REPRESENTING STRATEGIC ORGANIZATIONAL KNOWLEDGE VIA DIAGRAMS, MATRICES AND ONTOLOGIES

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***Abstract**: The paper describes methods and tools for organizational knowledge representation in the field of strategic management. Visual and matrix/table-based methods are actively used for knowledge representation in this domain. Diagrams solve problems associated with the managerial thinking (cognitive challenges), managerial communications and coordination (social problems), and the ability of managers to motivate and involve their employees (emotional problems). On the other hand, there are types of information and tasks that are better supported by matrices. In order to effectively combine diagrams with matrices the paper suggests multi-representation of organizational knowledge using ontologies. Such multi-representation capabilities for organizational knowledge are already supported by some enterprise architecture management software tools. Two of these tools are described in the paper.*

***Keywords**: organizational knowledge, knowledge management methods, knowledge representation, knowledge structuring, ontologies, strategic management.*

***ACM Classification Keywords**: A.0 General Literature - Conference proceedings*

Introduction

Nowadays there are more and more new methods and tools for the effective operation of corporate knowledge. This article describes some results of the project INNOVARRA "Innovations in Organizational Knowledge Management: Typology, Methodology and Recommendations", aims to identify and develop knowledge management (KM) methods and tools, which are the most appropriate for particular knowledge type and domain of the company. Various enterprise knowledge domains (e.g. product/service knowledge, customer knowledge, operations management or strategic management knowledge etc.) have different knowledge characteristics and knowledge types. Systematization of knowledge types, characteristics and domains in INNOVARRA project is designed to differentiate KM methods and tools better suited for a particular knowledge domain. The project is based on the idea of the “triad” (Figure 1): “knowledge domain – the type or characteristics of knowledge – a method or a tool of knowledge management". Analysis and systematization of studies linking types and domains of expertise with KM methods and tools was performed in the INNOVARRA project in order to differentiate KM methods and tools. Three tracks of the INNOVARRA project are considering the examples of KM methods and tools in several areas, namely: management of customer knowledge and knowledge about the products and / or services, knowledge in the field of operations management, knowledge in the field of strategic management and organizational development. This paper describes preliminary results for knowledge representation methods in the field of strategic management.

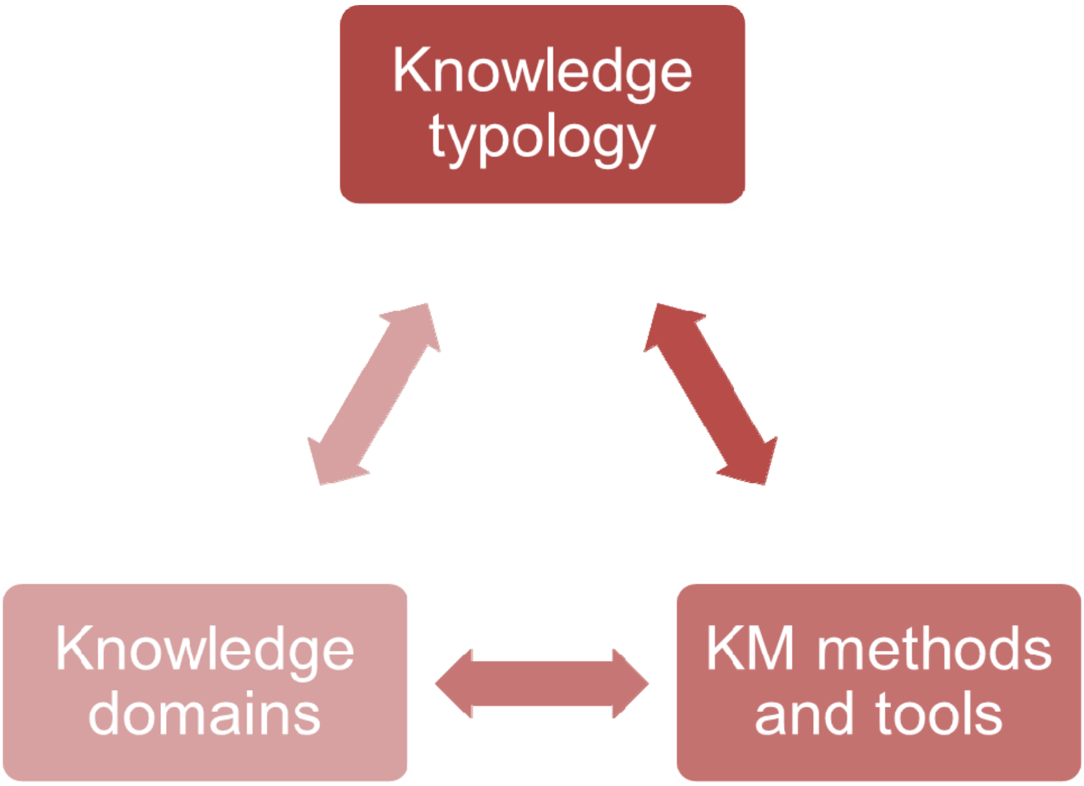


Figure 1. “Triad” of differentiation of KM methods and tools

An analysis of the literature identified the following problems in the development and implementation of the strategy: 1) cognitive (information overload, the rigidity of the old points of view, etc.) 2) social (different viewpoints of the team members and the need for their integration, etc.) 3) emotional (lack of a sense of belonging to strategies, etc.). Diagrams and matrix/table-based methods helps to overcome these problems, but should be used cooperatively. This cooperation can be provided by ontology-based tools. In the strategic management domain this technology can be implemented through ontology-based enterprise architecture management tools, which are initially aimed to process knowledge about an organization.

The use of visual methods in strategic management

Strategic planning processes are one of the most difficult issues which managers face today. It can be an overwhelming challenge – at the same time to take into account the development of new technologies and social trends, and the behavior of competitors, customers and regulatory authorities, changes in the legal, environmental and financial base. The problem is compounded by the limited time, market uncertainty, the constant changes and internal tensions. Strategic planning task is further complicated by the need for communication, implementation and monitoring of these decisions. Taken together, these activities create numerous cognitive (eg. information overload), social (eg. coordination of several groups and hierarchical levels) and emotional (eg. employee involvement) problems for the manager. However, visualization – a graphical representation of data, information and knowledge – may offer significant advantages in each of these three spheres. And, together with tables and diagrams, it is becoming more and more popular knowledge management tool in the domain of strategic management.

The relationship between the key issues of the process of strategic management and the benefits that have been made possible thanks to the visualization are shown in Table 1. This table shows the potential benefits from the use of graphic representation of strategic content for the strategy development process.

Table 1. Strategic issues and ways to solve them with the help of visualization [Eppler & Platts, 2009]

Possible problems in strategy development	**Corresponding strengths of visualization**
Cognitive	
Information overload Overload due to the large amount of information in the analysis, its complexity	**Facilitating elicitation and synthesis of information** The visual channel improves the perception, there is compression of information, the patterns and structures of data set are seen more clearly
Stuck in old view points The development of strategic options often requires novel perspectives and divergent thinking	Visual methods enable reframing, change points of view, inspire creativity and contribute to perspective switching
Biased comparison and evaluation	Better, more exhaustive comparisons

Paralysis by analysis Omission of strategic information due to the large flow of information relating to daily operations	Visualization helps to remember the current strategic conversations, visual recall is better than verbal recall
Social	
Diverging views or assumptions between team members Strategy development and formulation requires collective sense making processes and input from various team members	**Integrating different perspectives** Visualization can equilibrate participation and reduce the dominance of certain participants, identifies areas of disagreement
Incomplete communication of basic assumptions Managers need to assure that their reasoning is properly understood by employees	**Assisting mutual understanding** Visual tools often make basic assumptions explicit
Coordination difficulties Strategizing requires coordination both in communications and actions. This is especially true for globally dispersed teams	Visual artefacts provide explicit reference points for mutual coordination and alignment, the ability to share network modeling
Emotional	
Lacking identification with strategy	**Creating involvement and engagement** Pictures can create involvement and engage people's imagination
Employees should perceive the strategy as something worthwhile pursuing, something that aspires and motivates	Helps to inspire and motivate people
The strategy needs to be communicated to employees convincingly	Visualization is ideally suited for convincing communication and presentation purposes

Cognitive, social and emotional benefits could be better represented by a different genre of strategy visualization with the help of typical visualization tools and formats used for the strategy process as shown in Table 2.

Table 2. Four genres of strategy visualization methods [Eppler & Platts, 2009]

Visualization Method Type	Main Features	Examples of Typical Visual Formats
Structuring Methods (Analysis Phase)	Provide a ready-to-use structure (incl. categories) to organize and synthesize information	Bar diagram, line chart, system/loop diagram, 2by2 positioning matrices (BCG, McKinsey, SWOT), Porter's five forces diagram, S-curve diagram strategy chart, product-market diagram
Elaboration Methods (Development Phase)	Provide rules and a relatively open structure to elaborate on information, discover new patterns, build a common understanding and develop options	Decision tree, Ansoff matrix, morphological box, knowledge map, concept map, Mind Map, Parameter Ruler, influence diagrams, strategy canvas
Sequencing Methods (Planning Phase)	Provide rules, categories and graphic structures to organize information, such as tasks or goals, chronologically to prepare action	Timeline, flowchart, Gantt chart, road mapping, CPM diagram (critical path method), PERT diagram, swim lane diagram, loop diagram, Synergy Map
Interaction Methods (Implementation Phase)	Provide an interface to capture, aggregate, present and explore information.	Management controlling dashboard/ cockpit, Strategy Map, visual metaphors, tracking diagrams such as flight plans

Cognitive advantages of visual representations include facilitating the identification and compilation of information. This provides new perspectives that allow carrying out comprehensive comparison of alternatives and facilitate planning of the sequence of actions. Social benefits include different integrations, helping people to understand and support each other. Finally, the emotional benefits include creating a sense of participation and involvement, providing inspiration and forging closer ties.

Additional review and classifications of visual knowledge processing techniques can be found in [Gavrilova, Gulyakina, 2011; Kudryavtsev, Gavrilova, 2016].

The use of table / matrix methods of knowledge structuring in strategic management

With the increasing complexity of management technology, demands on decision support tools and methods to solve specific business problems are growing as well. It is important that the tools, processes and structures supporting management technologies have the following characteristics:

- reliability;
- economic and practical feasibility (would not be too complex or resource intensive);
- ability to integrate (would work together with other frames, processes and tools already deployed in business);
- flexibility (the ability to adapt to the specific context of business goals, market environment, the available resources and information, corporate culture, etc.).

Such tools can take many forms, including matrix or state-space solutions, matrix connections, tables, profiles, checklists, taxonomy, software, and combinations thereof.

As noted above, there are many different types of control instruments, methods, processes, structures and patterns. In this paper, the focus is just on the "Matrix Tools" presented in Table 3. Such a structure can facilitate understanding and help in decision-making, or recommend specific managerial actions.

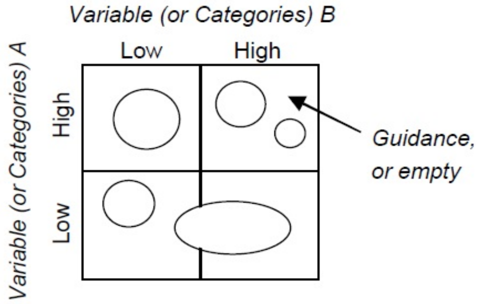
Classical "2x2 matrix" is a typical example of this type of a tool, widely used by consultants and managers in business, as well as by researchers. These tools are widely discussed in the literature, although a guide on applying them in practice could be rarely found. Phaal with the colleagues [Phaal et al, 2006] offered 4 different types of matrices: a matrix or state-space solutions, matrix connections, tables, profiles; on the basis of a large sample of more than 850 tools and mechanisms of matrix tools.

Matrix methods are relatively simple and orthogonal. Most often, these structures are two-dimensional, but the dimension may be higher. The structure connects the key aspects of the problems to be solved. The axes can be divided into categories or specific variables that can be qualitative and quantitative, discrete and continuous. The matrix can either already contain text, structured along the axes and related categories, or can be "empty", that allows the user to explore the relative position of the various options for the relationship between the key dimensions and categories.

Table 3. Matrix tools (revised and extended version of [Phaal et al, 2006])

<table>
<tr><th>Types</th><th>Descriptions and examples</th></tr>
<tr><td>

Positioning and decision matrices



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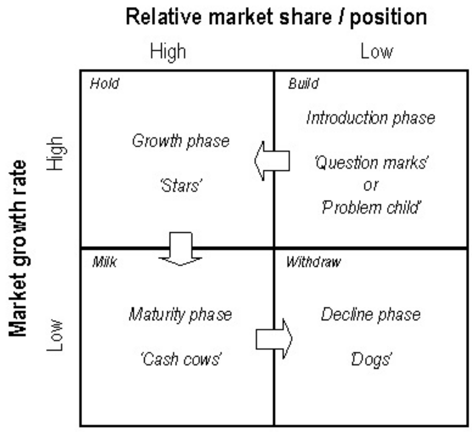
Categories are usually split into multiple values. If the matrix is empty, attention should be focused on the study of the mutual arrangement of the various options. This is the most common type of instrument.

Example: BCG Matrix



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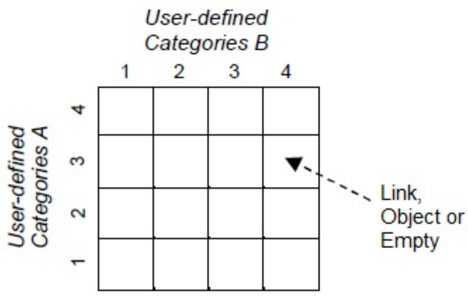
Matrices of relationships (Generic grids)



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Axles are divided into a plurality of different categories, the number and content of which are specified by the user. The matrix provides a structure that allows the user to explore the relationship between the axes and associated with them categories.

Example: Responsibility Matrix

	ROLE 1	ROLE 2	ROLE 3	ROLE 4
TASK 1	R	C	I	A
TASK 2	I	I	R	A
TASK 3	C	R	A	I
TASK 4	A	R	I	
TASK 5	R	A	C	I
TASK 6	C	C	A+R	I

R=responsible A=accountable C=consulted I=informed

</td></tr>
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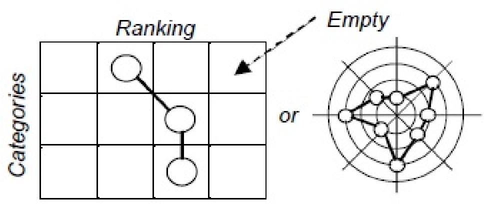
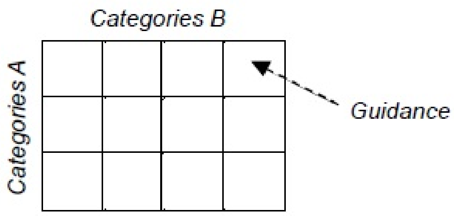
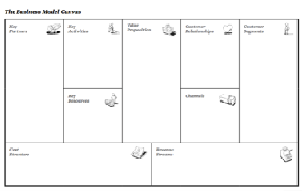
<table>
<tr><th>Types</th><th>Descriptions and examples</th></tr>
<tr><td>Generic scored profile

</td><td>One axis is divided into separate defined categories, and the other indicates the scale that allows the user to evaluate an action in terms of specific categories. The tool may be in the form of radial graph.</td></tr>
<tr><td>Generic table

</td><td>The axes are divided into individual, specific, pre-defined categories. The matrix typically contains text providing information about the axes and associated categories.
Example:
<table>
<tr><th></th><th></th><th colspan="2">Strategy</th></tr>
<tr><th></th><th></th><th>Corporate strategy</th><th>R&D strategy</th></tr>
<tr><td rowspan="4">Area of influence</td><td>Resources</td><td>Allocation between functions - marketing, production, R&D, …</td><td>Allocation between projects</td></tr>
<tr><td>Objectives</td><td>Related to business environment</td><td>Related to corporate environment</td></tr>
<tr><td>Business areas</td><td>Product / market strategy, Product / market mix</td><td>Technology / product strategy, Portfolio balance</td></tr>
<tr><td>Timescale</td><td>Balance between long / medium / short term</td><td>Balance between long / medium / short term</td></tr>
</table></td></tr>
<tr><td>Canvas (table-based template)
</td><td>Example: Business Model Canvas [Osterwalder, Pigneur, 2010]
The tool is used as a visual chart with elements of business models describing a firm's or product's value proposition, infrastructure, customers, and finances. It allows aligning and challenging activities of the companies.</td></tr>
</table>

The following benefits of matrix methods are allocated in the studies:

1. They are relatively simple, both in terms of their concept and in use. Most of these tools can be represented as a simple scheme.

2. Typically tools based on matrices are flexible – they can be applied to specific situations in the company. You may need adjustment in accordance with the current context, which in general meets the criteria of flexibility.

3. Assuming that axis and parameters can be combined, matrix-based tools have the ability to be linked to form a more powerful integrated set of tools.

However, matrix tools have potential drawbacks:

1. Many practical problems or issues cannot be simplified to two dimensions that make the matrix tools ignore other important factors.

2. The use of these instruments as a rule requires research or settings, which may not be an easy task.

3. The use of tools of this class is impossible when the theoretical foundations of the instrument are not clear, or if knowledge and skills necessary for their effective application are inadequate.

Combining diagrams and matrices

The effects of tables and graphs on elementary tasks are generally well studied [DeSanctis & Jarvenpaa, 1985; Jarvenpaa, 1989; Jarvenpaa & Dickson, 1988; Vessey, 1991]. Specifically, Jarvenpaa and Dickson summarized several studies, finding that graphs lead to faster or better performance for most elementary tasks, including summarizing data, showing trends, comparing points and patterns, and showing deviations. Tables, however, lead to better performance for the task of reading the value of single points. Two theories serve to predict the effects of tables and maps on problem solving, and both preach compatibility between the demands of the task and the representation of information. The first, cognitive fit [Vessey, 1991], recommends spatial information for spatial tasks and symbolic information for symbolic tasks, and explains the effects found by Jarvenpaa and Dickson [Jarvenpaa, Dickson, 1988] in that light. The second theory, the Proximity Compatibility Principle (PCP), espouses physical proximity of data if the task demands its integration [Wickens, 1992; Wickens, Merwin, & Lin, 1994].

There are two papers [Ghoniem et al, 2005; Keller et al, 2006] that compared the representation power of matrix and node-link diagrams. Ghoniem et al. [Ghoniem et al. 2005] showed that matrices outperform node-link diagrams for large or dense graphs in several low-level reading tasks, except path finding. This difference is supported by user study experiments conducted by Keller et al., as they found that node-link diagrams offer better visual representation for small, uncomplicated entities, but they are a complex form of representation for large systems and propagation across systems [Keller et al, 2006].

So diagrams and matrices/tables have their own advantages and disadvantages. It is important to find cognitive fit between task, type of information and representation format. Typically the same information can be represented in either format for different purposes. Let’s consider a couple of strategic management models, which are represented in both visual and table form.

The first example of using visual forms for strategic knowledge representation was described in [Gavrilova, Alsufiev, Yanson, 2014], where visual conversion of classical business model CANVAS [Osterwalder et al, 2005] into a mind map was proposed (see Fig. 2). That map suggests the most compact and compressed form of strategic company knowledge. The proposed business model template in the form of a mind map uses a blend of modern theories of knowledge engineering, cognitive sciences, and Gestalt psychology. The presented approach employs the building graphs methods and techniques, particularly mind maps [Buzan, 2003]. The canvas business model traditionally consists of nine blocks that reflect the structure of business processes: key partners, key resources, key activities, value proposition, sales channels, customer segment, customer relationships, revenue streams, costs.

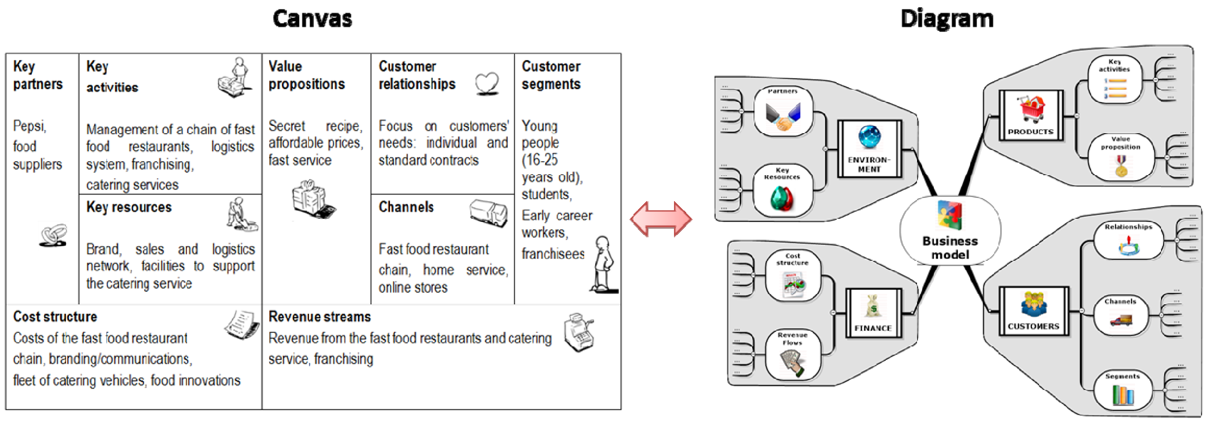


Figure 2. Business model representation in canvas and diagram

The 2 forms of representation (table vs map) were evaluated by 16 managers from executive education cohort. The obtained results allow concluding that as a way of representing a business model, a mind map is more effective than a business model canvas in terms of several important factors: easiness to use, speed of perception, clarity and understandability, aesthetic pleasure, opportunity to use in operational activities. The highest difference was seen in the criteria "opportunity to use of operational activities". This major difference can be explained by the fact that rich functionality of contemporary mind mapping software (e.g., MindManager, iMindmap, iThoughts) facilitates using of the visualized business models for strategic management.

The second example is based on [Kudryavtsev et al, 2014, a, b]. The papers suggest the model-oriented method for business architecture alignment, which uses proven matrix-based Quality Function Deployment (QFD) methodology for analysis, decision making and communication. The central element of this method is the matrix, which is called "The House of Quality" [Hauser, Clausing, 1988]. This matrix method can augment famous visual method of strategic planning – Kaplan and Norton's Strategy Maps [Kaplan, Norton, 2004], see Fig. 3. Strategy map in this example is better for capturing "big picture" and strategy communication, while matrix-based representation is better for detailed analysis of relationships between objectives (elements of strategy map).

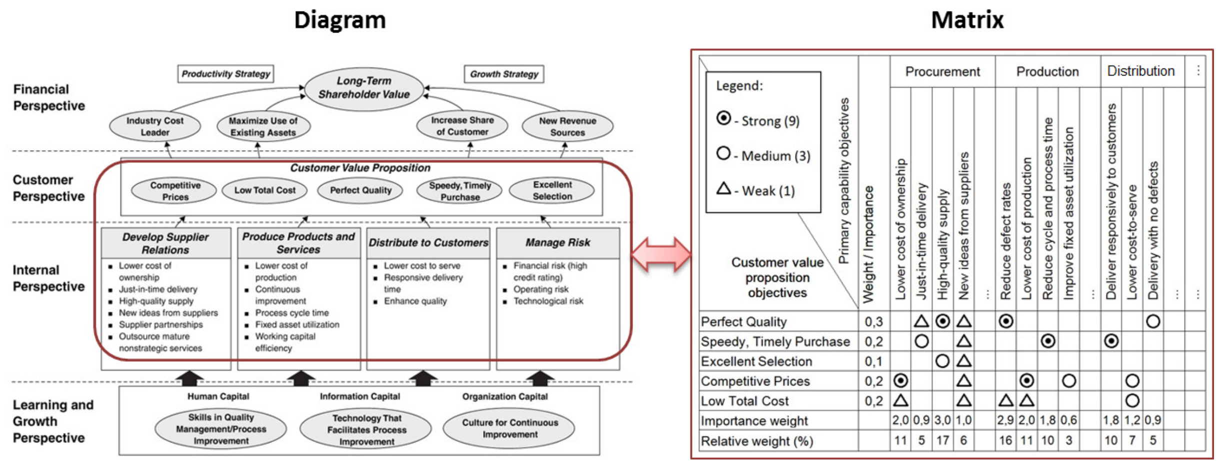


Figure 3: Strategy map and corresponding matrix with relationships

Multi-representation of organizational knowledge using ontologies

Organizational knowledge for strategic management can be structured and processed by specialized enterprise architecture management tools. Enterprise architecture (EA) is an approach to provide insight and overview in order to manage the complexity of an organization and to aid strategic decision making [Op’t Land et al, 2009]. EA is based on enterprise modeling and implies documentation of enterprise strategies, business capabilities, business processes, organizational structures, and information technologies, and especially their interaction and dependencies. From representation perspective EA models include catalogs, matrices and diagrams [TOGAF, 2011]. Originally, EA was developed as a tool for information systems management [Kappelman et al, 2008]. During the previous decades the concept has evolved more towards an instrument for business IT alignment [Simon et al, 2013]. EA has included business goals, value chain, business capabilities etc. as elements since it was first introduced by Zachman [Zachman, 1987] in the late 1980s. Now EA is more and more attached to enterprise transformation [Labusch, Winter, 2013] and strategic management [Aldea et al, 2013; Simon et al, 2013]. Simon at al. [Simon et al, 2013] show that EA could support the strategic planning process in several phases. According to them, EA would be most valuable in the strategy formulation and implementation phases, when assessing the readiness of the organization for transformation and deciding on how to execute the chosen strategy. Furthermore, they show that EA is least valuable in the strategy review phase. This is because the final performance can have been impacted by a variety of soft factors such as the employee resistance to change, which cannot be measured with the aid of EA. Enterprise architecting is supported by corresponding tools [Bittler, 2012]. Enterprise architecture management tools not only capture relevant information, but also process this information, e.g. using reports, visualizations or applying analytical methods.

As we've mentioned diagrams and matrices/tables have their own advantages and disadvantages. It is important to find cognitive fit between task, type of information and representation format. The same information should be represented in different formats depending on the task and context. The ontology-based approach for enterprise architecture management can be used for this purpose. Ontology is a formal, explicit specification of a shared conceptualization [Studer et al, 1998]. A 'conceptualization' refers to an abstract model of some phenomenon in the world by having identified the relevant concepts of that phenomenon. 'Explicit' means that the type of concepts used, and the constraints on their use are explicitly defined. For example, in medical domains, the concepts are diseases and symptoms, the relations between them are causal and a constraint is that a disease cannot cause itself. 'Formal' refers to the fact that the ontology should be machine readable, which excludes natural language. 'Shared' reflects the notion that ontology captures consensual knowledge, which is not private to some individual, but accepted by a group. Ontologies and corresponding semantic technologies are actively used for information integration, knowledge management, e-commerce, education and semantic web [Domingue et al, 2011; Gavrilova, Laird, 2005; Gomez-Perez et al, 2003; Gorovoy, Gavrilova, 2007]. Ontologies are also used for enterprise modeling, but these applications are mostly geared towards business process modeling/management and data integration. Ontologies for business architecture modeling, visualization and reporting are not yet applied.

It is suggested to use ontology as a metamodel for enterprise models. A populated enterprise ontology is equal to an enterprise model. All the necessary stakeholders' concerns are satisfied using ontology-based views. These views can be either document-oriented (text, table) or visual (diagram). The contents and the form of these views are defined using specifications (or viewpoints). Figure 4 represents the transition from the collection of independent diagrams and tables to the mapping between the diagrams, matrices and the enterprise ontology. This mapping provides the translation of ontology-based enterprise model into the partial views. Similar ideas and methods are currently being discussed in the "Semantic Cartography" community: https://www.linkedin.com/groups/8101187 and are organized by Bernard Chabot on his website https://www.topincs.com/SemanticCartography/1345.

Examples of ontology-based tools for multi-representation of organizational knowledge

The aforementioned idea is implemented in the following two technologies.

The ORG-Master modeling approach has originally been conceived in the course of the development of the business engineering toolkit in 1998 [Kudryavtsev et al, 2006; Grigoriev, Kudryavtsev, 2011; Grigoriev, Kudryavtsev, 2013]. Fig. 5 represents the suggested technology.

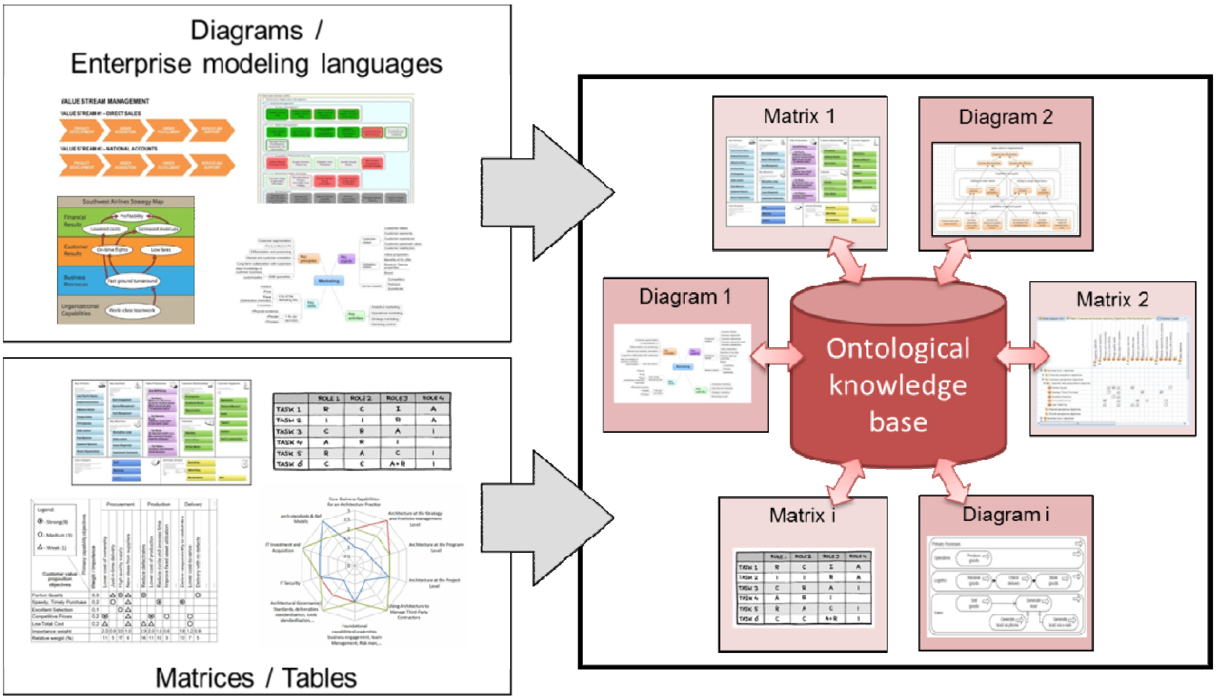


Figure 4. Multi-representation of organizational knowledge using ontologies

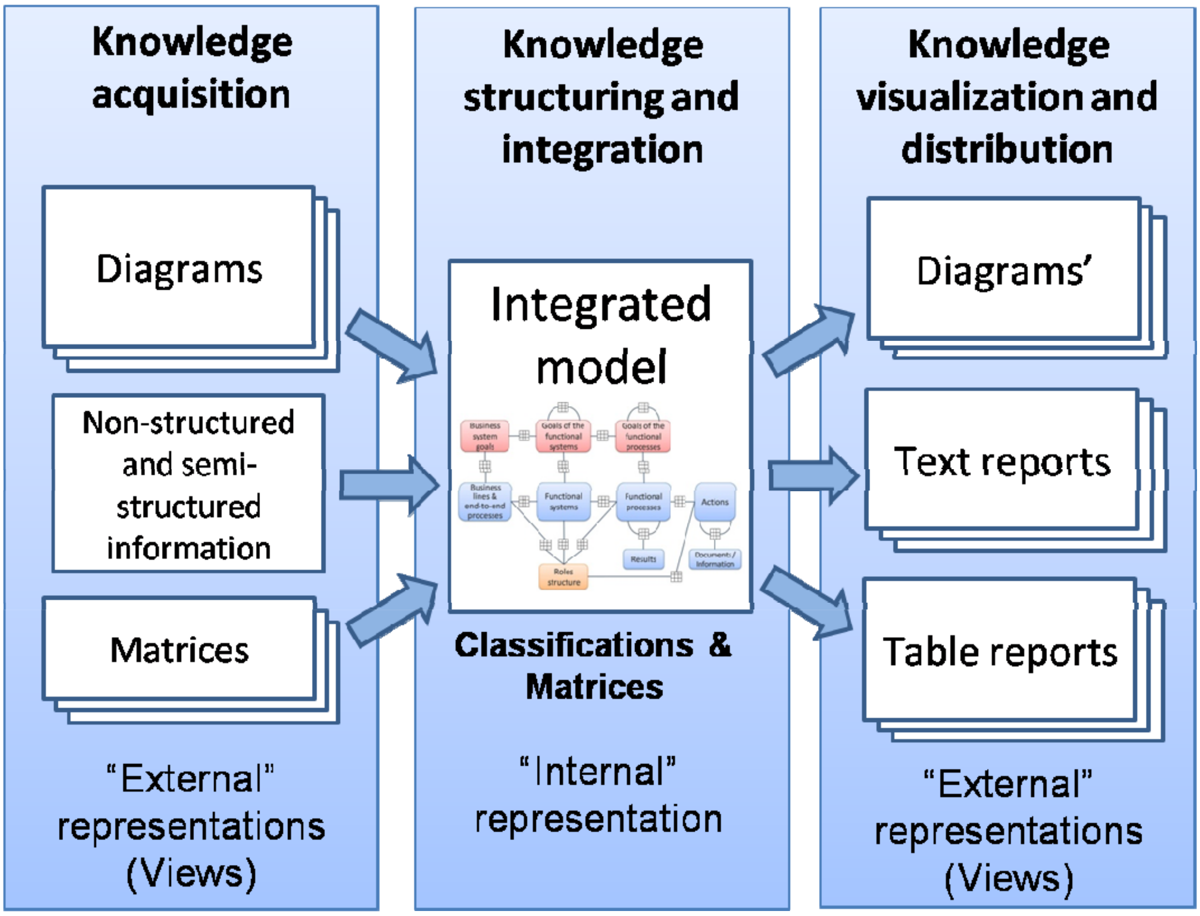


Figure 5. ORG-Master modeling approach

The non-diagrammatic method plays the central role in this technology. The modeling process starts from knowledge acquisition. Enterprise modelers collect information about an enterprise from various sources (people's memory, documents etc.), then organize it using diagrams, classifications and matrices. Diagrams can be created in ORG-Master graphical editors, which are based on Microsoft Visio. Typically process flow diagrams, concept maps, strategy maps and organizational chart are in use during business architecture engineering. These artifacts can be discussed and agreed upon with managers (managers can also make models by themselves). This step is standard for EAM tools. Then ORG-Master integrates all the acquired knowledge using classifications (hierarchical lists) and matrices – so called “internal” representation. These integration and complex structuring is typically done by highly qualified modelers. This step helps to provide holistic big-picture and consistency in large-scale EA models. However the resultant integrated model is inappropriate for final users and enterprise stakeholders, so ORG-Master provides capabilities to specify and generate partial views from this model (diagrams, text and table reports), which will suit various concerns of various stakeholders. Consistency of the “internal” model and of the “external” views is achieved through automatic model transformations, which are based on a shared unified metamodel (enterprise ontology) and mappings (between different notations and shared metamodel).

The second technology – Essential project – is suggested in [Mayall, Carter, 2015]. The Essential Project [2016], a ten-year development program that has produced an open source enterprise architecture support toolkit with a comprehensive metamodel. In common with other enterprise architecture management suites, Essential enables users to define and describe their enterprise in terms of its current and future states. The Essential Project is the collective name for a set of open source, enterprise architecture support tools that have been developed for use in conjunction with a variety of Enterprise Architecture approaches and frameworks.

More specifically, the components that currently comprise the Essential Project are:

- The Essential Meta-Model, a framework-independent set of semantic definitions for knowledge related to the building blocks and relationships of an enterprise.
- The Essential Architecture Manager, a knowledge repository and reporting tool for capturing and then querying information based on the Essential Meta-Model.

The Essential Architecture Manager is a toolset that is focused solely on supporting enterprise architecture practices, applied in the context of a variety of business and IT management processes (e.g. strategy management, IT governance, solution delivery, service delivery). The toolset offers all the required features of an enterprise architecture tool as defined by the Gartner Group. Fundamentally, these features can be grouped into two areas of functionality; functions that support users in the modeling of an enterprise, and functions that provide users with discrete views of this model in support of reporting and analysis. This grouping is reflected in the underlying design of the toolset in that it comprises two main components, which separate the capture of information from the analysis (Fig. 6):

- Essential Modeller, providing support for capturing and maintaining the enterprise architecture model
- Essential Viewer, responsible for generating reports that allow users to view and analyse the enterprise architecture model. These reports can be in different forms: text, tables and diagrams.

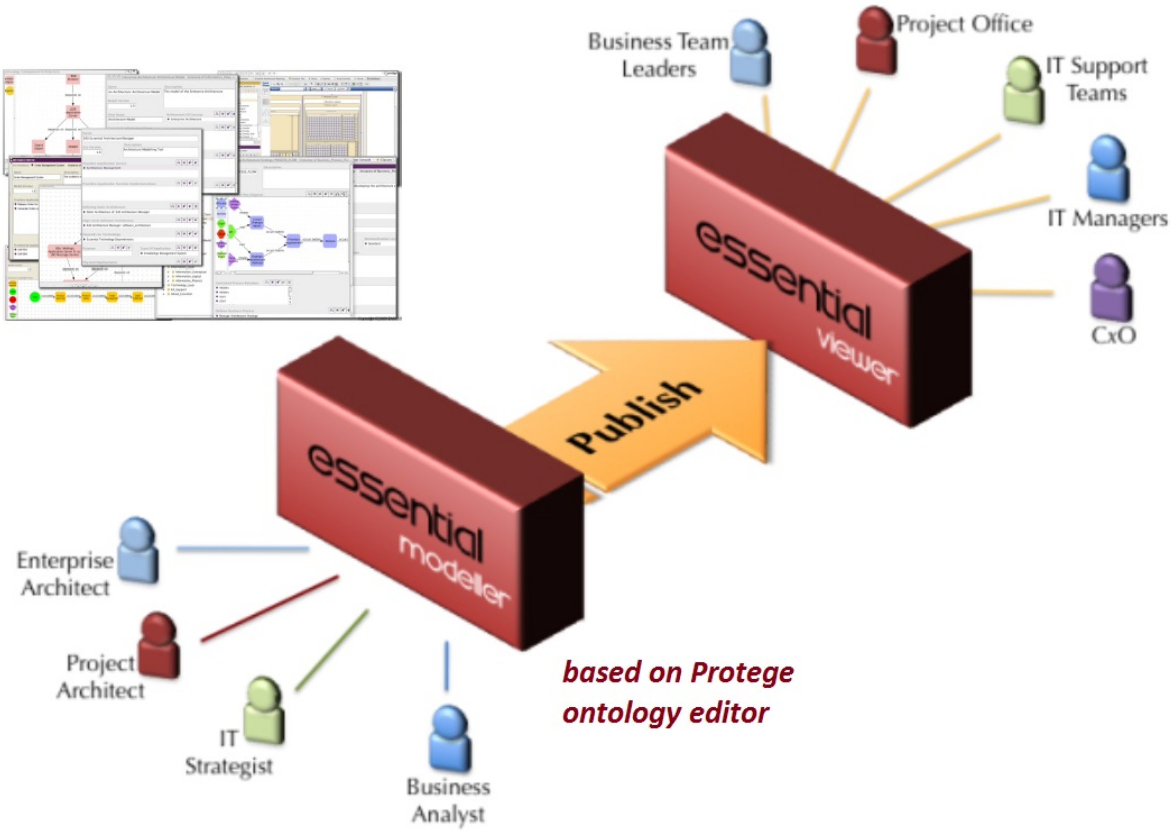


Figure 6. The Essential Architecture Manager [Essential project, 2016]

Conclusion

The paper discusses methods and tools for organizational knowledge representation in the field of strategic management in the form of diagrams, matrices and ontologies. These three types of tools are used in strategic management for different purposes. Diagrams are better suited to solve problems associated with the managerial thinking, communications and coordination. Matrix tools can improve decision-making and elaborate analysis in strategic management. In order to provide multi-representation of organizational knowledge the third tool described in the paper could be used – ontologies. Ontologies are actively used for information integration, knowledge management and analytics. Two technologies are described in the paper as examples of ontology-based tools: ORG-Master modeling approach, which helps to collect information about an enterprise from various sources, organize it using classifications and matrices, and generate partial views from them (including diagrams and matrices) suiting concerns of various stakeholders; and Essential project, which provides meta-model and software tool to develop ontology-based enterprise models and publish them in various forms.

Acknowledgements

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