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The Knowledge Maturing Scorecard: A Model Based Approach for Managing the Innovation

Vedran Hrgovcic
BOC Asset Management GmbH
Bäckerstraße 5, 1010
Vienna, Austria
Email: vedran.hrgovcic@boc-eu.com

Gwen Wilke
University of Applied Sciences
Northwestern Switzerland
Riggenbachstrasse 16,
4601 Olten, Switzerland
Email: gwendolin.wilke@fhnw.ch

Abstract— **The paper proposes a model based approach to manage knowledge based innovation aspects of an enterprise by applying Knowledge Maturing Scorecards. The Knowledge Maturing Scorecard approach is used to define, manage and visualize indicators for the innovation potential of established enterprise goals. The paper (1) introduces the conceptual background of Knowledge Maturing Scorecards, (2) proposes a generic modelling framework for managing knowledge based innovation, and (3) presents a web based prototype for the proposed model.**

Keywords: Knowledge Maturing, Innovation Management, Knowledge Space, Meta Models, Balance Scorecard, Intellectual Capital

I. INTRODUCTION

IN the modern-day business world, characterized by globalization, rapidly evolving markets and ever changing customer requirements, the major goal of any enterprise is to manage its assets as best as it can in order to be competitive and survive in the global arena. History has taught us that even very large "unbreakable" corporations are not immune against wrong decisions (e.g. Kodak, IBM in 80's) and that it's not that the strongest and biggest that survive but those that can adapt best. In today's market setting this adaptation skill paired with strict management of the available resources results in a winning combination. Based on the fact that we are living in the information era we can adapt this winning formula toward the hypothesis that adaptation equals – at least partly – to innovation. Here, knowledge is a resource that is required for generating business value. Innovation is a result of learning, and, more generally, of knowledge maturing [28]. In the present paper, we introduce the *Knowledge Maturing Scorecard* as a conceptual method for monitoring, measuring and managing the innovation potential in a company. The Knowledge Maturing Scorecard method is a means of providing managerial guidance to achieve the strategic position - innovation. The paper uses a hybrid combination of a knowledge modeling and balance scorecard modeling method for designing a model of the Knowledge Maturing Scorecard. The approach is based on the concept of *Knowledge Spaces* [8] and uses the meta-modeling specification framework outlined in [16]. A realization of the model as a web-based management component is presented that was implemented using the meta-modeling platform ADOxx® [17].

As a running example throughout the paper, we use as a concrete business scenario a specific department of the University of Applied Sciences and Arts Northwestern Switzerland (FHNW), namely the Competence Center for Information Management (CC IM). It is part of the Institute for Information Systems of the School of Business of the FHNW. The CC IM carries out research projects in the field of information management, contributes to teaching in bachelor and master degree programs and in continued education programs, and provides consultation services for companies in the field of information management.

As outlined in first paragraph, achieving adaptation through innovation is a quite complex task, because (1) innovation is not a strictly defined good or service and (2) knowledge within a company is in most cases available in an implicit and if explicit, unstructured way – [1] argues that the percentage of unstructured knowledge within one company is as much as 80%. If we take it one step further that knowledge available within the enterprise and the surrounding environment is directly responsible for generating innovation it becomes obvious that techniques for managing the enterprise-wide knowledge is a necessity for business survival. Even more, such techniques are seen as a vehicle to identify, externalize and structure, thus make knowledge available, as most of it is "hidden" within the company – e.g. known only to domain experts.

This challenge was recognized decades ago, by both commercial as well as scientific communities and resulted over time in the development of different knowledge management methods and tools, including their deployment in different business settings.

During the last two decades authors have observed three phases of knowledge management: (1) Process Oriented

Knowledge Management, (2) Service Oriented Knowledge Management and (3) Service Oriented Knowledge Provisioning (cf. [2], [3], [4], [5]). In the work presented in this paper methods and techniques from all three phases have been used to define knowledge, structure it and use it as measurement for innovation. Before setting the scene for innovation indicators based on changes in enterprise wide knowledge and trying to measure them, one should focus on measuring or attaching a value to knowledge in a first. Approaches toward such activity – known as intellectual capital monitoring – have been applied over time in different settings. Research carried out previously as in [6] and [7], state that there is a strong link between intellectual capital and innovation capability of the enterprises, which is in line with the approach presented in this paper, but it doesn't take into account the maturing dimension of knowledge, applied to govern the innovation indicators.

As mentioned previously, before aligning the available intellectual capital with the innovation potential of the company, the first step is structuring of accessible knowledge. This is done by managing the Knowledge Space, which is defined as the currently available knowledge concerning a specific domain or part thereof in a specific timeframe (see [8] for more details on Knowledge Space). It is used to model the so-called Knowledge Maturing Scorecard method, which can be used to measure the intellectual capital of the enterprise (for details and an example of such a knowledge scorecard without maturing dimension see [9]). In a next step, Knowledge Maturing Indicators are defined in order to provide an overview of the enterprise wide innovation capability. Knowledge Maturing Indicators provide information concerned with changes in the intellectual capital – from knowledge perspective.

This approach is described in this paper as follows: In the following section II, we introduce the Knowledge Maturing Scorecard method as a conceptual method to monitor, assess, visualize and manage innovation potential in a company. It is based on the specification of Performance Indicators for Knowledge Maturing, which can be used as indicators for innovation potential. In section III, we present a Knowledge Maturing Scorecard model: We describe the model-driven approach to designing the KMS and propose a formalization of the KMS method. A brief outline of the realization approach is given, presenting the web-based runtime environment. Finally, section IV concludes the paper and gives an outlook to future work. The research presented in this paper has been carried out as part of the EU-projects MATURE [27] and BIVEE [25].

II. The Knowledge Maturing Scorecard Method

This section introduces the concept of knowledge maturing and the Knowledge Maturing Scorecard method. We propose to use indicators for knowledge maturing to measure, monitor and manage the innovation potential in an organization.

A. Knowledge Maturing as Indicator for Innovation

As outlined in the introductory section, agility is today a critical success factor for competitiveness of companies in a rapidly changing environment. One characteristic of agility is the amount of innovation generated in a company. In the scope of this paper we focus on innovation generated through positive changes in the knowledge recourses that are available in a company. More specifically, we focus on knowledge maturing and its management.

Here, the term *knowledge maturing* is understood as a generalization of term *learning*: "The knowledge maturing process [33] is distinguished from mere learning by the fact that it regards individual and organizational knowledge development as directed, i.e., derived from and coordinated with respect to an organizational context" [28, p.29]. While learning addresses only changes in the personal knowledge of individuals, knowledge maturing additionally addresses the social dimension of knowledge and its change: When individual learning processes are interlinked by social interaction, e.g., in an organizational context, the resulting social knowledge is more than the sum of the individual knowledge of the participants. E.g., "in a meeting in which experts of different domains come together, each of them usually brings in arguments (from her specific perspective) that often directly respond to previous arguments of other experts from other domains [29]. The result of such communication is a chain of arguments that enriches the knowledge of the group, and results in a qualitatively new aggregate of knowledge" [30, p.39].

The present paper is based on the assumption that knowledge maturing in an organization is a precondition for innovation. Within the MATURE project, indicators for knowledge maturing have been identified, and we propose to use them as indicators for the innovation potential in a company.

Knowledge maturing is a generic concept that can have different meanings in different scenarios. For example, in one scenario the relevant knowledge may comprise operative process knowledge, and the maturing of this knowledge may be required to execute production processes more efficiently; in a different scenario, the relevant knowledge may comprise the business knowledge of a specific role in the knowledge process such as the role of a department manager, and knowledge maturing may be required to allow for timely reactions to market changes.

In the project MATURE [27] knowledge maturing has been described as a process that can be characterized by the *Knowledge Maturing Phase Model* (cf. [20]). Its phases comprise (1) *Expressing Ideas* and *Appropriating Ideas*, (2) *Distributing in Communities*, (3) *Formalizing*, (4) *Ad-Hoc Training/Piloting*, (5) *Formal training/Institutionalizing* and *Standardizing.* In each of the phases, *Knowledge Maturing Indicators* (KMIs) can be identified that make the process of knowledge maturing visible [20]. Since knowledge maturing is a generic concept, KMIs are generic as well. They must be concretized for each specific Knowledge Space that represents the relevant knowledge in the company, department or project in question. An example of a KMI is “A group of individuals meets certain quality criteria for collaboration”. For the CC IM instantiation, the KMI has been concretized by “a high percentage of CC IM employees feel that they work in a cooperative environment”. The fact was determined by a survey among employees.

The following subsection introduces the basic principles of the Knowledge Maturing Scorecard as a conceptual tool for monitoring and managing knowledge maturing in a concrete Knowledge Space. Here, performance in knowledge maturing is measured using *Knowledge Maturing Scorecard Indicators* (KMSIs), which are concretizations of KMIs.

B. Basic principles of the Knowledge Maturing Scorecard

In 1996, Kaplan & Norton introduced the now well-known *Balanced Scorecard* as a conceptual tool for performance measurement in organizations. The application of the Balanced Scorecard to Human Recourses departments and, in particular, to training departments led to the development of the so called *learning* or *training scorecard*[31]. In a master thesis by [32], and subsequently as part of the MATURE project, the learning scorecard concept has been developed further to include not only maturing of individual knowledge (i.e., learning), but also maturing of social knowledge. The result of the efforts is called the *Knowledge Maturing Scorecard* (KMS).

Similar to the Balanced Scorecard, the Knowledge Maturing Scorecard differs from other scoring methods in that it not only considers financial performance measures but includes also non-financial measures that are considered relevant for business success. It includes a design approach that comprises guidelines, hints, and possible pitfalls to facilitate the choice of performance measures for knowledge maturing. Here, knowledge maturing performance measures that are relevant for business success are determined by considering different perspectives on an enterprise, department or project, such as a financial perspective or a customer perspective. For each perspective strategic goals are determined, and for each strategic goal at least one performance measure is specified. Each measured value is compared to a target value, and both together constitute a *Knowledge Maturing Scorecard Indicator* (KMSI) for the strategic goal in question. Strategic goals of different perspectives often influence each other, and these influences are explicitly represented as cause-effect relationships between goals, e.g., in the form of a graphical diagram. From the indicators and the mutual influences of the strategic goals, a report is compiled that provides a summary of the KMSI performances for the intended audiences of the KMS- this is usually the management board of a company or department. It is an important aspect of the Balanced Scorecard and of the Knowledge Maturing Scorecard that they provide a method for determining what is considered the most relevant information for the intended audiences and for communicating this information to them in the form of an easily understandable summary report. Different variations of the Knowledge Maturing and Balanced Scorecard approach mainly differ in the specification of what is considered relevant information, and in the way to determine it. The summary report is often provided in the form of a written report or in the form of a graphical cockpit. The graphical cockpit has the advantage that it not only allows for monitoring the values of single KMSIs and the summary representation, but that it also allows for adapting the design of the scorecards to changing business requirements. I.e., perspectives, goals, KMSIs and target values can be changed interactively, facilitating the management of performance goals. The main difference between the Balanced Scorecard method and the KMS method is that the Balanced Scorecard is a generic method, while the KMS is specifically tailored to capture knowledge maturing goals.

C. Perspectives, Goals an KMSIs

The set of standard perspectives that is provided by the design approach of the KMS is tailored to capture knowledge maturing goals. It comprises (1) an *Enterprise* perspective, (2) a *Topics* perspective, (3) a *People* perspective, (4) a *Maturing Processes* perspective, and (5) a *Maturing Innovation* perspective. Here, the Enterprise perspective comprises knowledge maturing goals that directly add business value for the enterprise. It captures the company’s visions and overall strategic goals with respect to knowledge maturing. For example, the CC IM is part of the FHNW, and the Enterprise perspective of the CC IM KMS comprises strategic goals of the FHNW that directly add business value, such as “offering degree study programs”. In contrast to that, the Topics perspective specifically considers knowledge maturing goals, which address topics that are relevant in a company. E.g., for the CC IM, it is essential to ensure that the topics in teaching are state of the art. The People perspective involves opinions, motivations, backgrounds and skills of people who are involved with the company. E.g., for the case of the CC IM, it is desirable that professors have a good reputation within their respective scientific communities. The Maturing Processes perspective focuses on processes that support knowledge maturing, such as internal training programs. In the CC IM, for example, this perspective includes services that foster a cooperative environment such as the maintenance of a wiki for sharing experiences on certain issues. Finally the Maturing Innovation perspective targets possible improvements of existing knowledge maturing processes. An example from CC IM is the staff exchange program, which allows employees to become acquainted with, e.g., collaboration initiatives of other institutions, which they can adapt and apply to the CC IM environment.

The idea behind the introduction of different perspectives is that monetary aspects alone are usually not sufficient to adequately describe and assess the relevant performance goals of a company, department or process. Especially in large companies, a diversity of factors contribute to the overall business success, and many of these factors do not directly create added business value, but contribute only indirectly to business success. This is particularly true for the domain of knowledge maturing. As an example, consider again the case of the CC IM introduced in the introductory section. Here, a cooperative environment among researchers strongly improves and accelerates the competence development of each involved individual, and helps them to keep their knowledge and teaching state of art. As a consequence, courses in the bachelor and master programs, as well as in the continuing education programs, are improved, which leads to a higher reputation of the FHNW as an educational institution. This eventually results in a higher number of students per semester and creates added business value for the FHNW via increased revenue from tuition fees.

In the above example, "facilitating a cooperative environment in the CC IM" is a performance goal that does not directly create added business value for the FHNW, but still is a crucial factor for business success. From a purely financial perspective, it is hard to identify that it is a relevant performance goal and, conversely, performance with respect to this goal cannot be measured in terms of financial KMSIs. In the CC IM KMS, "facilitating a cooperative environment in the CC IM" has been identified as a strategic goal in the People perspective: The People perspective includes in particular the opinions, motivations, backgrounds and skills of CC IM employees, and from this point of view, a cooperative environment is clearly beneficial and can easily be identified as a strategic goal. Once the goal has been identified, an appropriate KMSI can be determined. In CC IM KMS, "percentage of employees who are satisfied with the cooperativeness in their professional environment (determined by survey)" has been established as an appropriate measure for the goal. A survey among the employees is used to determine its value, and the target value has been set to 100%.

D. Linking Knowledge Maturing to Business Value

One major difference between the Balanced Scorecard method and the KMS method is that in the Balanced Scorecard method all perspectives are equally important, while the KMS method distinguishes one perspectives from all others: The Enterprise perspective of the KMS differs from the other perspectives in three points: (1) It addresses the overall strategic goals of the entire enterprise, while the other perspectives consider specific aspects of the enterprise. (2) The Enterprise perspective targets knowledge maturing goals that directly create added business, while the goals in the other perspectives often cannot be assessed in terms of financial indicators. (3) While other perspectives can be adapted to the requirements of a specific Knowledge Space, the Enterprise perspective is required to be part of *every* Knowledge Maturing Scorecard and cannot be changed.

The Enterprise perspective is required to be part of every KMS in order to make a connection between knowledge maturing and added business value. As discussed in the forgoing subsection, the knowledge maturing goals in different perspectives of the KMS are connected by cause-effect relations that indicate their mutual influences. If a knowledge maturing goal can be connected to a goal of the Enterprise perspective by a series of cause-effect relations, this is called a *value chain*. Value chains connect knowledge maturing with added business value. The proposed design approach for KMS requires that every knowledge maturing goal must be connected to the Enterprise perspective by a value chain. Value chains can easily be identified in the graphical representation of the KMS, cf., e.g., figure 1.

E. The KMS as a Tool for Managing Innovation Potential

As discussed in subsection II.A, KMSIs are concrete instantiations of the more general KMIs and the KMS method can be used to measure, monitor and assess knowledge maturing within an organization, e.g., via a cockpit or summary report. The present paper regards organizational knowledge maturing as a precondition for innovation, and KMSIs are consequently indicators for the *innovation potential* in a company. As an example, consider again the goal "facilitating a cooperative environment in the CC IM", which is measured by the KMSI "percentage of CC IM employees who feel that they work in a cooperative environment (determined by survey)".

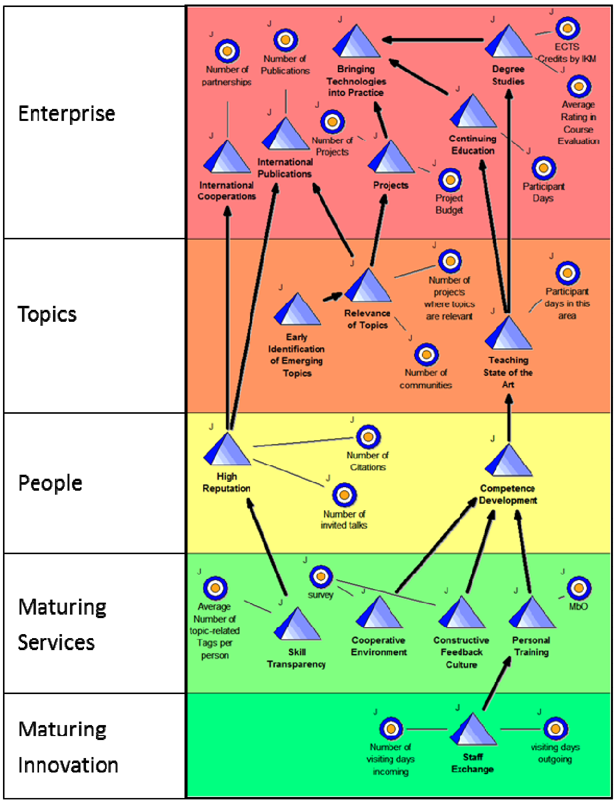

Fig 1. A graphical representation of the CC IM Knowledge Maturing Scorecard created with ADOxx®.

If this indicator is high (i.e., close to the target value of 100%), teamwork and personal competence development is facilitated considerably, and this in turn fosters the development of new ideas in research as well as in teaching. In other words, the innovation potential is increased. The KMS can, consequently, be used to measure, monitor and assess innovation potential. Due to the interactive character of the KMS, it can also be used to *manage* the innovation potential in a company: The indicator values are updated regularly and the design approach of the KMS allows the management to continually adapt the KMS design to changing requirements. In section III of this paper, we present a web-based realization of the KMS model that facilitates this task by providing an interactive cockpit. The KMS in particular facilitates *managerial guidance* with respect to the innovation potential in company: The cause-effect relations between goals of the different perspectives link innovation potential with business value and help identifying gaps in the value chains.

III. The Knowledge Maturing Scorecard model

In the following subsections the Knowledge Maturing Scorecard model is described, by (1) describing the knowledge method used to design the Knowledge Space, (2) extending this through applying a hybrid modeling approach to incorporate concepts from balance scorecard method, (3) formalizing the "hybrid" KMS and (4) presenting the web based realization of the KMS.

A. Knowledge Spaces: A Meta-Modeling Approach

As outlined in the previous section, the first step towards defining knowledge based approach to modeling the innovation potential in an organization is the identification of relevant knowledge resources. The knowledge resources must be structured, and the structure can be used to design a so-called *Knowledge Space*. In [8], Karagiannis and Woitsch define a knowledge space as the currently available knowledge concerning a specific domain or part thereof in a specific timeframe. It comprises four dimensions: (1) The *Form* dimension specifies the syntax and semantic used for describing the knowledge resources. Examples are human expert statements in natural language, text documents, models, program code, mathematical formula or statistics. (2) The *Content* dimension defines the actual domain of the Knowledge Space (or a part of it). Examples are military knowledge (as, e.g., used in [9]) or e-Government knowledge (as used in [5]). (3) The *Interpretation* dimension specifies how the Knowledge Space is interpreted. E.g., in Knowledge Engineering the focus may lie on machine based interpretations, while in Knowledge Management, a human based interpretation may be favored. Finally, (4) the Use dimension, defines how the Knowledge Space is used, e.g., for model processing (e.g. in the sense of KMS using model analysis to define the granularity level of the defined indicators). The process of designing the Knowledge Space is carried out by applying a specific knowledge management method, cf., e.g., [10, 12, 13]. The present paper uses the knowledge management method PROMOTE [12]. PROMOTE is based on the generic modeling framework proposed in [11], which allows for incorporating the Balanced Scorecard approach, cf. [14, 15, 16]. In general, the choice of a knowledge management method strongly depends on the environment and on the involved stakeholders (i.e., on the users of the Knowledge Space). Since the Knowledge Maturing Scorecard is a generic tool that should be independent of the specific environment and stakeholders, it is necessary to choose a knowledge management method that allows for a wide range of modeling types, and thus for flexibility in the definition of the Knowledge Space. More formal methods in general have the advantage that the represented Knowledge Space is more easily "processable". Yet, they also have the disadvantage that they require involvement of knowledge engineers (cf., e.g., [10]) and are often not well accepted by the actual bearers of the knowledge – the domain experts, who are more comfortable with tools and notations they use in their everyday business. Acceptance among domain experts is of crucial importance for the success of the Knowledge Maturing Scorecard: As described in subsection II.E, the Knowledge Maturing Scorecard is not only a tool for assessing and managing innovation in a company, but also a tool for communicating the innovation goals of a company among the involved parties (e.g., different departments of a company).

Following PROMOTE, different model types can be used to design the Knowledge Space. These are: (1) *Business-Oriented* models like Business Process models and Working Environment to enable a tight coupling with business process management approaches; (2) The *Knowledge Management* related models start with the description of the Knowledge Product model, where typically a Knowledge Product Fact Sheet is generated; (3) The *Knowledge Management Process* models as well as the Knowledge (Skill) Environment model describe the processes and the required roles and skill-profiles that are necessary, when producing the knowledge product; (4)The *Knowledge Structure* is a concept map that is used to classify resources, to list skills and to specify domains; (5) The *Knowledge Resource* related models like the Knowledge Tool and the Knowledge Resource models define access coordinates such as links, tool parameters and the like to properly access the knowledge infrastructure.

These model types each have a special focus and are used according to the specific scenario at hand. To enable a simple navigation, additional overview models are provided: (1) the *Process Map* allows for an overview over all processes; (2) the *Team Map* lists all worker, roles and skill profiles and enables an overview over all key-players; (3) the *Knowledge Landscape* is an overview across all models, i.e., it provides an overview over the full knowledge management system. This model type is used to structure and classify the existing knowledge management infrastructure and to indicate extensions. For a more detailed description of the model types of PROMOTE, as well as the PROMOTE modeling procedures and sample scenarios see [18].

In the following subsection we describe how PROMOTE has been used to create a model of the Knowledge Maturing Scorecard. The model was realized using the modeling method specification framework proposed in [16] and the meta-modeling platform ADOxx® [17].

B. Designing the KMS

In the forgoing subsection, we outlined the modeling approach, and its model types. We used model types to model the KMS method. The Knowledge Resource model was for example used to identify and classify knowledge resources that are directly connected with indicators defined in the Knowledge Maturing Scorecard and Knowledge Management process model is used to define the processes carrying out the innovation creation. Applying the knowledge management approach as described in this chapter results in a fully functional instance of the Knowledge Space. This instance is declared as so-called static Knowledge Space and can be extended for example by multi-agents (as applied in eHealthMonitor Project [19]) to realize dynamic Knowledge Spaces that can be extended on demand based on the current requirements imposed by the stakeholders (users of the Knowledge Space).

Some scenarios, including the KMS, require application of different modeling methods. In order to create such amalgamated modeling methods covering the requirements it is important to keep in mind that such models will be processed using previously existing mechanisms and algorithms. To ensure this processability, the modeling languages that are applied have to be specified using the generic modeling method specification framework – as proposed in [16]. Since the KMS is a means of communication between different stakeholders (e.g., different departments in a company and the management board), it is of vital importance for the success of the KMS model that different languages are supported and can be amalgamated within one KMS model. The generic modeling method specification framework [16] defines three modeling method elements: (1) The *Modeling Language*, which comprises notation, syntax and semantics; (2) the *Modeling Procedure,* which is usually a text document that defines the different steps of modeling and specifies the overall aim of the model-based approach by introducing the expected modeling results; (3) The *Mechanism and Algorithms, which* are used for enabling the model language and model processing. They can be implemented in a generic way (i.e., they are implemented for all modeling languages available in a modeling framework), language specific (i.e., they are implemented just for a specific modeling language) or hybrid (i.e., a combination of specific and generic). Both PROMOTE as well as Balance Scorecard methods have been developed following the proposed specification framework, thus their incorporation in the KMS was a straightforward task.

C. A Formalization of the KMS

In order to implement the realization of the KMS model with the ADOxx® platform, it was necessary to provide a formal representation of its components. In the following, we briefly sketch the formalization we used. Due to the limited space in this paper only the main idea is presented, omitting less important detail. We denote by P_i the perspectives of a KMS. Here, $i=1,..,n$, and n is the number of perspectives used to model a specific Knowledge Space. G_{ij} denotes the Goals in the perspective P_i, where $j=1,\dots,m$, and m is the number of goals in P_i. $I_{ijk}=(v_{ijk}, t_{ijk})$ denotes the KMSIs that are associated with the goal G_{ij}. It is an ordered pair of values, comprising the measured value v_{ijk} and the target value t_{ijk}. Here, $k=1,\dots,u$, and u is the number of KMSIs attached to G_{ij}. A concrete instance *KMS* of a KMS can be represented as follows:

$$\begin{aligned} KMS &= \{P_1, P_2, \dots, P_n\}, \\ P_i &= \{G_{i1}, G_{i2}, \dots, G_{im}\}, \ (i=1,..,n), \\ G_{ij} &= \{I_{ij1}, I_{ij2}, \dots, I_{iju}\}, (j=1,\dots,m). \end{aligned} \qquad (1)$$

The proposed implementation of the KMS model includes the automatic generation of a summary report, which is visualized in the form of a graphical cockpit. Here, every KMSI, goal and perspective of the KMS is assigned a discrete status, which assumes one of the values *green*, *yellow* or *red*. The status green is used to indicate that the current performance with regard knowledge maturing meets the expectations of the designers of the KMS; the status yellow is used to indicate that the current performance is acceptable, but needs improvement. Finally, the status red indicates that the current performance is not acceptable.

The status $S(I_{ijk})$ of a KMSI $I_{ijk}=(v_{ijk}, t_{ijk})$ is derived from the measured value v_{ijk} and the target value t_{ijk}. In order to allow for algebraic manipulation of status values, we express every status by a numerical value: green is represented by 1, yellow is represented by 2/3, and red is represented by 1/3. We calculate the status of a KMI as follows:

$$S(I_{ijk}) = \begin{cases} 1 & \text{if } \left|v_{ijk} - t_{ijk}\right| \in [0, T^1_{ijk}] \\ 2/3 & \text{if } \left|v_{ijk} - t_{ijk}\right| \in (T^1_{ijk}, T^2_{ijk}] \\ 1/3 & \text{if } \left|v_{ijk} - t_{ijk}\right| \in (T^2_{ijk}, \infty) \end{cases} \qquad (2)$$

Here, $T^1_{ijk}, T^2_{ijk} \in [0,\infty)$, $T^1_{ijk} \le T^2_{ijk}$, are threshold values that must be assigned to each of the KMSIs I_{ijk} during the design process of the *KMS*. They specify how the absolute distance $\left| v_{ijk} - t_{ijk} \right|$ of the measured value v_{ijk} to the target value t_{ijk} is mapped to a status value. For example, the status 1 (*green*) indicates that the measured performance value v_{ijk} differs not more than T^1_{ijk} from the target value v_{ijk}. Using the absolute distance allows for different "reading directions": The target value may be approached from top-down, from bottom-up or from both sides. The status $S(G_{ij})$ of a performance goal G_{ij} is calculated as a weighted arithmetic sum of the KMSIs that are attached to G_{ij}:

$$S(G_{ij}) = \frac{\sum_{k=1}^{u} W_{ijk} \cdot S(I_{ijk})}{u} \quad (3)$$

Here, $W_{ijk} \in [0,1]$ are weights that are accessible from the cockpit and allow the users of the *KMS* to fine tune how the status of a goal is influenced by the single KMSIs attached to it. The status $S(P_i)$ of a perspective P_i is calculated from the statuses of the goals that are associated with P_i:

$$S(P_i) = \frac{\sum_{j=1}^{m} W_{ij} \cdot S(G_{ij})}{m} . \quad (4)$$

Finally, the overall status of the KMS is calculated from the statuses of all perspectives:

$$S(KMS) = \frac{\sum_{i=1}^{n} W_i \cdot S(P_i)}{n} . \quad (5)$$

In order to visualize the numerical statuses $S(G_{ij})$, $S(P_i)$ and $S(KMS)$ in a cockpit, threshold values must be assigned to each of the G_{ij}, P_i and KMS.

D. A Web based realization of KMS

The realization of the KMS through the model-driven approach described above produces first the model input file (as shown in Fig 1.). The model input file describes the Perspectives, Strategic Goals, and Knowledge Maturing Scorecard Indicators that are, in a subsequent step, introduced to the web based environment (as in Fig 2.) for further management and usage. It has to be mentioned that a realization of the KMS model can also be produced using only the web based management tools depicted in Fig 2.

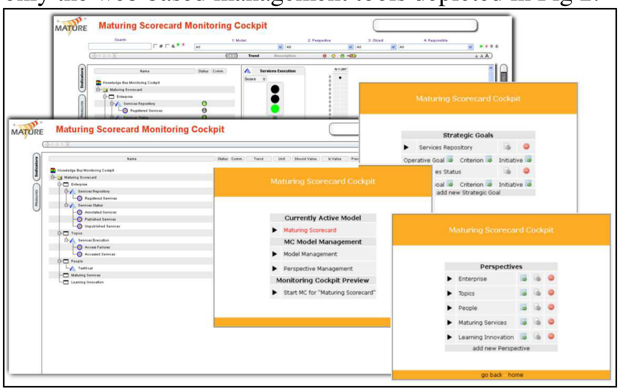

Fig 2. Knowledge Maturing Scorecard Web Based Environment

Yet, the domain experts who design the KMS instantiations and afterwards use the system have in most cases opted for more visual generation using the graphical models. After the design of the KMS instantiation (moving from general concept toward exact goals and set of applicable knowledge maturing indicators), either using the graphical modeling in rich client or web based components, the next step is continuous updating of the defined criterions for each strategic goal of the perspectives.

For this purpose a web based management component has been developed in order to allow both (1) manual update of the indicator values, as well as (2) periodical automatic update using web service interfaces. Fig. 2 provides an overview of the web based components used to manage the deployed Knowledge Maturing Scorecard instantiation. As outlined in previous section one of the goals of utilizing such a system is "...It is a communication means, making the strategy of the enterprise transparent and thus improving its achievement…". This requirement is tackled by the Knowledge Maturing Scorecard cockpit which provides a transparent and easy way of displaying the current status of all enterprise perspectives (and corresponding, strategic goals, and indicators) and allows application of corrective measures (if applicable) to achieve the overall goal – successfully managing enterprise goals responsible for innovation. Knowledge maturing Scorecard is realized using a SOA based approach. All components presented in this paper can be accessed and used online (web browser) and they offer integration API's using standardized web service interface. Web service interfaces are important as in the BIVEE project [25] the KMS is used to measure the innovation potentials of interconnected Virtual Organizations as part of the innovation Mission Control Room (see [24] for details).

IV. Conclusion and Future Work

This paper provided an overview of how knowledge maturing can be applied to manage the innovation potential of an enterprise through application of a web-based Knowledge Maturing Scorecard. We introduced the KMS *method* and argued that it can be used as a conceptual tool for monitoring, assessing and managing innovation potential in a company. We then introduced a model-based approach for the design of a KMS *model*. As a basis for the approach, the concept of Knowledge Space was introduced. We provided a formalization of the KMS method and outlined its realization as a web-based management component. This setting has been applied in different scenarios ranging from creating KMS for a University department – as described in this paper – to evaluating the innovation potential of a large mobile provider as well as analyzing and tracking innovation of a Spanish e-Learning provider. Based on observations of these pilots and further research work we have identified points that are currently being addressed in two research projects, namely current focus is on (1) dynamic aspects of the Knowledge Space used as base for design of the KMS – employing multiagent systems to enable decision support on innovation based goals – as in [19] and (2) extending the innovation management capabilities of the system by connecting it to the Mission Control Room (MCR) platform. The MCR is developed in the BIVEE Project, and serves goal to better address direct changes in the innovation management based on the "live" results from the application field (see [24] for details on MCR and [25] for details on the project).

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REFERENCES

[1] Cencioni, "Intelligent Content in FP7", *Intelligent Content and Semantics*, Information days, Luxembourg, ftp://ftp.cordis.europa.eu/pub/ist/docs/kct/intelligentcontent-fp7-ict_en.pdf

[2] V. Hrgovcic, R. Woitsch and A. Leutgeb, "Knowledge Bus - The PROMOTE Approach For Knowledge Service Orchestration", eChallenges 09, Turkey, IOS Press, 2009

[3] K. Hinkelmann, D. Karagiannis, R. Telesko, „PROMOTE - Methodologie und Werkzeug zum geschäftsprozess-orientierten Wissensmanagement" *Geschäftsprozess-orientiertes Wissensmanagement*, Springer-Verlag, 2002

[4] R. Woitsch, "Process Oriented Knowledge Management: A Service Based Approach", PhD Thesis, University of Vienna, 2004

[5] V. Hrgovcic, and R. Woitsch "Enhancing Semantic E-Government Workflows through Service Oriented Knowledge Provision", (ICIW 09), Venice, Italy, IEEE, 2009

[6] G. Tovstiga, D.W. Birchall, E. Tulugurova, "Determinants of Enterprise Performance in Small Technology-Intensive Enterprises: Intellectual Capital and Innovation Capability in the Firm", *PICMET*, Portland, Oregon, 2007

[7] H. I-Chieh, R. Sabherwal, "From Intellectual Capital to Firm Performance: The Mediating Role of Knowledge Management Capabilities", *IEEE Transactions on Engineering Management*, Volume 58, Issue 4, 2011

[8] D. Karagiannis and R. Woitsch, "Knowledge Engineering in Business Process Management", *Handbook on Business Process Management 2*, International Handbooks on Information Systems, ISBN: 978-3-642- 01982-1, Springer, 2010, pp 463 - 485

[9] R. Woitsch, W. Utz, K. Mak and J. Göllner, "Intellectual Capital Management using Knowledge Scorecards: A Best Practice Implementation at the Austrian National Defence Academy", (KM 09), Solothurn, Switzerland, 2009

[10] A. De Nicola, F. Taglino, "Usage of the ontology in the LD-CAST project", Addendum to the deliverable D4.2 of the LD-CAST project, 2008

[11] D. Karagiannis, H. Kühn, "Metamodelling Platforms. Dexa 2002, Aix-en-Provence, France, September 2-6, 2002, LNCS 2455, Springer-Verlag, Berlin, Heidelberg, p. 182.

[12] R. Woitsch, V. Hrgovcic and R. Costin, "Knowledge Product Modelling for Industry: The PROMOTE Approach", (INCOM 12), Bucharest, Romania, 2012

[13] N. Gronau, „Modellieren von wissensintensiven Geschäfts-prozessen mit der Beschreibungssprache K-Modeler", *Gronau N. Wissensmanagement: Potentiale – Konzepte - Werkzeuge*, GITO Verlag, 2000, p3-30

[14] H. Kühn, "Methodenintegration im Business Engineering", PhD Thesis, Vienna, 2004

[15] V. Hrgovcic, R. Woitsch and D. Karagiannis, "Hybrid Service Modeling in Enterprise Computing", 13th CEC, Luxembourg, September 5-7, 2011, IEEE

[16] D. Karagiannis, V. Hrgovcic and R. Woitsch, "Model Driven Design for E-Applications: The Meta Model Approach", (ERPAS2011), Vietnam, December 5-7, 2011, ACM

[17] The ADOxx® Metamodelling Platform, Workshop "Methods as Plug-Ins for Meta-Modelling" in conjunction with "Modellierung 2010", Klagenfurt, Austria

[18] PROMOTE HP: http://promote.boc-eu.com, access 27.3.2012

[19] eHealthMonitor Project, http://www.ehealthmonitor.eu, access 27.3.2012

[20] MATURE Project, D1.3 "Results of in-depth case studies, recommendations and final knowledge maturing model", available at www.mature-ip.eu

[21] MATURE Project, D9.2 "Business Model for ASP", available at www.mature-ip.eu

[22] Kaplan & Norton, "Balanced Scorecard: Translating Strategy into Action", *Boston: Harvard Business School Press*

[23] Andrea Back, „Balanced Learning Scorecard: Den Wert von (E-)Learning-Innovationen für Geschäftsziele kommunizieren.", Ehlers, U.-D. & Schenkel, P. (Eds.), *Bildungscontrolling im E-Learning*, Springer-Verlag

[24] BIVEE Project, D6.2, "BIVEE Environment Architecture and service platform specifications", available at www.bivee.eu

[25] BIVEE Project website: www.bivee.eu, access 27.3.2012

[26] Kaplan R S and Norton D P (1996) "Balanced Scorecard: Translating Strategy into Action" HBS Press.

[27] MATURE Project website, www.mature-ip.eu, access 27.3.2012

[28] Uwe V. Riss, Hans Friedrich Witschel, Roman Brun, Barbara Thönssen. What is Organizational Knowledge Maturing and How Can It Be Assessed? (I-KNOW '09), Graz, Austria, 2009, pp. 28-38

[29] Domik, G., & Fischer, G. (2010). Coping with complex Real-World problems: Strategies for developing the competency of transdisciplinary collaboration key competencies in the knowledge society. vol. 324 of IFIP Advances in Information and Communication Technology Springer,

[30] MATURE Project, D2.4_3.4 "Design and delivery of the final prototype of PLME / OLME", available at www.mature-ip.eu (to be submitted)

[31] Schmidt, Lynn (2003). Implementing Training Scorecards – In Action. American Society for Training & Development ASTD.

[32] Kaenel, Urs (2011). Measuring the success of learning, training and knowledge development in a company. Master thesis, FHNW, Switzerland.

[33] Schmidt, A.: Knowledge Maturing and the continuity of Context as a Unifying Concept for Knowledge Management and E-Learning. I-KNOW '05, Graz, 2005.