An indicator wizard for the Knowledge Governance Framework

Using System Dynamics to Implement the Knowledge Governance Framework

Colophon

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Synopsis:

In Metis 2002 Smits and De Moor presented a model to analyze the effectiveness of knowledge management (KM) in organizations. In 2003 the model was applied in two knowledge intensive organizations. The cases showed a variety of linkages between long term KM, operational KM, knowledge resources, and business objectives. This report describes how these management linkages can be qualified and quantified in a system dynamics model. System Dynamics modelling is used to simulate the effects of knowledge management in a medium sized firm in the insurance industry.

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1 Introduction

In today's business environment enterprises are trying to find new approaches to improve their organization's performance. Therefore they need to manage their sources of competitiveness effectively. In knowledge intensive organisations, these sources rely more and more on the intangible parts of the organization; the knowledge and know-how of its employees, the relationship of the organization with its stakeholders, its trademarks, patents, etc. Management of these resources –also known as intellectual capital- should enable the organization to sustain its current viability and success and ought to be the basis for innovation. The organization should be able to adopt and use new knowledge that is indispensable to maintain its core competences. The development of new knowledge resources and the ability to apply this knowledge and turn it in to a source of competitive advantage requires a process in which the key components facilitating this advantage are carefully controlled (Wiig 1993, Wiig 1997, Davenport and Prusak, 2000; Daniels and Smits, 2005).

A common definition of knowledge management (KM) is "the collection of processes that govern the creation, dissemination and leveraging of knowledge to fulfil organizational objectives" (Ching Chyi Lee, 2000). Davenport and Prusak (2000) define KM as: "to identify, manage, and value items that the organization knows or could know: skills and experience of people, archives, documents, relations with clients, suppliers and other persons and materials, often contained in electronic databases". In line with these definitions, we define KM as 'purposeful interventions of knowledge development to realize sufficient knowledge availability at the time and place where the organization needs it'. Nonaka et al (2000) distinguish the four well-known SECI processes (Socialization, Externalization, Combination, Internalization) through which knowledge is created.

How exactly knowledge resources and KM processes tie to strategic, tactical, and operational business objectives and workflow is often left implicit or not addressed at all in business practice (Nahapiet and Goshal, 1998). To specify these relationships, Smits and de Moor (2004a, b) developed the 'knowledge governance framework', linking operational KM to long-term KM to organizational objectives. Other frameworks have been developed by Lei et.al. (1996), Gongla and Rizutto (2001), and Holsapple and Joshi (2001), all focusing on a specific type of knowledge linked to one business objective.

Figure 1 represents the 'knowledge governance framework', showing the knowledge resources, either as 'available resources' (lower left side) in or around (in case of outsourcing) the organization, or 'in use', assigned to projects or business processes (lower right side). Knowledge development processes can take place in projects as well as after projects in various training and educational activities. Knowledge resources can be both human and machine-based, such as employees and databases. The central part of Figure 1 shows the links between operational KM, long-term KM, and business strategy. Operational KM performs activities such as assigning knowledge resources to projects, forming project teams, based on customer needs, available knowledge resources and long-term KM objectives

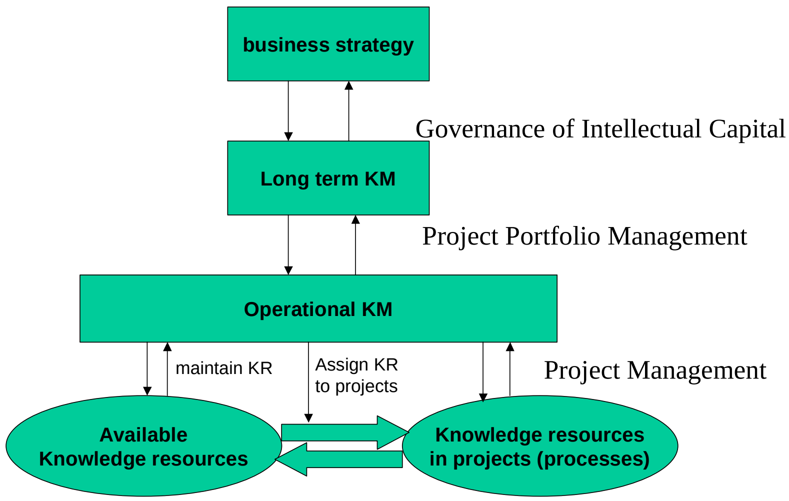

Figure 1 The Knowledge Governance Framework: Positioning Intellectual Capital, Knowledge Management (KM), Project portfolio Management, and Project Management (based on Smits and De Moor, 2004)

(Smits and de Moor, 2004).

The Knowledge Governance Framework (KGF) is a model of the managing – or more precisely 'governing'- of intangible assets like knowledge resources and intellectual assets (Smits and de Moor, 2003). The KGF defines many dependencies between KM parameters. To become really useful, however, the framework needs to be operationalized and applied to solving real-world KM problems. Well-defined key performance indicators can be helpful in effective knowledge management by allowing key aspects for decision making to be measured (Smits and de Moor, 2004a and 2004b). Such measurements can be useful triggers for internal communication between organizational stakeholders, provided that they are expressed in the specific terms in use in the organization (Stam, 2002).

The KGF distinguishes between qualitative and quantitative indicators for different purposes and management levels. Quantification of both soft and hard variables often leads to important insights into the structure and dynamics of a problem (Sterman, 2002). Measuring can help managing the knowledge-production and application processes throughout the knowledge system by tracing and documenting the causal relationships between activities that produce and apply knowledge (Wenger et al., 2002). However, these interrelated parameters have complex relations and change strongly in value over time. Without systematic support, it is very difficult for busy professionals such as managers to developing a sense of which measurements are essential in developing a deep understanding of the critical success factors of the KM they are involved in. The result is that many – costly – measurements may actually not contribute to improved KM, while other – essential – measurements are not performed at all.

One way to address this lack of understanding is through the use of theories and tools from system dynamics. System dynamics provides many practical tools to examine complex, dynamic phenomena in the world, yet at the same time is theoretically well grounded in control and non-linear dynamics theory (Sterman, 2000). The approach allows for the explicit modeling of human decision-making and operational behaviour and aims to help users understand patterns of behaviour, not precise predictions of the future. The methodology is well suited to capture and reason about essential aspects of the dynamic complexity of modern business organizations. It contains many analytical instruments that can be used to understand, present and discuss about how various organizational parameters and their interrelationships contribute to the success and failure of knowledge management.

1.1 Research question

In this study, we have focused on the following question: 'To what extent can system dynamics contribute to a better definition of knowledge management indicators?' The idea is that by using simulations of the KGF, the *key* aspects, which have a significant effect on knowledge management effectiveness, can be identified. Measurement efforts can then be focused on those aspects.

The simulation process should be embedded in a systematic indicator definition process. In such a process, organizational stakeholders such as managers define their own knowledge management indicators, both the parameters and their (ranges of) values, and see how they interrelate with other measurements. To this purpose, stakeholders first identify the key parameters and their interdependencies that operationalize key constructs of the KGF. The KGF is the underlying organizing framework that allows for dependencies between parameters to be defined and their effects to be explored over time. System dynamics simulation then allows users to (1) identify the areas in the KGF in which measuring makes sense at all, (2) examine how the indicator values evolve over time, and (3) if other indicators or relations between indicators are needed. In this way, the particular indicator set adopted by an organization can be validated, to see whether the results make sense, are consistent, and complete. In short, a system dynamics perspective helps organizations to get a sense for and increase the value of their measurements. As measuring is costly, and not measuring some essential KM processes and their outcomes even more, a system dynamics approach should allow for a more systematic evaluation of the need for KM metrics than possible with ad hoc measurement definition approaches.

In Sect. 2, we first explain basic system dynamics concepts. In Sect. 3, we present our model, based on analyzing a particular case (the ABZ case). In Sect. 4, we discuss related work and required future research. We end the report with conclusions in Sect. 5.

2 System Dynamics

System dynamics comprises a vast field of theory and practice. In this section, we will only give a brief overview of the key concepts and stages of the modelling process, the interested reader is referred to for instance (Sterman, 2000) for an extensive treatments of core theory and methods.

2.1 What is System Dynamics?

An important insight from system dynamics is that much systems behaviour is counterintuitive. Many people are not able to visualize the non-linear and feedback effects of interventions in complex systems. We extrapolate linearly, but much behaviour is much more complex, because of dependencies between variables and feedback loops in which the output of a system component ultimately has an effect as an input in the future. Additional complexity is introduced by the existence of accumulations (stocks) and delays. People often dramatically underestimate the inertia of systems, leading to incorrect policy conclusions. To handle such complexity, computer-aided simulations are indispensable. System dynamics is a methodology particularly suited to analyze such complex, large-scale, non-linear, partially qualitative dynamic socio-economic systems (Sterman, 2002; Diker, 2004)

System dynamic models can generate very complex, realistic behaviour. However, they consist of combinations of several simple concepts. To understand the essence of system dynamics, it is important to know these concepts.

- **Stocks**. Stocks are accumulated quantities or resources, characterizing the state of the system. Stocks give systems inertia and memory. A stock continues to exist, even if all the dynamics of the system come to a halt. An example of a stock is the number of employees of an organization at a certain point in time.
- **Flows**. A flow is a change to a stock that occurs during a period of time. A flow that is an input to a stock is called an inflow; a flow that departs from a stock is an outflow. A stock can only grow or deplete by its inflows or outflows. An example of an outflow of the stock Employees is the average number of employees leaving the organization per unit of time.
- **Feedback Loops**. Two basic types of dynamic behaviour are exponential growth and goal seeking.
  - Positive feedback loops. Exponential growth is displayed by positive feedback loops, which reinforce what is happening in the system. An example of such a loop would be: more investment in training leads to more highly educated employees, which leads to more production, which leads to more profits, which leads to a higher educational budget, which leads to more investment in training.
  - Negative feedback loops. A negative feedback loop counteracts change, and is self-correcting, in the sense that it stabilizes around a certain parameter value. For example, more highly educated employees leads to more offers from competitors to employees, which leads to less employees, which leads to less production, which leads to smaller profits, which leads to a lower educational budget, which leads to less investment in training, which leads to less highly educated employees.

All systems consist of networks of such positive and negative feedback loops. The resulting dynamics arise from the interaction between these loops and can result in very complex behaviour.

- **Delays**. A delay is a process whose output lags behind its input in some fashion, and is modelled by stocks and flows. There are two main types of delays: material delays and information delays.
  - Material delays. In a material delay, the outflow is related to the inflow, but takes into account an average delay time. An example of a material delay would be the stock ‘Employees in Training’, in which the outflow rate is dependent on the inflow rate, while taking into account a certain training delay.
  - Information delays. Information delays represent the gradual adjustment of perceptions or beliefs. In a material delay, the stock is the quantity of the material in transit and the output of the delay is a flow. An information delay typically takes the form of a goal-seeking, negative feedback system, in which, for example, learning delays can be modelled, in other words, the gradual process of obtaining a desired level of expertise.

2.2 The Modelling Process

There are various ways in which the system dynamics modelling process can be subdivided. A classic approach is the one provided by Sterman (2000). His sequence of steps comprises the following: (1) problem articulation; (2) formulation of the dynamic hypothesis; (3) formulation of a simulation model; (4) testing; (5) policy design and evaluation. In this paper, we use a simplified version of these steps that captures the essence of the dynamic modelling process (Vennix, 1996; Smits and Takkenberg, 1995): (1) problem structuring; (2) causal loop modelling; (3) making a dynamic model; (4) running the simulation; (5) implementing the results.

1. **Problem Structuring**. The problem is identified and initial data are collected. This stage has been extensively covered in previous METIS deliverables, e.g. (Smits and de Moor, 2003; Smits and de Moor, 2004).
2. **Causal Loop Modelling**. A causal loop diagram models the feedback loops that exist between variables in the model. Variables are linked with arrows, which indicate their causal relations. An arrow can be labelled with a plus or a minus sign. If connected by a plus sign, when the first variable changes, the second one changes in the same direction; when labelled with a minus sign, the target variable changes in the opposite direction. When looking at multiple arrows, loops can be detected. These loops are either reinforcing loops (creating exponential growth or collapse) or balancing loops (keeping things in equilibrium around a certain normative value). A loop is reinforcing when the net effect of the plus and minus signs of the arrows that make up the loop is positive; it is balancing when the net effect is negative. An example of a balancing loop in the KGF causal model is given in Fig.2.

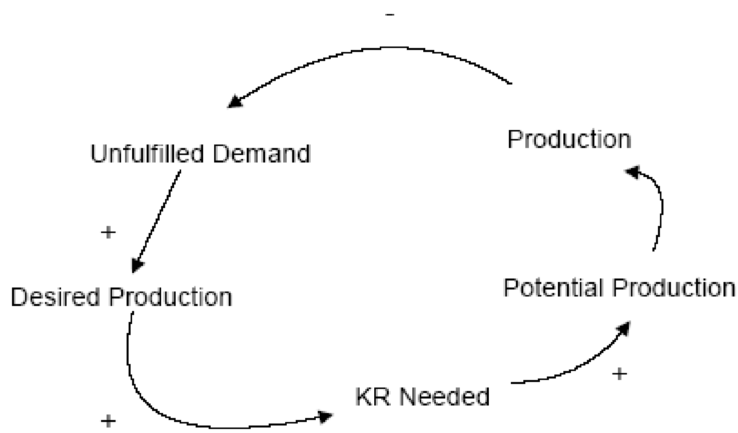

Fig 2 An Example of a Balancing Loop

Figure 2 shows how unfulfilled demand leads to more desired production. To achieve this production, more KR are needed. More KR leads to more potential and actual production. More production leads to less unfulfilled demand. Overall, this loop thus has a dampening effect.

A full causal loop diagramming process includes a number of steps: the main variables are identified; the behaviour over time graphs is prepared; a causal loop diagram is developed; the loop behaviour over time is analyzed; archetypes are identified; key leverage points are identified; and intervention stages are developed.

For the purpose of this study, we have taken the existing KGF dependencies as the main source of the KGF arrows and their signs. Additional variables and relations have been introduced where necessary to operationalize KGF concepts that are too high-level to be measured directly.

3. **Making a Dynamic Model**. The stocks and flows are modelled. A stock is an accumulated quantity or resource. A flow is the change to the stocks that occurs during a period of time. A stock can only increase or decrease by means of inflows and outflows. Stocks can be used to model both tangibles, such as produced goods, and intangibles, such as knowledge, as long as clear units of measurement are defined. An example of a stock plus its in- and outflows is given in Fig. 3.

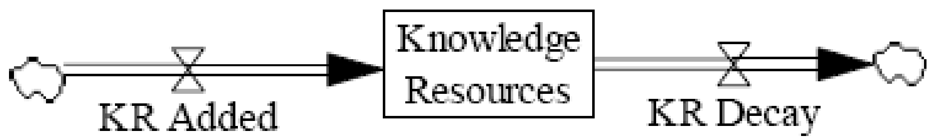

Fig-3 An Example of Stocks and Flows

This figure shows how the stock of knowledge resources grows by the amount of KR added, and decreases by the amount of KR decayed per unit of time. If the inflows and outflows per time are equal, the stock remains of the same size.

4. Running the Simulation. Using the dynamic model created in the previous step, the value of each parameter over time can be calculated, giving insights into key concepts of interest to a particular stakeholder, such as a knowledge manager. Different scenarios can be calculated, using differerent configurations of constants and initial values of variables. Sensitivity analyses allow for the interpretation of which changes initial values lead to the largest changes in results.

   For our purposes, a main application is to determine where KM measurements are useful. Because the dynamic model takes into account feedback loops and a long time horizon, which closely mimics properties of KM processes, simulations can help in developing a good sense of the relevance of measurements. One practical approach is to calculate scenarios for a range of parameter values of key variables and to see which changes in variables lead to the largest change in KM effectiveness. It then makes sense to concentrate measurement efforts on those variables.

   Fig. 4 is an example of how knowledge resources would evolve using the particular values chosen in an initial version of our KGF dynamic model (See Sect. 3).

   Of course, the value of the simulations depends on the initialization of the variables. These must accurately reflect the order of magnitude of real-world variables. One way to validate a dynamic model is by modelling real world cases and have experts judge if the values make sense. When calibrated this way, the model becomes more useful for a particular organization.

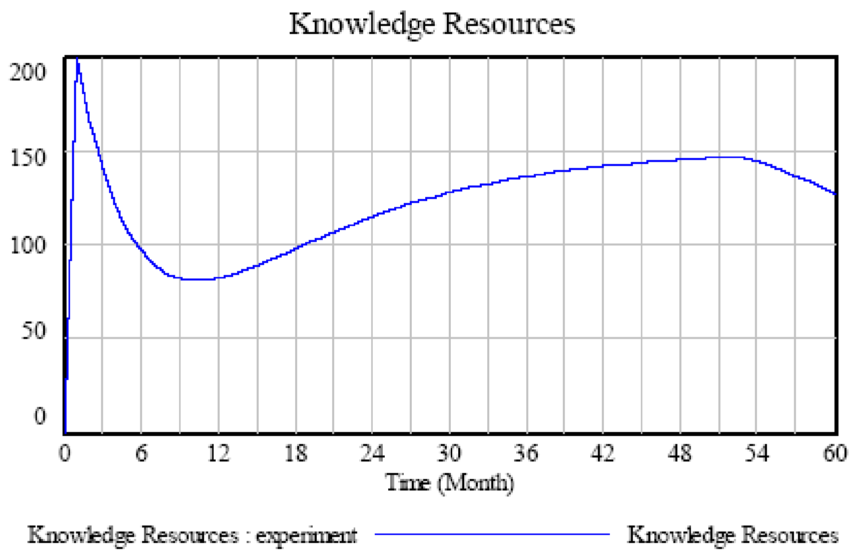

Fig-4 An Example of Knowledge Resource Dynamics

5. **Implementing the Results**. The results of simulations in general are implemented in policies, system designs, and decision-making processes. For our purposes, such purposes could be indicator refinement, the selection of key areas on which to focus the application of KM resources, examining the role of KM in business processes, and so on.

   System dynamics provides the tools and processes to expand the boundaries of our mental and formal models. All models are wrong, however. Instead of trying to validate models in the sense that they are 'true', the focus should be on creating models that are useful, the process of testing, the ongoing comparison of the model against data of all types, and the continual iteration between model experiments and experiments in the real world (Sterman, 2002). Thus, the process of modelling, explicating and testing assumptions, and interpreting results rather than providing exact predictions is key.

   The KGF is a highly abstract model. In a sense it is a meta-model, which aggregates many of the variables and their interrelationships into generic constructs like 'operational knowledge management' and 'mappings'. Managers, however, often use much more concrete concepts, such as 'training budget' and 'management summary' in their thinking and talking. These concepts and terminologies vary widely across organizations and KM situations.

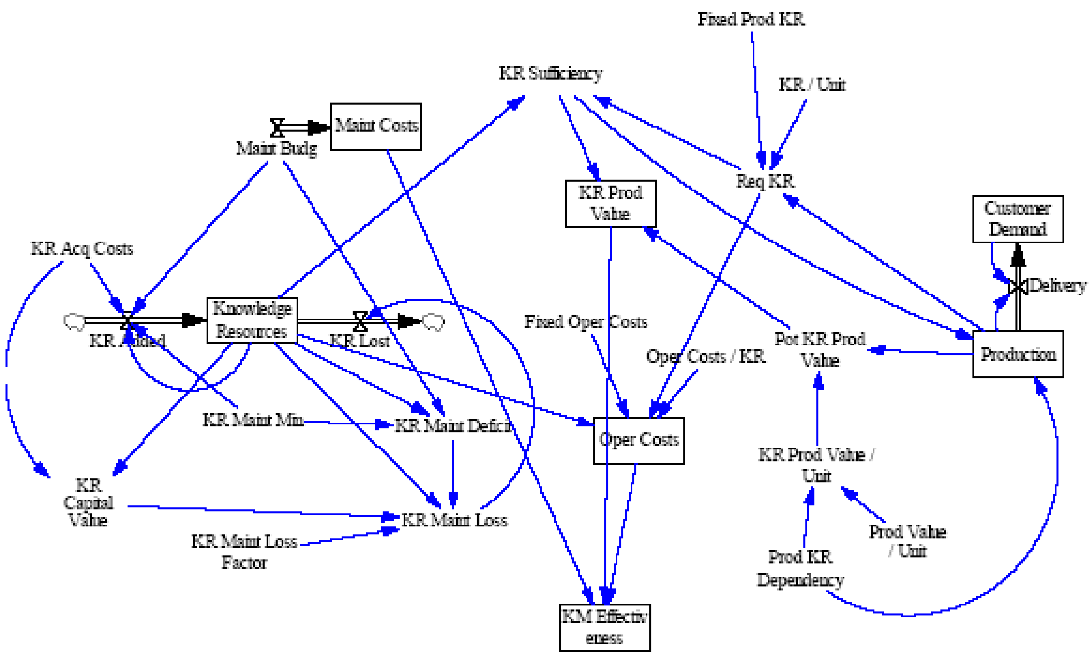

Fig. 5 The initial dynamic model of the KGF

To arrive at a useful dynamic version of the KGF, we therefore decided to develop a model in two stages. First, we developed a generic dynamic model of the KGF, which we kept as closely as possible to the key meta-variables and relations of the KGF. We then refined and operationalized this model by applying it to one case examined in our METIS-research: the ABZ-case. It is this model that we will present in detail in the next section. To illustrate how we followed the philosophy prevailing in system dynamics not to get stuck to endlessly refining a particular model, but rather to try many 'quick and dirty' models and then selecting one, we show the initial model we started our analysis with in Fig. 5. Note how very different it is from the model presented in the next section, both in focus and concepts and relations used. We found that building and testing the model while taking into account the specifics of a particular case helped in identifying which aspects of the KGF should be most useful for practice. It also made us aware of which abstract concepts required further extension and operationalization, which is a key benefit of simulation reported in the literature.

3 A System Dynamics Model of the KGF

In this section, we describe the dynamic model that we used for analyzing KM behaviour in the AB case. It is an evolved version of our initial model shown in Fig. 5. First, we present the AB case. We then introduce the model we made of this case. Finally, we run the simulation, and discuss some of the results.

3.1 The AB Case

Case AB is a midsize, project-based organization (200 fte in 2004, revenues 40 million euro in 2003) providing technology services in the insurance industry, primarily in the Netherlands. AB has about 8000 customers (insurance companies and intermediaries) in the Dutch insurance industry. AB's mission is to help customers to improve their operational performance against lower costs. AB offers 'trusted Business Services Provisioning' based on a variety of web-services, together forming the XNET service portfolio. XNET services include database management and secure communications to enable complex transactions between insurance companies and intermediaries. AB can handle all electronic messages and communication for its customers and also provides the related metadata and management information.

The AB organization consists of a four-headed management team (CEO, chief financial officer, chief operations officer, and chief technology officer (CTO)), standard staff functions for finance and personnel, and three departments that perform the key business processes: Marketing, Production, and the XNET resource center (XNRC). The Marketing department covers business development, sales, business architecture delivery, and the customer contact centre. Production does systems development, testing and systems management for customers. XNRC is the intermediary between Marketing and Production, and aims to match the customer needs (specified by Marketing) with AB capabilities (specified by Production).

XNRC consists of five groups: 'business service management' (a business service is a service that AB provides to a customer; a business service consists of ten well defined service elements), 'service element management' (service elements consist of software modules), 'standardization management' (maintains standards for data, communication, and systems, within AB as well as for customer groups and the insurance industry), 'project management', and 'technology architecture'. Technology architecture plays the central role in evaluating business opportunities (in the form of project proposals) and the development of new business services (in projects). Technology architects aim to minimize the risks of business service development, to maximize the fulfillment of customer needs, and to maximize the use of existing knowledge resources and revenues.

AB distinguishes between the following knowledge resources:

- **Knowledge residing in people** (implicit knowledge), grouped in departments. The Marketing department is organized in focus areas each covering a customer group or a customer process. The XNRC department has knowledge on AB products (business services and service components). The Production department has knowledge of system development methods, software platforms, and knowledge of opportunities for outsourcing production activities (knowledge on AB suppliers).
- **Knowledge residing in databases** (explicit knowledge). One database covers 'all' car damages in the Netherlands since 1985, another database contains the sales and distribution processes for insurance policies in the Netherlands. AB also deploys a large database to store all individual transactions that AB executes for its customers.
- **Knowledge in the form of AB programming and communication standards.** Some are explicitly stored; others are implicitly available in people ('this is how we do/ make it').

3.1.1 Operational and Long-Term Knowledge Management

Operational knowledge management is regarded to be the assignment of knowledge resources to projects and project proposals. Typically, AB has a portfolio of about 25 project proposals (varying from 'requests for information', 'request for proposal', to 'project has started recently') and about 15 running projects. Key objective for operational KM is to maximize the financial and strategic values of the total portfolio (per year) and to minimize the risks. AB is looking for new tools and methods to support the complex, ongoing process of portfolio management, which is currently based on the functioning of the internal and external communities of managers of AB, insurance companies and intermediaries.

Technology architects and project managers from the XNRC department, together with the production manager, assign people and other resources to projects. Resource assignment is an informal ongoing process, with only some formal rules. Before a project is started, AB uses a formal process to decide on project proposals. Each proposal includes the development of a 'business service'. A proposal can be customer-driven (blue sheet projects) or internally-driven (green sheet projects). Both project types are evaluated in two rounds: first a global check is done on (i) financial criteria (a draft business case is made by XNRC architects, with inputs from sales), (ii) strategic fit (a joint decision by the CTO, marketing, and XNRC management), (iii) a complexity scan of the proposed service by XNRC architects ('to what extent can this project be done, using existing AB competences?'), and (iv) sometimes a scan on legal aspects. The project proposals that successfully pass the first round are further evaluated in detail, by the impact on ten service elements, or as the XNRC manager stated 'AB determines the delta between the available service elements and the service elements that are required to fulfill the customer service'.

3.2 The System Dynamics Model

Adapting our initial model to the requirements of the ABZ case resulted in the model of Fig.6. The unit of time used in the model are months. A core concept is Knowledge Resources. These are initially set 0. KR added is the product of the workforce and the knowledge productivity factor. Each month KR are lost: the KR decay depends on the Knowledge Resources and a decay factor. KR available equal the Knowledge Resources times a time factor, to indicate potential inefficiencies in the resources becoming accessible.

Knowledge Resources are not created for their own sake, but should contribute to the production of goods of services. First, we need to know the KR dependency of production, which we define as the number of knowledge resources needed per unit of production. The total number of KR needed is thus the desired production times the KR dependency. The potential production (from a KR point of view, not taking into account other constraints on production, such as lack of physical resources, of course), is the minimum of the KR needed and KR available, divided by the KR dependency. Actual production is the minimum of desired production and potential production.

Desired production equals the unfulfilled demand divided by the average time to finish order. Unfulfilled demand is increased by the orders received and decreased by the actual production. In principle, the orders received equal the average number of orders, but in real business practice deviations from this average are often observed, which we can investigate by allowing a sudden increase or decrease at a particular point in time to be modelled.

The revenues in a certain month are the actual production times the average price per

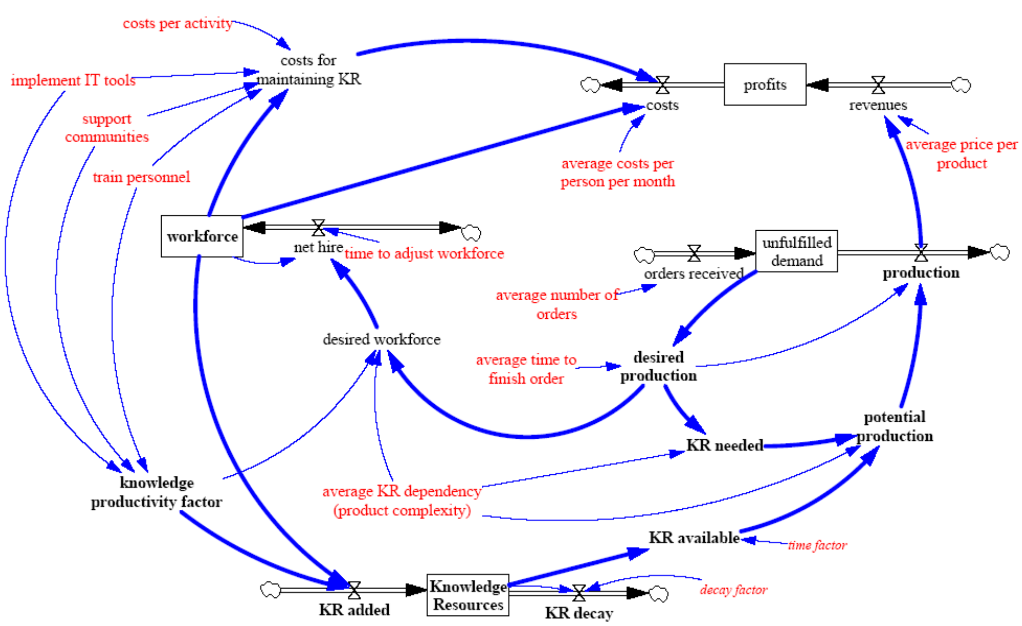

Figure 6. The System Dynamics model of the KGF for the ABZ case

product. The net increase in profits in a month are the revenues minus the costs. These costs are the average costs per person per month times the workforce plus the total costs for maintaining KR.

Key in determining fluctuations in the workforce in our model is the net hire rate. We have not yet modelled other factors, such as average rate of staff loss due to moving jobs and so on. The net hire rate is the desired workforce minus the actual workforce divided by the time to adjust workforce. The desired workforce is determined by the desired production divided by a productivity factor, which we define as the number of products a person can create per month.

Finally, the effect of KM policies on costs and productivity needs to be modelled. We distinguish three main policies: implement IT tools, support communities, and train personnel. Each of these is modelled as a percentage of total KR maintenance activities. The costs for maintaining KR are the weighted average of IT costs, community costs, and training costs times the workforce. The knowledge productivity factor is the weighted average of IT productivity, community productivity, and training productivity.

The model in figure 6 has two balancing feedback loops:

- Workforce - KR added - Knowledge Resources - KR available - potential production – production - unfulfilled demand - desired production - desired workforce - net hire.
- Unfulfilled demand - desired production - KR needed - potential production – production.

Appendix 1 contains the formulas and the initial values of the variables for the model. This base model can be adapted for different scenarios, as we do when running the simulation.

The dynamic model presented here by no means should be seen as a stable reference model. Many of the variable and value choices made are still arbitrary and need to be refined in future (empirical) case research. Instead, it is a preliminary model to inspire future case studies and experiments. Over time, more stable generic models can evolve, distilled from many applied models such as the one discussed in this section. Still, the model presented in this paper should show proof of concept of the necessity and feasibility of (1) developing dynamic versions of KM models like the KGF and (2) concrete approaches that can be understood and help to inspire business practitioners.

3.3 Running the Simulation in two scenarios

One way to use system dynamics is to (1) focus on several key *variables of interest*, (2) run the simulation for different scenarios with different settings for *steering variables*, (3) analyze the results and (4) use these as an input for organizational discussion or decision making. The aim of this initial study was to focus on steps 1 and 2, in future research we intend to explore steps 3 and 4 systematically.

As our variables of interest we choose knowledge resources, costs for maintaining KR, and profits. Steering variables are (initial) workforce and implement IT tools, support communities, and train personnel, as well as IT productivity, community productivity, and training productivity. We limit ourselves to running the simulation for two scenarios.

The first scenario is called 'High-Tech'. In this scenario, the organization invests heavily in IT solutions for knowledge management (implement IT tools = 0.6), pays quite some attention to training (train personnel = 0.3) and very little to community building (support communities = 0.1) Initial workforce = 180. IT productivity is a bit higher than average (1.2), and community productivity much below average (0.6).

The second scenario is called 'Strongly Social'. In this scenario, the company invests in people, by having a larger initial workforce (220) and relatively focusing more on community instead of IT solutions: implement IT tools = 0.2, train personnel = 0.3 and support communities = 0.5. IT productivity is a bit below average (0.9), community productivity much above average (2.0).

In both scenarios the costs of IT solutions are the lowest (IT costs = 100), the costs of training personnel the highest (training costs = 300), and the community costs are in between (community costs = 200).

Next, we present – for each scenario - the figures of the variables of interest (knowledge resources, costs for maintaining KR, and profits). The high tech scenario output is presented as the three left sided graphs in Figure 7. The strongly social scenario output is shown at the right hand side in Figure 7.

3.4 Analysis

As stated above, in this study we did not aim to do a systematic analysis of the differences between the scenarios. System dynamics offers many techniques such as games, sensitivity testing and optimization. This is subject of future research. However, an informal first analysis already leads to some interesting observations.

In both scenarios, profits accumulate almost identically. After an initial dip, profits increase almost linearly, only to slightly level off at the end of the five year period.

Both scenarios also show a similar pattern in development of knowledge resources: first a sharp increase to meet initial demands, then a rather strong decline, after which there is a gradual increase. At the end of the period, knowledge resources start to decrease slightly. Still, an interesting difference is that the Strongly Social scenario in the middle period gives a total number of knowledge resources of around 200 instead of the 150 for the High-Tech scenario. Given that profits are almost equal, management might decide to go for the Strongly Social scenario, since a higher number of knowledge resources means more flexibility, capacity to innovate, and so on. Costs for maintaining KR are somewhat higher for the Strongly Social scenario, but these costs don't affect total profits negatively, so they are not a reason for concern.

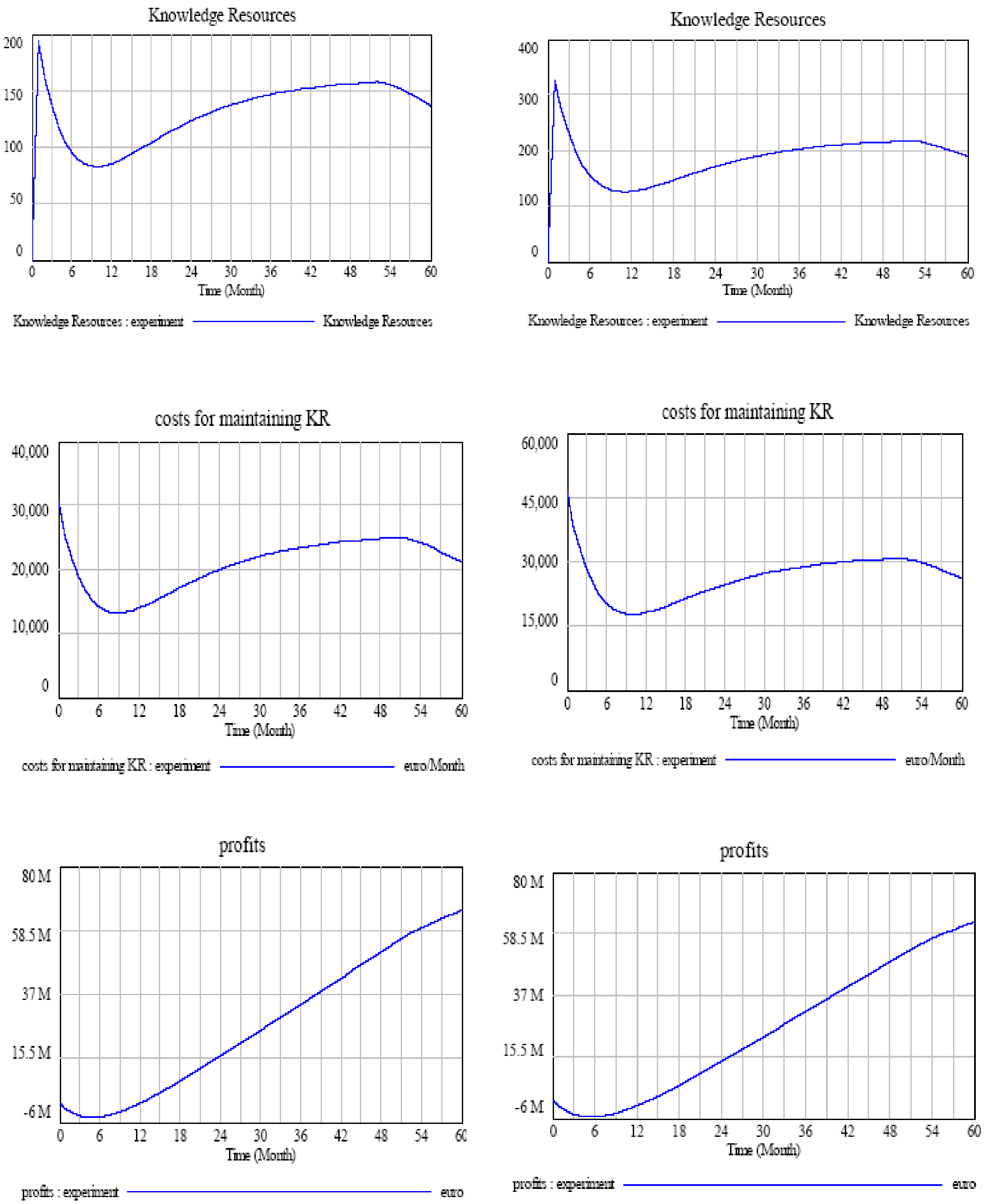

Figure 7. The output of the High Tech scenario (left) and the Social scenario (right). For explanations, see text.

4 Discussion

We have shown how dynamic models can be used to study the relationships and behaviour of KGF indicators. System dynamics models should not be used to produce exact predictions, but can be very useful for seeing larger patterns of change. It then becomes possible to make informed choices about which parameters in KM really matter in particular scenarios. Indicator definition and measurement efforts can then be channelled to where they are most effective.

The model produced in this paper is still rudimentary, but shows the relation between long-term KM decisions (invest in IT tools, communities, and training of personnel), the availability of knowledge resources, and the use of these resources in business processes. In system dynamics research, interesting work has been done on related models, such as Intangible Assets Monitor (Sveiby et al., 2002; see also www.systemdynamics.org/index.html). Such approaches can inform the refinement and extension of our dynamic model of the KGF.

However, focusing on extending the quality of the dynamic models alone is not enough. Another issue requiring future research is how exactly to organizationally embed system dynamics modelling processes in reflective activity about KM practices. Who defines and validates these indicators? Who is to interpret their usefulness? How to integrate different views on the value and importance of various indicators? How to combine quantitative indicator measures with tacit and informal knowledge required for their interpretation? How are such practices to be supported by organizational and technological means?

Indicator validation and interpretation of the results of system dynamics models require two things: (1) systematic, continuous discussion in (2) a natural, userfriendly mode. Wenger et al (2002) strongly favor measurement activities embedded in the organizational context. Static measures are not enough. They should be made useful in the context of stories that explain the causal links between them. A method supporting such embedded knowledge measurement activities should demonstrate causality through stories and ensure systematicity through rigorous documentation (Wenger et al., 2002).

One socio-technical approach that could achieve such a systematic story-telling approach are distributed weblog conversations, in which, over time, experts weave a web of relevant professional domain knowledge, linking their own ideas to ideas of others, thus building a collective interpretation of a complex piece of reality (de Moor and Efimova, 2004; Efimova and de Moor, 2005). In those discussions, new ideas for relevant variables and their values will also be generated, which can then be fed back into the dynamic model. Thus, the measurement system consists of a dynamic model (the explicit part), which drives a distributed conversation about its incorporation into organizational KM practices (the implicit part), which in turn extends and refines the dynamic model. The focus of the current study has been on the explicit part, in future research we would like to examine how to implement the dynamic model in an organizational conversation context. To deal with the complexity of such a system, developing an indicator definition wizard guiding users through the various model and blog functionalities would be very useful.

5 Conclusions

The Knowledge Governance Framework was introduced in earlier work as a conceptual model that makes visible relationships between key concepts of various levels of knowledge management. Although it has been used to successfully describe, analyze and compare various cases, one drawback is that the model is highly abstract. In this study, we have shown how the KGF can be made alive using simulation techniques from the field of system dynamics.

We have presented one operationalization of the KGF by creating a dynamic model inspired by a particular case. The model is still primitive and requires validation and extension by applying it in practice. Also, system dynamics offers a magnificent toolkit of modeling techniques, many of which would be very useful. One example would be to develop cockpits that allow end-users to easily play with models, tailored to their specific needs. Another important extension would be to do formal sensitivity analyses, allowing for the more precise identification of which aspects measurement efforts can be best focused on.

Measurements and models alone will probably not be very useful to the organization. Such techniques need to be embedded in a carefully aligned socio-technical system. A combination of system dynamics, web logs, and an 'indicator wizard' providing guidance to users in their various organizational roles could be a promising direction to explore.

In this paper, we have charted the tip of the iceberg of possibilities that system dynamics offers in combining KM research and practice. We are looking forward to exploring what is below the surface.

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7 Appendix 1: the Base Model

(01) average costs per person per month= 10000

Units: euro/(person*Month)

(02) average number of orders = 30

Units: products/Month

(03) average price per product= 100000

Units: euro/products

(04) average time to finish order= 12

Units: Month

(05) community costs= 200

Units: euro/Knowledge Resources

(06) community productivity= 1

Units: Dmnl

(07) costs= (average costs per person per month*workforce)+costs for maintaining KR

Units: euro/Month

(08) costs for maintaining KR= ((implement IT tools * IT costs)+(support communities * community costs) + (train personnel * training costs)) * workforce

Units: euro/Month

(09) decay factor= 1

Units: 1/Month

(10) desired production= unfulfilled demand/average time to finish order

Units: products/Month

(11) desired workforce= desired production/productivity factor

Units: person

(12) FINAL TIME = 60

Units: Month (The final time for the simulation)

(13) implement IT tools= 0.33

Units: Knowledge Resources/(Month*person)

(14) INITIAL TIME = 0

Units: Month (The initial time for the simulation)

(15) IT costs= 100

Units: euro/Knowledge Resources

(16) IT productivity= 1

Units: Dmnl

(17) knowledge productivity factor= (implement IT tools * IT productivity) + (support communities * community productivity) + (train personnel * training productivity)

Units: Knowledge Resources/(Month*person)

Note: the learning factor is the aggregate of maintenance activities

(18) Knowledge Resources= INTEG (KR added-KR decay, 0)

Units: Knowledge Resources

Note: The knowledge resources are initially set 0, and change monthly

(19) KR added= knowledge productivity factor*workforce

Units: Knowledge Resources/Month

each month KR are added, depending on the amount of personnel and the KP factor

(20) KR available= time factor*Knowledge Resources

Units: Knowledge Resources/Month

(21) KR decay= Knowledge Resources*decay factor

Units: Knowledge Resources/Month

KR decay equals KR so that at the end of each month KR = 0

(22) KR dependency= 0.2

Units: Knowledge Resources/products

(23) KR needed= KR dependency * desired production

Units: Knowledge Resources/Month

the KR needed to fulfill desired production depend on KR dependency

(24) net hire= (desired workforce - workforce)/time to adjust workforce

Units: person/Month

The net hire rate.

(25) orders received= average number of orders * (1 + STEP(-0.5,50))

Units: products/Month

(26) potential production= (MIN(KR needed, KR available))/KR dependency

Units: products/Month

(27) production= MIN(desired production,potential production)

Units: products/Month

(28) productivity factor= 0.2

Units: products/(person*Month)

(29) profits= INTEG (+revenues-costs, 0)

Units: euro

(30) revenues= average price per product*production

Units: euro/Month

(31) SAVEPER = TIME STEP

Units: Month [0,?]

The frequency with which output is stored.

(32) support communities= 0.34

Units: Knowledge Resources/(Month*person)

(33) time factor= 1

Units: 1/Month

(34) TIME STEP = 1

Units: Month [0,?]

The time step for the simulation.

(35) time to adjust workforce= 6

Units: Month

The time to adjust the workforce.

(36) train personnel= 0.33

Units: Knowledge Resources/(Month*person)

(37) training costs= 300

Units: euro/Knowledge Resources

(38) training productivity= 1

Units: Dmnl

(39) unfulfilled demand= INTEG (orders received-production, 0)

Units: products

(40) workforce= INTEG (net hire, 200)

Units: person

The number of working people.