Flexible Office: Assignment of Office Space to Enhance Knowledge Work Productivity[1]

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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 and 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 organisational impact and lessons learned from field test and practical experience.

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. The technical infrastructure provides advanced discovery, publication, collaboration and learning services for a knowledge worker's (KW) work place, sometimes called semantic desktop [Sauermann, 05].

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However advanced these infrastructures are, many of the more human-oriented KM protagonists 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. 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

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 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 bureaus 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. This means that KWs improve their competencies, are engaged in learning activities and co-develop themes that span organizational units and project teams. 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, workplace 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,

knowledge base layer: comprises knowledge resources, themes and competences embedded in people, procedures, documents and the organizational culture,

project team layer: comprises self-organizing project teams pursuing time- and resource-constrained goals.

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. 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. In order to support this, the Flexible Office solution considers all dimensions of the hypertext organisation 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.

3 Flexible Office Concept

The Flexible Office conceptual solution consists of a technical and an organisational component. *Organizational issues* concern selecting employees, designing office space, analysing 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, organisational 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, organisational 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 KM 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, workplace 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 proceeding 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.

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. Also, KWs can submit a project preference stating that it is this project that they will be working on mostly in the booking time frame. This means that overlappings are exclusively considered with respect to the preferred project. If there are no project preferences, the following formula calculates project overlappings po between project team members a and b: ps_{ai} is 0 if KW a is not on project i and is the project's score if a is on project i. $ps_{ai\wedge bi}$ is the project's score if KWs a and b are on project i and 0 otherwise.

$$po_{ab} = \left(\frac{\sum\limits_{i \in P} ps_{ai \wedge bi}}{\sum\limits_{i \in P} ps_{ai}} + \frac{\sum\limits_{i \in P} ps_{ai \wedge bi}}{\sum\limits_{i \in P} ps_{bi}} \right) / 2$$

Formula 1: project overlappings

Project overlappings are only considered if $po_{ab}>0.6$ because they are only thought to be relevant if there are sufficient and sufficiently important projects that KWs share.

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 are working on. The assumption behind this is that KWs working on similar themes should be assigned to the same room in order to improve knowledge sharing. Again, KWs can submit theme preferences which in this case means that they 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. Overlappings then are exclusively considered for the preferred theme. In all other cases, theme overlappings *to* between KWs a and b are calculated according to the following formula:

$$to_{ab} = \left(\frac{\sum\limits_{i \in P} th_{(a \wedge b)i}}{\sum\limits_{i \in P} th_{ai}} + \frac{\sum\limits_{i \in P} th_{(a \wedge b)i}}{\sum\limits_{i \in P} th_{bi}} \right) / 2$$

Formula 2: theme overlappings

th_{ai} is 0 if KW a does not work on theme i and is 1 if a works on theme i. $th_{(a \wedge b)i}$ is 1 if KWs a and b both work on theme i and 0 otherwise. Theme overlappings are only considered if KWs have an equal skill level or if a has a lower and b a higher skill level, but not the other way round.

Factors regarding the business system layer
 work group overlappings: KWs can submit a preference for a certain work group meaning they wish to work with members of this group. The score for work group overlappings *wgo* reflects the number of KWs in the assigned room that belong to the preferred work group.
 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 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 also consider room preferences that KWs have submitted. KWs can submit a preference for a type of room, e.g., a single office, a room with specific equipment, e.g., a beamer. If the new solution means a move into a room that the KW prefers, then there are no moving costs 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.

The optimization problem is solved in two steps. In a first step, the following utility function is maximized in order to get a quick solution that considers the exclusive reservations by project managers. The mathematical problem can be solved with the 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 moving costs mc are subtracted. Thus, the utility function can be written as follows:

$$U = \sum_{(i \in R)} \sum_{(j \in P)} (X_{ij} \times (\alpha \times ra_i \times ps_j - \beta \times mc_{ij})) \rightarrow MAX$$

Formula 3: Utility function for the first optimization problem

Constraints are as follows: elements of the decision variable have to be positive integers, each room has a limited capacity, no more than the number of KWs that have been ordered by project managers are assigned to rooms and projects requested as exclusive do not have to share rooms with other projects.

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 quadratic mathematical problem can be solved 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 Table 1. The utility function can be written as follows:

$$U = \sum_{(i \in R)} \sum_{(j \in E)} (X_{ij} \times (\alpha \times ra_i - \beta \times mc_{ij})) +$$
$$\sum_{(r \in R)} \sum_{(a \in E)} \sum_{(b \in E)} (X_{ra} \times X_{rb} \times (\gamma \times po_{ab} + \delta \times to_{ab} + \varepsilon \times wgo_{ab})) \rightarrow MAX$$

Formula 4: Utility function for the second optimization problem

Constraints are as follows: elements of the decision variable have to be Boolean, each KW is only assigned to one room and each room has a limited capacity.

4   Realization and Experiences

The Flexible Office project was carried out in two phases: (1) a feasibility study and a conceptual plan and (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)[2] 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.

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 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 [3] 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

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[2] 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.

[3] 1 = I fully agree – 0 = I fully disagree

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 workplace 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 not 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 ten months, 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.

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. 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. 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.

5   Conclusions and Outlook

This paper presented 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. 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[4] focussing on organisational 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. Several advancements are planned or currently tested. On the technical side, it is planned to integrate the hotelling software with the company's MS Exchange server, its MS Project server and the LDAP system to minimize administrative expenses. 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. Last but not least, the user interface is improved to make it more intuitive, especially the graphical representation of room assignments.

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.

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