and \sum_{i \in P} pa_{bi} \neq 0$$

$$pao_{ab} = 0 \quad otherwise$$

$$ppo_{ab} = \left(\frac{\sum_{i \in P} pp_{ai}{}^{*} pa_{bi}}{\sum_{i \in P} pp_{ai}} \right) for \sum_{i \in T} pp_{ai} \neq 0$$

$$ppo_{ab} = 0 \quad otherwise$$

$$pa_{ei}, pp_{ei} \in \{0,1\}, \forall i \in P; \forall e \in E$$

$$pao_{ei}, ppo_{ei} \in [0,1], \forall i \in P; \forall e \in E$$

$$\alpha = 1 - \beta \quad 0 \leq \alpha \leq 1, \quad 0 \leq \beta \leq 1$$

Formula 1: Project overlappings

Project overlappings: this criterion values the relationships between KWs with respect to their work in projects. Goal is to assign those KWs to the same room who are members of the same projects in as many cases as possible. In Formula 1, project overlappings po_{ab} between two KWs *a* and *b* are calculated as the weighted sum of joint project assignments pao_{ab} and project preferences ppo_{ab}. Project assignment overlappings pao_{ab} are calculated as follows: pa_{ai} is the project assignment of KW *a* to project *i* as Boolean expression. The term in the numerator counts every project overlapping between *a* and *b*, i.e. if *a* and *b* are assigned to project *i,* the term value is 1, otherwise it is 0. In the denominator, the number of assignments of KWs *a* and *b*

are separately counted. Then, the average of both ratios is calculated. The value 0 is assigned to the term *pao* in case either one of the KWs *a* or *b* is not assigned to any project. Also, KWs can submit a project preference pp_{ai} stating that KW *a* prefers to work on project *i* mostly in the booked time frame. This means that these overlappings are considered twice with respect to the preferred project of KW *a*. The value 0 is assigned to the term *ppo* in case there are no preferences. Due to *pao* and *ppo* being defined in the interval [0;1] as well as $\alpha=1-\beta$, the resulting term *po* is also defined in the interval [0;1].

$$to_{ab} = \alpha * tao_{ab} + \beta * tpo_{ab}$$

$$tao_{ab} = \left(\frac{\sum_{i \in T} to_{abi}}{\sum_{i \in T} ta_{ai}} \right) for \sum_{i \in T} ta_{ai} \neq 0$$

$$tao_{ab} = 0 \quad otherwise$$

$$to_{abi} = 1 \quad for \quad |SL_{ai} - SL_{bi}| \leq \varepsilon, i \in T; a,b \in E$$

$$to_{abi} = 0 \quad otherwise$$

$$tpo_{ab} = \left(\frac{\sum_{i \in T} tpo_{abi}}{\sum_{i \in T} tp_{ai}} \right) for \sum_{i \in T} tp_{ai} \neq 0$$

$$tpo_{ab} = 0 \quad otherwise$$

$$tpo_{abi} = 1 \quad for \quad tp_{ai} = 1 \quad and \quad SL_{bi} \geq SL_{ai}, i \in T; a,b \in E$$

$$tpo_{abi} = 0 \quad otherwise$$

$$ta_{ei}, to_{abi}, tp_{ei} \in \{0,1\}, \forall i \in T; \forall a,b,e \in E$$

$$tao_{ei}, tpo_{ei} \in [0,1], \forall i \in T; \forall e \in E$$

$$\alpha = 1 - \beta \quad 0 \leq \alpha \leq 1, \quad 0 \leq \beta \leq 1$$

Formula 2: Theme overlappings

Factors regarding the knowledge base layer:

Theme overlappings: similar to project overlappings, theme overlappings consider the relationship between two KWs according to the themes that they work on. The assumption behind this is that KWs working on similar themes who also have a similar level of skills concerning these themes should be assigned to the same room in order to improve knowledge sharing. Theme overlappings too are calculated according to the first expression in Formula 2, i.e. they are the weighted sum of theme assignment overlappings *tao* and theme preference overlappings *tpo*. As for *tao*, theme assignment ta_{ai} is a Boolean expression and is 0 if KW *a* is not assigned to theme *i* and is 1 if a works on theme *i*. The formula only takes into account those theme overlappings to_{abi} for which skill levels SL_{ai} and SL_{bi} of KWs *a* and *b* with respect to theme *i* do not exceed the threshold ε. Again, KWs can submit theme preferences tp_{ai} which in this case means that KW *a* would like to sit in a room with a

person that has the same or a higher skill level with respect to the preferred theme *i*. In this case, theme preference overlappings *tpo* are calculated according to the second expression in Formula 2. This additionally considers overlappings of preferred themes for which KW *b* has a skill level at least as high as KW *a*. The value 0 is assigned to the term to in case KW *a* is not assigned to any theme. Due to *tao* and *tpo* being defined in the interval [0;1] as well as $\alpha=1-\beta$, the resulting term to is also defined in the interval [0;1] and is higher with increasing congruence of theme assignments between KWs *a* and *b* reflecting the assumption that the better the congruence of context between KWs, reflected in similar theme assignments, the easier it is to transfer knowledge between them.

Factors regarding the business system layer

Work group overlappings: KWs can submit a preference for a certain work group wgpo meaning they wish to work with members of this group. The score for work group overlappings wgo between KWs a and b is 1 if b is assigned to the work group wga preferred by a and is 0 otherwise (see Formula 3). As there can be at most one preference for a single work group, the resulting term wgo is defined as a Boolean variable.

$$wgo_{ab} = \sum_{i \in WG} wgpo_{ai} * wga_{bi}$$

$$wgpo_{ei}, wga_{ei} \in \{0,1\}, \forall i \in WG; \forall e \in E$$

Formula 3: Work group overlappings

Moving costs and room preferences: the selected KWs have strong preferences for stability if changes are not too significant. This is why fictive moving costs mc have been introduced, so that small differences between criteria do not result in a large number of moves between offices without much effect on the utility function. Moving costs mc consists of a weighted sum of general moving costs mca and of moving cost to preferred rooms mcp. General moving costs mcaar are 0 if KW a is already assigned to room r, specified in raar, and 1 otherwise. Moving cost preferences mcpar consider a room preference rtpat that KW a has for room type t. KWs can submit a preference for a type of room, e.g., a single office, a room with specific equipment, e.g., a beamer. Room preferences rpar are then set to 1 for all rooms r that are of type t which is represented in the room type assignment rta that are preferred by KW a. If the new solution means a move into a room that the KW prefers, then there are no moving costs mcp calculated. If the KW has to move out of a preferred room, moving costs are higher than in the standard case of no specific preferences for rooms.

$$mc_{ar} = \alpha * mca_{ar} + \beta * mcp_{ar}$$
$$mca_{ar} = 0 \quad for \quad ra_{ar} = 1$$
$$mca_{ar} = 1 \; otherwise$$
$$mcp_{ar} = 0 \quad for \quad rp_{ar} = 1$$
$$mcp_{ar} = 1 \; otherwise$$
$$rp_{ar} = rtp_{at} * rta_{rt}; \forall a \in E; r \in R; t \in RT$$
$$mc_{er}, mca_{er}, mcp_{er}, rp_{er}, rta_{rt}, rtp_{et} \in \{0,1\}, \forall r \in R; \forall e \in E; \forall t \in RT$$

Formula 4: Moving costs

The optimization problem is solved in two steps. In a first step, the utility function depicted in Formula 5 is maximized in order to get a quick solution that ensures the exclusiveness of reservations made by project managers. The linear mathematical problem can be solved with a high performance algorithm, like simplex algorithm. The indices *i* and *j* in the two summarizing functions determine the matrix holding the decision variable X_{ij} meaning that *x* KWs of project *j* are assigned to room *i*. The only criteria considered in the utility function are the weighted multiplication of room attractiveness *ra* and project score *ps*, from which weighted moving costs *mc* are subtracted. Thus, the utility function including constraints can be written as follows:

$$U = \sum_{i \in R} \sum_{j \in P} \left(X_{ij} * \left(\alpha * ra_i * ps_j - \beta * mc_{ij} \right) \right) \rightarrow MAX$$
$$X_{ij}, k, a_j, P, R \in N, \forall i, \forall j$$
$$e_b \in \{0,1\}$$
$$\alpha = 1 - \beta \quad 0 \le \alpha \le 1, \quad 0 \le \beta \le 1$$
$$\sum_{i \in R} X_{ij} \le a_j, \forall i; \forall j \in P$$
$$\sum_{j \in P} X_{ij} \le k_i, \forall j; \forall i \in R$$
$$\sum_{a \in R} \sum_{b \in P} \sum_{c \in P} (X_{ab} * X_{ac} * e_b) = 0, \forall a; \forall b; \forall c$$

Formula 5: Utility function for the first optimization problem

Constraints are as follows: elements of the decision variable have to be positive integers, no more than the number of KWs that have been ordered by project managers a_j are assigned to rooms, each room has a limited capacity *k* and cannot carry more than k_i KWs and projects requested as exclusive e_b by an project manager do not have to share rooms with other projects. The sum of the weighting factors α and β is 1 and they are floating point numbers between 0 and 1.

The second step considers all KWs and rooms that have not been exclusively assigned in the first step. The weights of the criteria have been refined in a dozen rounds according to the preferences of the KWs participating in the pilot study. The

much more complex quadratic mathematical problem can be solved, e.g. with a branch and bound algorithm. The utility function consists of two terms. The first term reflects a matrix of rooms and KWs and the decision variable represents the Boolean assignment of KW *j* to room *i* with 1 for assigned and 0 for not assigned. With this term, room attractiveness *ra* is maximized and moving costs *mc* are minimized. The second term reflects a three-dimensional matrix of rooms *r* and the relationships between KWs *a* and *b*. Thus, the decision variable is 1 if the corresponding two KWs are assigned to the respective room and 0 otherwise. The term reflects the weighted criteria project overlappings *po*, theme overlappings *to* and work group overlappings *wgo* which have been explained in Formulas 1-3. The utility function including constraints can be written as represented in Formula 6.

$$U = \sum_{i \in R} \sum_{j \in P} \left(X_{ij} * \left(\alpha * ra_i * ps_j - \beta * mc_{ij} \right) \right) +$$

$$\sum_{a \in R} \sum_{b \in E} \sum_{c \in E} \left(X_{ab} * X_{ac} * \left(\gamma * po_{ab} + \delta * to_{ab} + \varepsilon * wgo_{ab} \right) \right) \rightarrow MAX$$

$$X_{ab}, X_{ac}, X_{ij} \in \{0,1\}, \forall a; \forall b; \forall c; \forall i; \forall j$$

$$\alpha + \beta + \gamma + \delta + \varepsilon = 1$$

$$0 \le \alpha \le 1, \quad 0 \le \beta \le 1, \quad 0 \le \gamma \le 1, \quad 0 \le \delta \le 1, \quad 0 \le \varepsilon \le 1$$

$$\sum_{i \in R} X_{ij} \le 1, \forall i; \forall j \in E$$

$$\sum_{j \in P} X_{ij} \le k_i, \forall j; \forall i \in R$$

Formula 6: Utility function for the second optimization problem

Constraints are as follows: elements of the decision variable have to be Boolean. The sum of the weighting factors has to be 1 and every factor has to be a floating point number between 0 and 1. Each KW is at most assigned to one room and the limited capacity of a room cannot be exceeded.

4 Realization and Experiences

The Flexible Office project was carried out in two phases: (1) a feasibility study and a conceptual plan as well as (2) IT implementation and a pilot study to test the software. In a first step, the situation at GISA was studied in order to determine the sharing ratio, i.e. the number of KWs divided by the number of work places. The investigation included

- literature analysis of relevant case studies,
- analysis of documents, e.g., floor plans, organizational structure diagrams, project management handbook,
- reports on times of absence, e.g., travel, holiday and home office days,
- self-reporting in a more detailed way with five KWs compiling time allocated to projects and customers as well as time spent on the work place, in other offices, meeting rooms, customers' offices etc.,

- personal interviews that helped to refine the information gathered above. The collected data was used to determine the organizational unit that would be the first to profit from Flexible Office (a unit with more than 80% of project work), the sharing ratio (1.2)[1] as well as several rules, e.g., clean desk policy, or limitations for booking a single work place.

The conceptual plan was then realized as a prototype software solution in the second part of the Flexible Office project. Seven GISA projects, 33 team members and nine rooms were selected for the pilot study. These KWs took over ownership of the Flexible Office project and closely and actively participated in the effort to refine both, the organizational and the technical part of the solution.

The first four weeks in the pilot phase were used to calibrate the weights of α and β in the first optimization problem. Thereby, the importance of β influencing the moving costs was increased over the time of calibration. It turned out that stability of room assignment during a timeframe of one week was one of the main criteria for acceptance of Flexible Office. Nevertheless, $\alpha > \beta$ was set in order to ensure prioritization of projects. Furthermore, room attractiveness was assigned by team leaders at first, but had to be revised in order to find a greater consensus in the whole Flexible Office team.

The following eight weeks were primarily used to calibrate the other weights, the ratio between α and β remained more or less stable over this time frame. The importance of project overlappings represented in γ was increased over time and finally had the greatest value followed by theme overlappings represented in δ. The importance of workgroup overlappings represented in ε decreased over time and finally had the lowest value. While at the beginning of the pilot phase, the whole Flexible Office team had underlined the importance of work groups as compared particularly to themes, this opinion changed during the pilot phase. The reason for this might be that the employees targeted were primarily engaged in projects, while the membership in work groups was less important when working on projects. This might be changed if the solution is rolled out to include organizational units with a lower emphasis on project work. Summing up, the relative importance of the weighting factors can be described as follows:

$$\gamma > \alpha > \beta > \delta > \varepsilon$$

Project overlappings are only considered if they exceed 0.6 because they are only thought to be relevant if there are sufficient and sufficiently important projects that KWs share. The weightings assigned to general project and theme assignments α were negotiated to be substantially lower than β, the weightings assigned to project and theme preference overlappings.

From an organizational perspective, success of introducing a flexible assignment of office space requires extensive communication of benefits and strong involvement of the participating employees. Especially identification of their prejudices and fears is important since a flexible assignment goes along with substantial change processes.

During the pilot study, all participating KWs were asked to fill out short online questionnaires and project managers were interviewed on a regular basis. Results of this study show a typical u-shaped curve concerning user satisfaction with the

[1] This was the most popular sharing ratio found in the literature. This is due to the consideration that it is not cost savings, but KM-related goals that are of primary interest here.

solution. It started out with high hopes, then some problems with the prototype and also the criteria that had not yet been sufficiently refined led to a decline in satisfaction. However, in the last three weeks of the pilot study, the curves reflecting usability, improvements in communication, efficiency, learning and knowledge transfer all showed a positive tendency. In addition to the question about user satisfaction, seven statements had to be answered on a weekly basis over the project´s life. Agreement [2] refers to the average of all (n= 33) respondents (see Table 1).

Respondents estimated COMM (significance level: 0,0017), NET (0,0127) and KEX (0,0099) significantly higher than SEARCH on a significance level of $\alpha \leq 0.05$. COMM (0,0497) was also estimated significantly higher than PWE. In addition, the main advantage identified by GISA employees was the support of project work. Consequently, reservations by project managers were the type of booking used most prevalently. Due to the optimized assignment of rooms and the possibility to cooperate with colleagues of other organizational units, information and knowledge exchange was supported significantly. Project managers especially mentioned their decreased efforts to communicate with members of their project team.

statement	***agreement***
COMM: Flexible Office strongly improves communication between KWs.	**0.66**
NET: Networking with other KWs is strongly improved.	**0.63**
KEX: Knowledge exchange with other KWs is strongly enhanced.	**0.63**
LEARN: Learning at the work place is strongly improved.	**0.60**
TRAN: Transparency about competencies of other KWs is largely increased.	**0.59**
PWE: Personal work efficiency is strongly improved.	**0.59**
SEARCH: Time for searching is strongly reduced.	**0.55**

Table 1: Empirical results on benefits of the Flexible Office solution

The possibility to use rooms for non project-related, day-to-day-business was seldom used. According to GISA employees, this is due to the fact that there were too few members in the pilot study and consequently too few skills to choose from and cooperate with. Instead, employees preferred work places with their own work group. In order to profit from potential benefits of theme development, managerial systems need to take this dimension into account and define strategic knowledge assets requiring attention and thus providing legitimation or establish communities providing commitment for efforts spent on theme development.

According to project managers, organizational units with a focus on consulting and projects took more advantage of the pilot than their colleagues involved in application support and in-house services. Therefore, after a period of more than one year, the project is accepted much more by colleagues involved in project work. However, the solution is supposedly generally feasible for organizational units having a high degree of out of office work like the ones focusing customer projects or sales.

Currently, nearly 50% of assignments in the system are due to project bookings made by project managers and calculated by Formula 5. The other 50% of assignments represent bookings concerning individual preferences or overlappings

[2] 1 = I fully agree – 0 = I fully disagree

and calculated by Formula 6. Of the latter assignments, the majority are automatically done by the system in case no other booking exists for the KW. In that case, theme and project overlappings are calculated automatically in order to find the best suited work place for the KW. In case the KW booked, preferences for a room type, workgroup, theme and/or project are considered additionally (see Formulas 1, 2 and 4). Furthermore, the opportunity for booking short-term work places not assigned in the calculation is generally accepted.

Besides the apparent advantages, there also remain some issues in need of further testing. Initially, there was a considerable amount of doubts at the side of KWs that they would lose efficiency if they could not personalize their work spaces and had to recreate their work environments every time they moved into a new office. This challenge was dealt with by providing mobile personal storage capacities as well as technical equipment that allowed for location-independent office work including home offices.

By extending Flexible Office after the pilot phase, the issue that projects or KWs need special equipment installed in rooms had to be considered. Therefore, the originally designed room types classified only by capacity were redefined and enriched by attributes considering special requirements. Thus, room types like, e.g., 6 person room with electronic whiteboard or 8 person rooms with a WLAN beamer can be booked.

Another serious concern of employees was that they would lose influence over the decision of where to be located to a mechanistic solution. This issue was dealt with by weekly feedback solicited from the KWs that was used to evolutionarily develop the set of preferences individual KWs could put forward so that they could keep influence on the decision. During the pilot study, there was a tendency to see the room as “the own” room if projects had the same room for a longer period. Consequently, KWs expected to get the exact room again. Also, when projects had to change offices more than twice a week, moving was seen as a great burden. By calibrating moving costs, currently KWs have to move approximately every two weeks. That average interval between movements is generally accepted and helps to build social relationships to improve knowledge exchange. Nevertheless, some people construct their bookings in such a way that chances to stay in the same office with the same people are increased.

However, on the one hand, some participants feared that a flexible office would mean losing their personal work space and their relationships with colleagues. On the other hand, more and more KWs not participating in the pilot study claimed their interest in Flexible Office. Longitudinal studies are required to see whether these personal opinions amount to measurable improvements in the dependent variables.

In the current release, the integration with the company’s MS Exchange server, its MS Project server and the LDAP system is already realized. Thus, on the one hand the currency of the data considered in the utility functions is ensured and on the other hand the administrative expenses are minimized.

5 Conclusions and Outlook

This paper presents the results of a joint research project on the deployment of a tangible KM instrument in the form of an optimization solution for the flexible

assignment of office space using knowledge management criteria. The solution consists of organizational and technical instruments which were field tested in a pilot study. The main difference compared to established approaches, like office 21[3] focusing on organizational rules and equipment, is the mathematical formalization of factors relevant for KM and the subsequent optimization of office formation.

Surveys and interviews with affected employees show promising results concerning realization of the expected benefits, particularly for the integrative consideration of business system and project team layers whereas the knowledge base layer needs further investigation. Organizational requirements have led to the addition of three more factors, i.e. influence of room properties, team-centered rooms and a distinction between members of the pilot study and regular workers, which are currently tested.

In the future, several extensions for the Flexible Office booking solution are planned. Concerning the technical solution, the look and feel for the KWs will be further improved by implementing an AJAX-based interface facilitating graphical inputs. Concerning the administrative solution, an interface for accounting room costs to projects will be implemented. Furthermore, the implementation of administration tools is planned in order to manage the skill profiles. Finally, performance improvement of the program executing the optimization solution is necessary, because calculation time grows strongly by an increasing number n of Flexible Office members (complexity $\theta \approx n^2$). The more significant organizational changes planned are to expand the project to include the company's other sites, to integrate work places of other organizational units and consequently improve knowledge sharing between them.

Main goal of this initiative was to improve productivity of knowledge work, specifically improving awareness about competencies readily available within the organization, co-development of knowledge, knowledge exchange within and across the boundaries of established organizational units, integration of newly recruited and work place learning. The results one year after going live with Flexible Office can be seen as a first success story. Initiatives to establish organizational and ICT infrastructures that are based on an intertwined design of knowledge types, processes and services therefore might profit from the additional consideration of space. The oftentimes quite vague approaches to implement knowledge management in organizations might be improved by formalizing knowledge management criteria in order to help evaluation and get evidence about improvements made.

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[3] http://www.office21.de/

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