DYNAMIC MODELLING OF A KNOWLEDGE MANAGEMENT SYSTEM EVOLUTION FOR A TECHNOLOGICAL CORPORATION

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November 2016
Creating an effective KM system in a company is always a unique task and does not have any established solutions. A KM system should be designed with account of the full life cycle of a specific resource, the “knowledge”, from idea to commercialization:

1. the generation of experts’ ideas which is the result of their individual or collective work
2. a formalization of knowledge and its transformation on physical media
3. selecting components of the formalized knowledge for legal protection (registering copyright and related IP rights)

It seems practical to develop KM system models used as decision support tools by the KM experts to demonstrate potential benefits associated with the KM system deployment in a company.
Modelling knowledge management processes

Queries ‘mathematical modeling, models of knowledge management’ in Google Search give about 6 million results.

Web of Science (WoS) and Scopus provide a large number of fundamental publications on the topic (622 in WoS and 1400 in Scopus) which reflect various aspects related to the development and application of mathematical methods for KM tasks.

The most common methods used for KM modeling:

- methods of system dynamics and simulation modeling
- multi-criteria decision making
- optimization and economic modeling
- etc
Main sub-models and parameters of the general KM system model

| Models of scientific staff reproduction | $x_1$ - the number of degreeless staff $x_2$ - the number of masters of sciences $x_3$ - the number of doctors of sciences ...
| Knowledge growth model | $y_1$ - the number of materials in hardcopies $y_2$ - the number of materials in softcopies $y_3$ - the number of research activities (projects, workshops, conferences etc) ...
| Commercialization and development | $z_1$ - the amount of intellectual property $z_2$ - the amount of finance per annum $z_3$ - the volume of sales per annum ...

Based on given assumptions it can be derived a system of differential equations of a KM system model with account of well-known relationships and models for social and economic dynamics.
Aggregated model of the KM system (1)

In the aggregated dynamic model of the KM system three generalized variables are considered: **human capacity** \((x_1)\), **accumulated knowledge** \((x_2)\), **profits** \((x_3)\)

The aggregated model is based on the assumption: each of generalized variables characterizes a certain output and can be described by a production function in which the production factors are the remaining generalized parameters.

**Cobb-Douglas production function**

The Cobb-Douglas function is used as production functions; their parameters should be determined in a computational experiment with account of statistics accumulated in a company.

\[
y = b \cdot x_1^\alpha \cdot x_2^\beta
\]

- \(b\) is the coefficient reconciling the both scales of the equation
- \(\alpha\) and \(\beta\) are the elasticities of factors 1 and 2 respectively determining the shares of input factors 1 and 2 in total output
The change rate of each generalized variable in the model is determined by:

- the natural losses – **the negative linear terms** in each equation characterize the irrevocable losses of human capacity, accumulated knowledge, profits
- the growth rate – **the nonlinear terms** are defined by the Cobb-Douglas functions

\[
\begin{aligned}
\frac{dx_1}{dt} &= -a_1 \cdot x_1 + b_1 \cdot (c_2 \cdot x_2)^{\alpha_1} \cdot (c_3 \cdot x_3)^{\beta_1} \\
\frac{dx_2}{dt} &= -a_2 \cdot x_2 + b_2 \cdot (c_1 \cdot x_1)^{\alpha_2} \cdot ((1-c_3) \cdot x_3)^{\beta_2} \\
\frac{dx_3}{dt} &= -a_3 \cdot x_3 + b_3 \cdot ((1-c_1) \cdot x_1)^{\alpha_3} \cdot ((1-c_2) \cdot x_2)^{\beta_3}
\end{aligned}
\]

- \(a_1, a_2, a_3\) - the irrevocable losses of each production factors in the KM system
- \(b_1, b_2, b_3\) - the normalization coefficients of relevant production functions
- \(\alpha_1, \alpha_2, \alpha_3\) и \(\beta_1, \beta_2, \beta_3\) - the elasticity coefficients of production factors
- \(c_1\) - share of HR involved in R&D, \((1-c_1)\) - share of HR involved in new production
- \(c_2\) - share of fundamental knowledge, \((1-c_2)\) - share of applied knowledge
- \(c_3\) - share of profit for HR development, \((1-c_3)\) - share of profit for technology development
Control parameters of the aggregated KM system model

The control parameters within the model, making it possible to change the KM system evolution and achieve the defined goals:

- the share of staff involved in R&D \( (c_1) \)
- the share of fundamental knowledge resulting from the KM system operation \( (c_2) \)
- the share of profit allocated to the HR development \( (c_3) \)

Depending on the goals of the KM system to be met, the control parameters can be selected in such a way as to ensure maximum closeness to the goals and serve as a tool for developing practical recommendations on managing the KM system.

NB! The proposed model is a basic one; it can be specified by means of detailing the relationships between the model parameters based on statistical data and empirical regularities including into an analysis new facts intrinsic to the full life cycle of the specific ‘knowledge’ asset.
**KM system evolution over time**

Here is examples of phase trajectories for a set of model parameters and initial conditions, showing the system possible evolution over time (the arrows on the phase trajectories demonstrate the motion of the system over time).

**“Pessimistic scenario”:** all phase trajectories tending to the zero point - a breakdown of the poorly designed KM system regardless an initial state and control parameters.

**“Equilibrium scenario”:** transition to steady-states - an efficient operation of the well-designed KM system (equilibrium states are defined as the equilibrium points).

**“Optimistic scenario”:** unlimited growth - a super-efficient, but an unrealistic operation of the well-designed KM system (due to the lack of system growth self-restraint accounting).
Expressions for coordinates of the equilibrium point

The equilibrium point of the KM system is as follows
(human capacity \( x_1 \), accumulated knowledge \( x_2 \), profits \( x_3 \))

\[
\begin{align*}
    x_{1}^{ep} &= \left[ \frac{a_1}{b_1 \cdot (c_2)^{\alpha_1} \cdot (c_3)^{\beta_1}} \right]^{1-\beta_2\beta_3} \cdot \left[ \frac{a_2}{b_2 \cdot (1-c_3)^{\beta_2} \cdot (c_1)^{\alpha_2}} \right]^{\beta_1\beta_3 + \alpha_1} \cdot \left[ \frac{a_3}{b_3 \cdot (1-c_2)^{\beta_3} \cdot (1-c_1)^{\alpha_3}} \right]^{\beta_2\alpha_2 + \beta_1} \\
    x_{2}^{ep} &= \left[ \frac{a_1}{b_1 \cdot (c_2)^{\alpha_1} \cdot (c_3)^{\beta_1}} \right]^{\beta_2\alpha_2 + \alpha_2} \cdot \left[ \frac{a_2}{b_2 \cdot (1-c_3)^{\beta_2} \cdot (c_1)^{\alpha_2}} \right]^{1-\beta_2\alpha_1} \cdot \left[ \frac{a_3}{b_3 \cdot (1-c_2)^{\beta_3} \cdot (1-c_1)^{\alpha_3}} \right]^{\beta_1\alpha_2 + \beta_2} \\
    x_{3}^{ep} &= \left[ \frac{a_1}{b_1 \cdot (c_2)^{\alpha_1} \cdot (c_3)^{\beta_1}} \right]^{\beta_2\alpha_2 + \alpha_3} \cdot \left[ \frac{a_2}{b_2 \cdot (1-c_3)^{\beta_2} \cdot (c_1)^{\alpha_2}} \right]^{\alpha_1\alpha_3 + \beta_3} \cdot \left[ \frac{a_3}{b_3 \cdot (1-c_2)^{\beta_3} \cdot (1-c_1)^{\alpha_3}} \right]^{1-\alpha_1\alpha_2}
\end{align*}
\]

These expressions may be used to determine the optimal values of control parameters of the KM system which ensure achieving the given goals (i.e. the profit maximization, maximization of the volume of accumulated knowledge etc) by varying

- the share of staff involved in R&D \( (c_1) \)
- the share of fundamental knowledge resulting from the KM system operation \( (c_2) \)
- the share of profit allocated to the development of human capacity \( (c_3) \)
Some results of the trial application of the aggregated KM model

Relative increase in general variables (equilibrium point) for different profit shares for the HR development (two types of companies)

- The higher the innovation potential of a company, the higher is its stability relative to the invested capital in the development of innovations.
- Sensitivity to profit reinvestments in the companies with high human capacity is significantly lower in the middle of the variation range and increases sharply, resulting in a loss of importance at low and high volumes of financing.
- The model predicts the fall of interest in research and human capacity in excess of investment that demonstrates the transition of high-tech companies into pure manufacturing ones.
The presented equations represent a possible aggregated model of the KM system in technological corporations, intended to simulate the system evolution over time including identification of possible catastrophic behavior of the system.

The model adequately reflects the KM system possible behavior over time and can be used with given modifications to solve various problems on forecasting the KM system deployment and assess the effectiveness of organizational measures aimed at improving the system performance.

Using this model, it is possible to simulate the KM system evolution over time and carry out scenario studies for different internal/external conditions as well as to select the optimal system control parameters in order to achieve certain goals and formulate requirements for the KM system components.

The performed trial analysis indicated some general patterns of the model behavior and possible scenarios for the KM system evolution.