THE CONCEPT OF SEMANTIC SYSTEM FOR SUPPORTING PLANNING OF INNOVATION PROCESSES

Jurczyk-Bunkowska M., Pawełoszek I.*

Abstract: The paper presents a concept of a system supporting planning of innovation processes, which aim is to estimate key parameters of newly launching innovation process. A base of this estimation is knowledge contained in a large number of different kinds of documents describing the innovation processes that have been implemented before. Considering the diverse and unformalized structure of such documents the system has been proposed basing on semantic search and document linkage mechanism. The paper presents how the estimations can support decision making in innovation management. The concept of architecture of this system along with the descriptions of its functions and modules also has been described. The paper also introduces the concept and role of innovation processes ontology in building the semantic innovation planning system.

Key words: innovation processes, semantic system, planning, ontology.

Introduction

Innovation is often discussed and defined in diverse kinds of publications, not only of scientific nature. Various aspects of innovation phenomenon are highlighted depending on context and the authors' aims. In hereby publication we discuss the problems concerning operational level of innovation management. Therefore we adopted the definition of O'Sullivan, who also considered innovation management on operational level (O`Sullivan and Dooley, 2009). He defines innovation as the process of making big and small changes, both radical and incremental, to products, processes or services. A result of these changes is introducing something new to an organization. This novelty can add value to customers and contributes to developing organizational knowledge. This definition emphasizes the process nature of innovation creation, highlighted also by other authors (Cooper, 1998) (Sotarauta and Srinivas, 2006).

Regarding innovation as the most important element of competitive advantage increases the interests of researchers and practitioners in innovation management both on strategic and operational level. The growing interest of national and regional regulatory institutions also can be observed (White, 2005). Additionally ever-increasing time pressure accompanying the innovation processes increases the number of participants involved (McNally et al, 2011). There is also a need to consider the influence of some new strategic concepts such as open innovation, crowdsourcing (Jóźwiak, 2014) or user driven innovation on realization of innovation processes (Jelonek, 2012). The idea behind these new concepts is to

* **Magdalena Jurczyk-Bunkowska,** Opole University of Technology, Faculty of Production Engineering and Logistics, **Ilona Pawełoszek**, **PhD**, Czestochowa University of Technology, Faculty of Management.
✉ corresponding author: ipaweloszek@zim.pcz.pl

extend the scope of innovation process by involving new stakeholders from the outside of the company (Chiaroni et al., 2011). Therefore the innovation processes performed nowadays, are not only realized inside the company, but with the significant contribution of different kinds of organizations or individuals (Vanhaverbeke, 2006). As the research shows the spatial aspects have significant influence on the nature of innovation systems in different regions (Pachura and Nowicka-Skowron, 2010). Smart growth based on knowledge and innovation also requires an increase in use of information technology (Frączkiewicz-Wronka and Wronka-Pośpiech, 2014; Lis et al., 2013).

Considering their nonlinear character, managing the innovation processes was always a difficult task. The aforementioned new trends, determine the need for increased management flexibility. Thus the question appears: how to reasonably manage the innovation processes? This question is relating to each of the management functions: planning, organizing, motivating, control and coordinating. However the possibility to estimate the innovation process parameters such as: duration, volume of expenditures, number and kind of critical tasks, list of risk factors are most important regarding the planning function. The enumerated parameters are related to the detailed plan of innovation process, which is in turn a basis for the other management functions. Unfortunately, because of the unknown structure of innovation processes it is not possible to apply an approach basing on process decomposition as it could be in case of projects.

Therefore there is a need to search for alternative approaches allowing the innovation process manager make reasonable assumptions about the time, cost and other parameters of the process. In this paper the Authors consider the issues of acquiring knowledge necessary for management of the newly-launched innovation process.

The aim of the paper is to propose the concept of the system which supports innovation management. The system allows for estimation of the new innovation process parameters, on the basis of many innovation processes performed in the past that had similar features.

The data for such analysis are contained in different kinds of documents created by diverse economic and organizational units. Some of these documents are formalized and other are rather informal, for example reports, notes, e-mails containing data in tabular form or unstructured text.

For this reason the semantic system for planning innovation processes parameters has been proposed. Such system gives a possibility to extract particular information out of various unstructured or semi-structured data sources.

The specificity of innovation management

The specifics of processes which result in implementation of innovations have been described under a broad research conducted as a part of Minnesota Innovation Research Program (MIRP) (Schroeder et al., 1986). One of the important findings of MIRP was that the innovation processes encompass convergent and divergent

activities, which may be repeated in time and different organizational levels. The main contribution of MIRP to innovation management discipline was demonstrating the nonlinear characteristics of the innovation processes management. The nonlinearity is mainly caused by experimental nature of tasks composing the innovation process (Van De Ven et al., 1999). These tasks lead to lead to new knowledge creation and consequently their effect may be surprising. As Kline and Rosenberg (1986) highlight that the innovation process should not be considered as linear in the sense that solving one problem leads to formulation of another one. Instead different problems are solved simultaneously as a consequence of interaction, feedback and coordination between specific activities of the process.

The presented characteristics of innovation processes illustrates how difficult is to manage them. However this effort is worthwhile and essential to achieve an expected outcome – which is growth of competitive advantage of the organization. Therefore, considering the issue of innovation processes management it is needed to take into account their specificity related to:

- uncertainty regarding the activities which are performed during the process,
- uncertainty of process structure resulting from the relations between activities, their consequences and number of repetitions,
- uncertainty relating to the number of the process contributors and their mutual relations.

The aforementioned features make the innovation process management more flexible than project management. On one hand that flexibility accelerates creativity, but on the other – it can be the cause of chaos.

Haushild describes innovation management as "the operative configuration of the processes of innovation". The author also highlights that decisions in case of innovation management differ significantly from administrative decisions in terms of their specifications, such as (Hauschild and Salomo, 2004):

- complexity,
- future orientation,
- high level of uncertainty and risk,
- required creativity.

This specificity illustrates the significant difference between the innovation processes and other processes in organization in general terms. For the manager it is necessary to concentrate on the process as a whole, rather than on its single activities. A low success rate of innovation implementations can be a proof that there are significant problems accompanying innovation process management. New product failure rate estimated at 40 to 75 percent (Stevens and Burley, 2003) (Clancy and Shulman, 1991). For this reason the main focus of consideration for scientists and practitioners is to search for and implement some tools which help to decrease this rate.

The need for support in innovation process planning

While launching a new innovation process a manager must make some reasonable assumptions to estimate the basic parameters of the new process. These basic parameters are:

- duration time of the process and its particular phases;
- volume of expenditures on each phase,
- critical activities for each phase,
- required skills and competences of the team members,
- required infrastructure,
- most critical risk factors, that accompany the given innovation process.

Making these assumptions is fundamental for creating a plan of innovation process. The manager's role is to define an approach to operative management of innovation process in terms of:

- how to create teams;
- how to finance innovation process;
- how to communicate (aims and forms of communication, reports structure for particular recipients);
- rules for accessing the research infrastructure;
- rules of process control;
- monitoring procedures for external and internal environment;
- risk management method;
- tasks priorities, etc.

All those issues require estimation of basic parameters of the newly launched innovation process. The task of estimation is difficult because the processes refer to practical implementation of a unique concept and therefore they are unconventional. Thus the question arises: What should the manager be guided by while defining the assumptions for the innovation process plan?

In hereby paper the authors present an original concept of an approach to resolve this problem. The authors propose the concept of estimation of basic parameters of a newly launched process, guided by information collected from large number of processes that had been already realized in the past. The approach will allow for discovering relations between process features and parameters.

Innovation specific knowledge is hidden in different kinds of documents accessible for the managers. Unfortunately most of the documents lack unified structure because they are created for different purposes i.e.: financial, marketing, and organizational. Additionally they are created by various organizational units as well inside as outside the company – documents can be found in different departments, such as: R&D, construction, technological, marketing, accounting etc. or in different organizations such as: institutions supporting innovativeness, financial, statistical, research institutions etc. Taking into account the diverse character of documents being the source of knowledge about innovation processes,

the concept of semantic system for planning innovation processes has been presented in the next section.

The aims and idea of the semantic system for supporting innovation process planning

The aim of the system is to support the innovation planning decisions on early stages of innovation process planning. The proposed system is to enable managers to search and analyse data of the processes that had been realized in the past. The most important assumption is that the data is acquired only form documents relating to innovation processes which are somehow similar to the one that is to be launched. The certain degree of similarity is needed to assure that the estimations will be accurate and will fit well to the characteristics of the planned innovation process.

Innovation processes differ significantly from one another. For this reason it is not right for example to predict duration time of radical innovation basing on data related to incremental innovation process. Similarly, data describing product innovation would not be valid while estimating organizational innovation parameters and vice versa. The semantic approach to analysing data of the processes previously performed will allow for selecting the right examples that can be used as reference base for the new process planning.

Development of the semantic system for supporting innovation process planning requires deciding about an approach to preliminary data processing and integration, data exploration and preparing results in a form useful for analysis and assessment.

At present the system development is on its first – conceptual phase. The preliminary architecture of a system is illustrated on Figure 1.

The concept assumes that the semantic system for supporting innovation process planning will be composed of four main modules, respectively: gathering information, analysis of information, knowledge sharing, and the user interface.

The function of information gathering module is to provide access to electronic base of heterogeneous documents containing information about different innovation processes that had been realized in the past. The document base should be continuously developed, maintained and verified. This module is somehow the answer to the postulate of organizational learning by innovation processes (Tidd et al., 2005). The document base contains only valid documents, verified in terms of credibility, containing information which allows for describing the innovation process and (at least partly) to determine its parameters. The system performs its main function at the moment of posing a query by the user about predicted parameters of newly launched innovation process. The interface enables the user to precise search query by indicating class and parameters of innovation process that is to be planned.

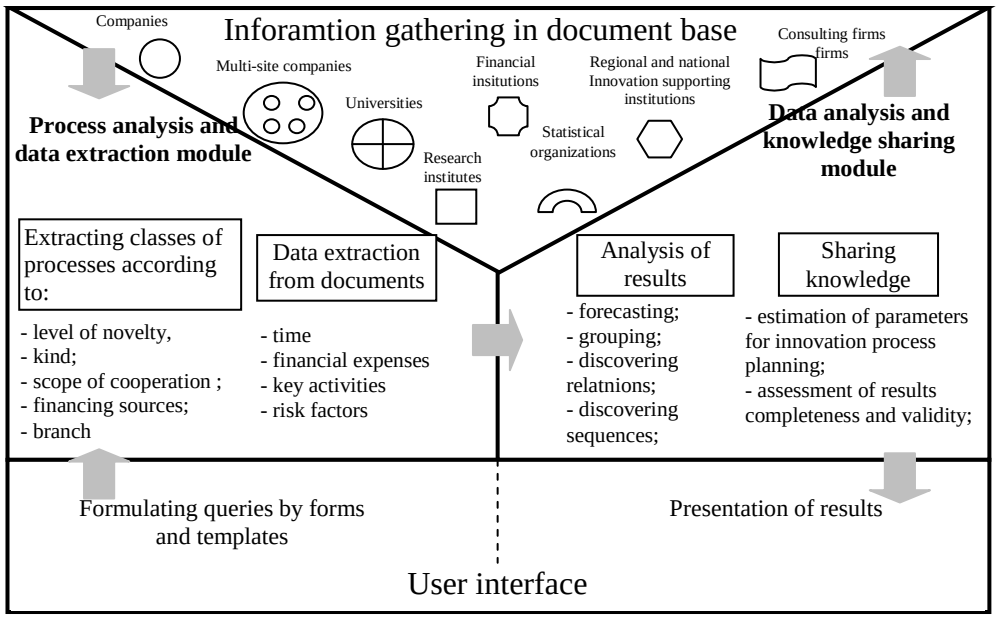

Figure 1. Architecture of semantic system for supporting innovation process planning

The user interface is a set of forms that assist the user in choosing the main elements of the process according to innovation process ontology. Let us say, for example the manager needs to estimate the duration time of product innovation with the given degree of novelty. Apart from the kind of innovation and novelty level the process can be also described by many other parameters such as external sources of financing, certification requirements, scope of cooperation, etc. Spatial aspect is also very important.

Thus the query is built of a set of keywords and additional parameters. The aim of building the query is to precise the problem by characterizing innovation process under consideration, which parameters are to be estimated. Complex queries can be saved as templates to be used or customized in the future.

The user interface plays also important role in results presentation. After estimating the parameters the user can specify granularity and scope of search results. For example it is possible to display indirect results, maximum and minimum values, lists of analyzed documents. The interface also enables the user to provide additional search restricting conditions, so it is possible to limit the search to the innovation processes of the specific organization/s, or to indicate the processes lead by a given manager.

The function of the analysis module is to extract the data from documents, select the data that is needed for further analysis, "data cleansing" and normalization, interpretation of incomplete or missing data and creating the working collection of documents that will undergo the process of reasoning.

For now the model of data exploration has not been yet developed, also the task of data extraction and reasoning requires further consideration taking into account the specifics of innovation planning.
The measures that can be applied to asses performance of the system modules are necessary, on a technical level we can consider precision and recall. The first one is to show the fraction of relevant documents that were used to reasoning process, to the whole number of documents that fulfill the user's criteria. The second measure represents the fraction of retrieved documents to all the documents that were selected to the reasoning process.
The objective the data analysis module is also to classify the innovation processes, for example extracting the groups of processes where the duration time were exceeded or the specific risk factor appeared. This function helps to discover the relations between some facts such as delays in organizational innovations and their linkage to commercialization. This kind of analysis can also lead to discovering sequences for example: the processes implemented in cooperation with research institutes are usually accompanied by tasks related to determining the extent of work and signing an agreement.
The next important function of the system is knowledge sharing. The system should be implemented as a platform for collaborative work so it would be possible to develop the document base collectively by its stakeholders such as companies, organizations, research institutes. For the first prototype implementation we choose the MediaWiki platform enhanced by semantic extensions (*Semantic Mediawiki*, 2014). It seems a good choice considering the collaborative nature of the wiki system, easy to learn user interface for editing documents and searching, as well as the possibility to modify the software which is accessible on the Open Source license.

Ontology for innovation process planning

The ontology for innovation process should facilitate the description of innovation processes from the operational point of view. It would be complementary to the ontologies that already exist in the domain of innovations, which are mainly describing the strategic level of innovation management (Riedl et al., 2009).
Ontology is a specification designed to categorize and help explain the relationships between various concepts of in the given area of knowledge and research. The most widely accepted definition of ontology in the context of knowledge sharing and information science was proposed by T. Gruber (1995), he says that ontology is a specification of a conceptualization. The interpretation of this definition can be that:

- Ontology provides a common understanding of a particular domain, or field, of study, and ensures a shared ground for those who study the domain.
- Ontology is useful of organizing concepts, information, and ideas; it helps to show the relations between concepts.

- Ontology can be formalized which means that it can be read and understood by computer applications.

The role of ontology in knowledge engineering is to enable construction of a domain model by describing a set of concepts and relations between them. In case of the system for supporting innovation process planning, the ontology should provide shared terminology that is valid for the reasoning process. Thanks to the ontology it is possible to link the information from different documents with parameters needed for innovation process management. It is consistent with the Gruber's pragmatic definition of ontology, which assumes that ontologies should be driven by application requirements. The idea behind ontology in artificial intelligence domain is to enable sharing and reusing knowledge. In the proposed system the role of ontology is:

- definition of kinds of documents that should be stored in the data gathering module,
- definition of attributes of innovation processes in a way that ensures they can be classified by the module of analysis and data extraction,
- definition of key parameters of innovation process planning in a way they could be extracted from documents relevant to particular class of innovation process,
- definition of parameters and attributes of innovation process planning according to the users' needs,
- describing relations between innovation processes and their parameters.

Applying semantic technology to the document base enables knowledge discovery that could be hard to obtain in traditional SQL relational data bases. On this moment the development of innovation process ontology is on its first stage – definition of requirements basing on analysis of separate disciplines connected with innovation processes. The range of concepts covered by innovation process ontology is illustrated on Figure 2.

Conclusions and future work

Nowadays innovativeness lays at the heart of business strategies in most of enterprises. Considering the dynamic growth in number of innovation process contributors, they require creating new solutions aiming at creating effective collaboration environment. The presented concept of semantic support of innovation process planning is well suited for the new market trends and information needs of managers. The key purpose is to connect knowledge management and innovation management on operational level. One of the most important effects of innovation process implementation are learning, increase in organizational knowledge resources and developing skills and competences necessary for innovation processes management.

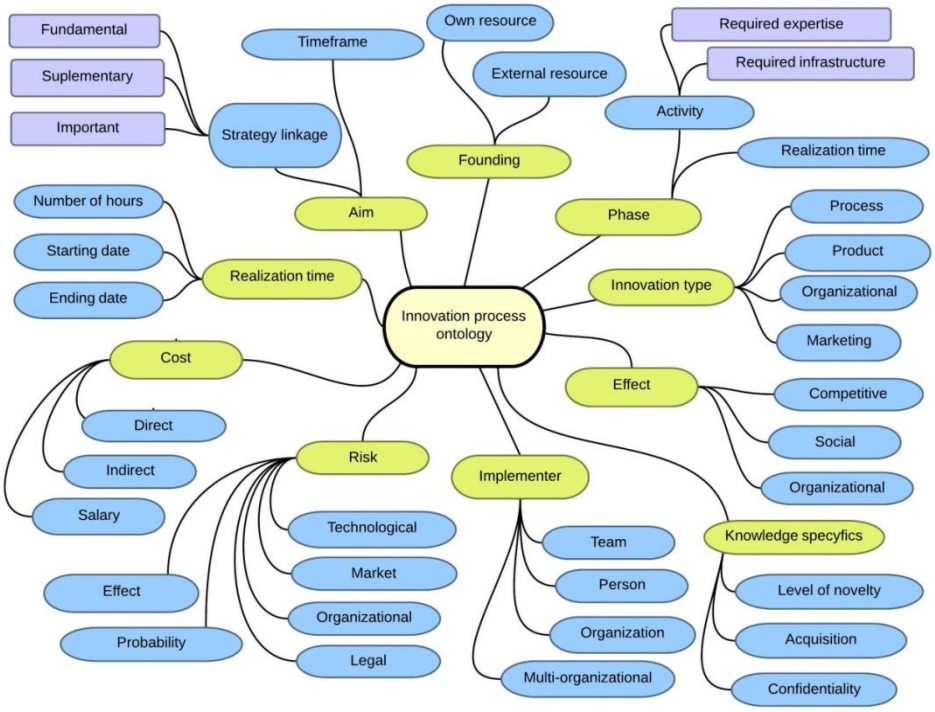

Figure 2. The thematic scope of innovation process ontology

It should be noted that these positive "side-effects" are attained regardless of the success of fail of implemented innovation. The idea of the proposed system is to improve knowledge sharing and reuse. The practical implementation of the concept requires appropriate software platform that would store data about innovation processes already implemented and estimate main parameters of a new innovation process. This will allow manager to make assumptions necessary for developing the plan of implementation of new innovation process. The proposed solution has pioneering character and it practical implementation requires solving many detailed problems.

For example the detailed description of innovation processes structure is necessary for the system development. However creating it is a difficult task considering the significant differences among processes. The role of created ontology is to provide a structure for such semantic descriptions, which could be applied to every case described in the document base. The next fundamental issue for innovation management domain is the development of the system for assessing similarity of innovation processes. We work on the similarity measure algorithm based on fuzzy logic; it seems to be right approach considering the processes can partly similar to one another. The system will allow for classification of dispersed knowledge and extraction of resources that are in some degree related with a decision situation at hand. The next fundamental problem that is to be addressed is the development of

reasoning algorithms. It is a complex task that requires establishing rules and facts for reasoning as well as selecting the proper data sets perform analysis.
Regarding the aforementioned practical and theoretical issues, research on the topic of semantic innovation process planning system can be considered significant contribution as well to innovation as knowledge management domain.

References

Chiaroni D., Chiesa V., Frattini F., 2011, *The Open Innovation Journey: How firms dynamically implement the emerging innovation management paradigm*, "Technovation", 31(1).

Clancy K., Shulman R.S., 1991, *The Marketing Revolution: A Radical Manifesto for Dominating the Marketplace*, New York, Harper Business.

Cooper J.R., 1998, *A multidimensional approach to the adoption of innovation*, "Management Decision", 36(8).

Frączkiewicz-Wronka A., Wronka-Pośpiech M., 2014, *The Use of ICT For Achieving The Objectives of The Business Model – Social Enterprise Perspective*, "Polish Journal of Management Studies", 10(1).

Greenly W., 2012, *Ontology for Innovation*, [Available at: http://www.lexicater.co.uk/ vocabularies/innovation/ns.html; Access on: 15.06.2014].

Gruber T., 1995, *Toward Principles for the Design of Ontologies Used for Knowledge Sharing*, "International Journal Human-Computer Studies", 43(5-6), [Avaliable at: http://tomgruber.org/writing/onto-design.pdf Access on: 15.06.2014].

Hauschild J., Salomo S., 2004, *Innovationsmanagement*, München.

Jelonek, D., 2012, *The Choosen Determinants of Customers Co-Created Innovations*, „Studia Ekonomiczne Zeszyty Naukowe Wydziałowe Uniwersytetu Ekonomicznego w Katowicach", 117.

Jóźwiak P., 2013, *Crowdsourcing Applications*, "Polish Journal of Management Studies", 8.

Kline S.J., Rosenberg N., 1986, *An Overview of Innovation*, [in:] R.Landau and N.Rosenberg (eds.), The Positive Sum Strategy, Harnessing Technology for Economic Growth. Washington, DC, National Academy Press.

Lis T., Brzozowska A., Korombel A., 2013, *Knowledge Management in an Enterprise as a Response to Contemporary Customers ' Needs*, [in] INFORMATICS 2013. Proceedings of the Twelfth International Conference on Informatics, (Eds.) Valerie Novitzka, Stefan Hudak. November 5-7, Spisska Nova Ves, Slovakia, Department of Computers and Informatics, FEEI TU of Kosice.

McNally R.C., Akdeniz M.B., Calantone, R.J., 2011, *New Product Development Processes and New Product Profitability: Exploring the Mediating Role of Speed to Market and Product* Quality, "Journal of Product Innovation Management", 28.

O`Sullivan D., Dooley L. 2009, *Applying innovation*, SAGE Publications.

Pachura P., Nowicka-Skowron M., 2010, *Theory of innovation in spatial perspective*, "Polish Journal of Management Studies", 1.

Riedl C., May N., Finzen J., Stathel S., Leidig T., Kaufman V., Belecheanu R., Krcmar H., 2009, *Managing service innovations with an idea ontology*, [in:] Proceedings of XIX International RESER Conference, Budapest, September 24th-26th, Hungary.

Schroeder R., Van De Ven A., Scudder G., Polley D., 1986, *Managing Innovation and Change Processes: Findings from the Minnesota Innovation Research Program*, "Agribusiness", 2(4).
Semantic Mediawiki [Available at: https://semantic-mediawiki.org/ Access on: 15.06.2014].
Sotarauta M., Srinivas S., 2006, *Co-evolutionary policy processes: Understanding innovative economies and future resilience*, "Futures", 38.
Stevens G.A., Burley J., 2003, *Piloting the rocket of radical information*, "Research Technology Management", 46.
Tidd J., Bessant J., Pavitt K., 2005, *Managing innovation: integrating technological, market and organizational change*, Wiley.
Van De Ven A., Polley D.E., Garud R., Venkataraman S., 1999, *The Innovation Journey*, Oxford, Oxford University Press.
Vanhaverbeke W., 2006, *The inter-organizational context of open innovation*, [in:] H.Chesbrough, W.Vanhaverbeke, J.West (Eds.), *Open Innovation: Researching a New Paradigm*, Oxford, Oxford University Press.
White S., 2005, *Cooperation costs, governance choice and alliance evolution*, "Journal of Management Studies", 42.

KONCEPCJA SEMANTYCZNEGO SYSTEM WSPOMAGANIA PLANOWANIA PROCESÓW INNOWACJI

Streszczenie: Artykuł przedstawia koncepcję systemu wspomagającego planowanie procesów innowacji. Jego istotą jest oszacowanie kluczowych parametrów nowo uruchamianego procesu innowacji na podstawie wiedzy zawartej w dużej liczbie różnego rodzaju dokumentów opisujących zrealizowane wcześniej procesy innowacji. Uwzględniając bardzo różnorodną, często niesformalizowaną strukturę takich dokumentów zaproponowano system bazujący na mechanizmie semantycznego wyszukiwania i wiązania informacji. W artykule przedstawiono, w jaki sposób tego rodzaju oszacowania wspomagają podejmowanie decyzji zarządczych. Przedstawiono też koncepcję architektury tego systemu wraz z opisem funkcji jego poszczególnych modułów. Omówiono również rolę ontologii procesów innowacji w tym systemie oraz pokazano jej zakres tematyczny.
Słowa kluczowe: procesy innowacji, system semantyczny, planowanie, ontologia.

語意支撐系統規劃過程中的創新理念

摘要：本文介紹了工藝規劃系統的支持創新的概念。其實質是估計創新過程的重新運行的關鍵參數。的基礎，這個估計是包含在大量的不同類型的描述以前實現創新過程文件的知識。鑑於基於語義的搜索機制和有約束力的信息，文件提出的系統的非常多樣，通常被非正式結構。這篇文章顯示了這種估計的支持管理決策的方式。也呈現了各個模塊的功能描述該系統的原始建築的概念。它還討論了本體論創新過程的基於語義的機制，並顯示她的片系統的發展中的作用。業務系統的概念的發展將需要在創新管理和知識管理等領域的解決方案根本性質和實踐的問題，因為在摘要突出
關鍵詞：創新過程中，語義系統，規劃，本體論