Preliminary Systematization of Corporate Knowledge Objects for the Use of Prescriptive Analytics Methods When Creating an Innovative Product by Small and Medium-sized Companies

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***Abstract*—Introduction. The article defines the relevance of work in the field of creating prescriptive analytics when creating an innovative product for small and medium-sized enterprises; presents a comparative analysis of approaches to creating such systems and identifies the features of small and medium-sized enterprises that need to be considered.**

Approaches and methods. The ontological approach of structuring linguistic objects describing elements of corporate knowledge is used as a methodological basis for the preliminary systematization of corporate knowledge objects. The research is conducted based on an ontological approach. The prospects of using the proposed set of methods for describing competencies are demonstrated.

The results of the study. The paper shows that the most effective way to create prescriptive analytics systems designed for use in small and medium-sized innovative enterprises with limited financial resources is to use a set of methods of enriching extensible ontologies combined into a single algorithm that continuously monitors external information sources to identify new market trends. For an adequate response of the company to the newly identified market trends, it is proposed to use the preliminary systematization of corporate knowledge objects using the principles of partitioning based on the concepts of intellectual resources of the enterprise, and as an instrumental basis for the systematization of corporate knowledge objects to use lexical subject ontologies that subdivide corporate knowledge objects into three categories: elements of object knowledge, elements of performing knowledge, elements of interaction knowledge. To conduct the work, it is necessary to use the results of a structural analysis of key business processes of the enterprise, based on the review of the repository of models of key information processes of the company.

Discussion and conclusions. The conducted work has shown the possibility of creating a single effective prescriptive analytics methodology for small and medium-sized innovative enterprises based on the interaction of methods of enriching extensible ontologies and the preliminary systematization of corporate knowledge objects proposed in the article. Based on the above conclusions, a conclusion is made about the possibility of continuing work to create a product designed for an integrated system of prescriptive analytics for small and medium-sized companies.

Keywords: prescriptive analytics, knowledge management, linguistic ontologies, branch subject ontologies, corporate knowledge.

I. Introduction

Timely actions of a company to introduce innovations into a product or service being marketed is one of the most significant competitive advantages [1]. Therefore, a competitive business of any level strives to use as much internal and external information available to it as possible to develop the right management decisions related to changes in the manufactured product and its manufacturing processes.

In this regard, prescriptive analytics becomes in demand, the main content of which is aimed at directly proposing a model of the company's actions in response to the identification of expected market changes. This requires taking into account a large number of factors related to the production of an innovative product [2], [3]. Therefore, solving such problems is one of the leading directions of using artificial intelligence methods in the field of improving company management technologies.

The successful direction of solving such problems was the creation of corporate knowledge management systems. These systems assume an integrated approach to the search, systematization, evaluation, and dissemination of information assets of the enterprise. At the same time, the main advantages acquired by the enterprise when using integrated corporate knowledge management systems [4] are: improving the overall efficiency of the company's functioning by accelerating the response to projected market changes and customer needs, making coordinated decisions, and accelerating the exchange of experience and best practices in connection with previously learned lessons.

Over the past twenty years, a large number of complex methodologies for creating corporate knowledge management systems have been developed and actively used: Know-Net [5], CommonKADs [6], DECOR [7], On the way to knowledge [8], which makes it possible to build comprehensive information and organizational environment to support the adoption of sound business decisions based on knowledge management processes and taking into account both the specifics of the company's external environment and the specifics of decision-making at each specific enterprise.

However, the creation of a fully functional corporate knowledge system based on the methodologies listed above is quite a long, expensive, and complex task that requires the restructuring of almost all organizational and information systems of the company [9]. Therefore, only large corporations can take the path of using integrated methodologies for creating corporate knowledge management systems using prescriptive analytics [10].

In addition to limited funding, which seriously complicates the creation of knowledge management systems, it should be taken into account and the fact that medium and small companies are forced to use disparate "inherited solutions" as part of their corporate information environment that solve specialized tasks (resource management, support of technological processes, document flow, relationships with customers and suppliers, etc.). Such software products, as a rule, contain their own mechanisms for consolidating best practices based on the logic of highly specialized solutions. This seriously reduces the possibilities of centralized management of corporate knowledge [11], [12] because these information products are designed to solve various tasks and are configured for different information and organizational systems.

This leads to the fact that small and medium-sized enterprises (numbering from several dozen to several dozen to several hundred employees) do not have time to fully adapt to changing market conditions and begin preparing for the introduction of innovations after such efforts have been made by large corporations using advanced methods of analyzing market changes and modernization of production processes.

To enable manufacturing enterprises of medium and small businesses to independently build corporate knowledge management systems, several specialized models have been developed for the phased development of unified knowledge management systems for such enterprises. The purpose of these solutions is to develop ways to consistently change the business processes of an enterprise when the external conditions of business functioning change. Among such solutions, Clever models can be distinguished [13] (Cross-sectional Learning in the Virtual Enterprise), Impakt (Improving Management Performance through Knowledge Transformation) [14] and Selekt (The Searching and Locating Effective Knowledge Tool) [15].

All of these models make it possible to create sets of techniques with the help of which it becomes possible to carry out the generation and current configuration of corporate knowledge management systems for changing external market conditions. However, because the implementation of these models is carried out by consistently carrying out a large amount of work related to the discussion of the situation by experts, conducting questionnaires, expert assessments, meetings, brainstorming, etc., the effectiveness of such solutions has serious limitations associated with the low productivity of expert teams [16].

The productivity of this process can be increased by introducing permanent analysis procedures for specialized text corpora into the proposed models using methods that identify signs characterizing the emergence of new trends that are significant for the enterprise and require their further consideration in the production process.

At the same time, for the identified market changes to be reflected in the change of production processes promptly, steps must be taken to create a systematic accounting of knowledge elements generated and used by various information systems of the enterprise.

This article is devoted to the description of the proposed method of preparing the company's information system for the application of prescriptive analytics techniques.

II. APPROACHES AND METHODS

The main prerequisite for the creation of an automated prescriptive analytics methodology involving NLP methods is the following [17]:

- knowledge is verbal,
- newly revealed knowledge is the development of previously accumulated knowledge and can be added to its previously accumulated knowledge by expanding them,
- specialized elements of corporate knowledge are reflected in the texts of internal corporate documents or arrays of industry and other publicly available data used by specialists of the enterprise in their work.

A sign of the emergence of new knowledge in a certain area is the fact of repeated use in the studied texts of previously unknown terminology describing new objects or their properties.

At the same time, the task of prescriptive analytics associated with identifying the emergence of new market trends and making changes to existing business processes of the enterprise for appropriate response can be reduced to the consistent application of methods of linguistic and semantic analysis of specialized text corpora and management tools of the corporate knowledge system, which can be presented in the form of a scheme fig. 1, which includes:

- statistical methods for determining entities with signs of newly identified market trends [18],
- methods of a contextual definition of concepts semantically related to newly identified entities [19],
- methods of checking semantic correspondences using a pre-trained language model [20],
- procedures for building relationships and rules linking newly identified concepts [21],
- methods of expanding corporate knowledge structures with new concepts [22],
- making coordinated changes to the structure of business processes of an enterprise [23],
- preliminary assessment of the effectiveness of the proposed changes [24].

One of the main information tasks that should be solved before starting work on creating such a system is to create a convenient way of structuring knowledge. At the same

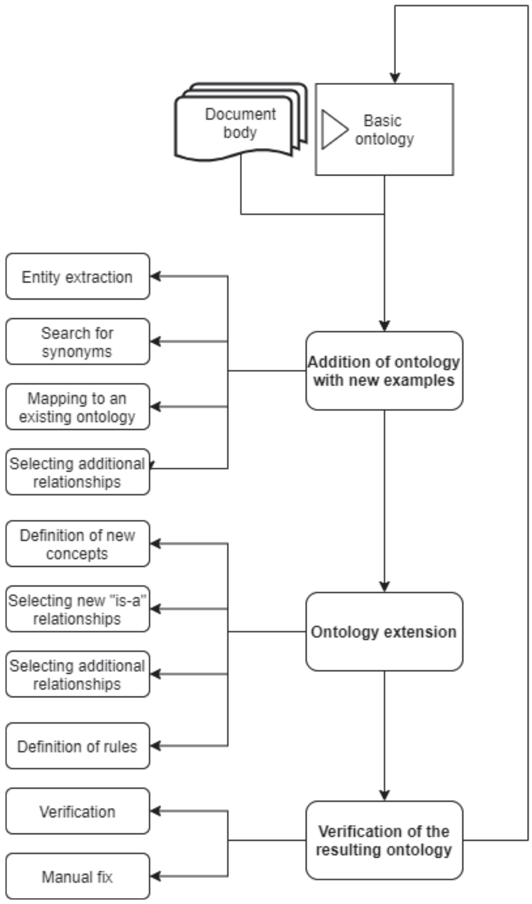

Fig. 1. The scheme of the method of linguistic and semantic analysis of the text using the capabilities of the corporate knowledge management system

time, the structuring method used should link the following components into a single whole:

- knowledge elements describing innovative market trends obtained from external sources,
- structural objects of business processes of the enterprise that require modification when introducing innovations,
- objects describing the macroeconomic characteristics of the company's activities, which are the main evaluation characteristics that determine the overall efficiency of the process.

Having formulated the problem of the need to create a preliminary systematization of corporate knowledge objects for the use of prescriptive analytics methods when creating an innovative product and having listed the groups of objects included in it, we will determine the most appropriate implementation of systematization.

Usually, as the most convenient way to formalize corporate knowledge, when conducting research, subject ontologies are used, consisting of a hierarchy of domain concepts, relationships between them, and laws that operate within this model [25].

The main advantage of using ontologies in describing elements of knowledge management systems is the ability to integrate heterogeneous information. The ontology defines the structure of the organization's knowledge base, providing quick access to its contents, provides a dictionary for describing documents (content) and competence profiles of company employees, and also acts as a general scheme for integrating various databases and data arrays.

Because semantic analysis of the corporate documentary base using NLP technologies is supposed to be used during prescriptive analytics procedures, it seems necessary to use lexical (or linguistic) ontologies. Their distinctive property is the use of lexicalized concepts (words) in one resource together with their linguistic properties. At the same time, the main source of concepts in ontologies of this type should be the meanings of linguistic units, which, in the case of creating a unified ontology of elements of corporate knowledge, should be described by subject branch ontologies.

Most often, the formal model of ontology O is understood as:

$$O =< C, P, R, A > \tag{1}$$

where: C is a finite set of concepts (classes of entities) of the subject area; P is a finite set of properties of these concepts (classes); R is a finite set of relationships between concepts (classes); A is a set of axioms, statements constructed from these concepts, their properties, and connections between them.

It should be borne in mind that the greatest gain when using such ontologies when performing specific production tasks is that subject-specific industry ontologies are always built based on a joint understanding of the industry features of the field of knowledge (key concepts) within a certain community [26].

Therefore, to increase the role of ontologies in the communication of individual professional communities, it was decided to expand the formal definition of ontology by introducing into it the sets of dictionaries of professional terms, including descriptions of key concepts describing the industry features of the field of knowledge under consideration [27].

$$O =< C, R, A, L, F, G, H > \tag{2}$$

where:

- $L = L_c \vee L_R$ — an ontology dictionary containing a set of lexical units (signs) for concepts L_C and a set of signs for relations L_R;
- C — set of ontology concepts;
- R — relations between ontology concepts;
- A — set of ontology axioms;
- F and G are reference functions that link sets of lexical units L_j in L with sets of concepts and relations to which they respectively refer in this ontology. In this case, one lexical unit can refer to several concepts or relations, and one concept or relation can refer to several lexical units;
- H - fixes the taxonomic nature of relations (connections), in which the concepts of ontology are connected by non-reflexive, acyclic, transitive relations $H \subset C \cdot C$. The

expression $H(C_1, C_2)$ means that the concept of C_1 is a sub-concept of C_2.

At the next step of task specification, it is necessary to define the general requirements for the ontology contained in the created one. To effectively use the knowledge elements defined by linguistic and semantic analysis (see Figure 1), in the production activities of the enterprise, the ontologies used to systematize corporate knowledge must provide solutions to the following main tasks:

- describe concepts that represent elements of corporate knowledge in understandable indicators and artifacts that characterize the activities of a particular enterprise (support for a unified taxonomy of corporate documents describing the main production indicators and their forms) (task T1).
- describe industry-specific features of the enterprise's business processes to ensure linguistic generality of the domain models used and conceptual and symbolic systems: thesaurus, glossaries, dictionaries (task T2),
- to describe the features of the presentation of information in the information systems used in the enterprise (to support unified models of the presentation of processes) (task T3).

The solution of these tasks (T1, T2, T3) allows us to present within one ontology the interaction of all stages of the response of the enterprise's corporate knowledge management system to changes in external conditions, namely:

- reflect in the general structure of concepts the appearance in the external information environment of new concepts and relationships that have signs of new knowledge,
- link the newly identified concepts with the internal documents of the enterprise to make changes to the production processes of the enterprise in connection with the newly identified trends as a single flowchart of a controlled process with feedback (see Fig.3.), implemented in the form of changes in the valuation of intangible assets [28], arising from the use of newly identified knowledge in enterprise management processes,
- reflect the necessary changes in the settings of the information systems used at the enterprise, thereby ensuring that the necessary innovative changes in the working technological processes of the enterprise are considered.

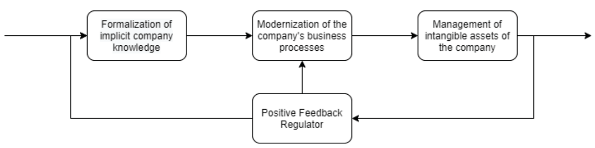

Fig. 2. Presentation of the management of the corporate knowledge management system in the form of a system with positive feedback

The creation of an ontology that solves T1-T3 tasks for each specific enterprise will actually mean the creation of a unified communication structure that allows you to track changes in external technical trends from specialized sources, reflect them in enterprise documents and effectively reconfigure the information environment of the enterprise.

At the first stage of work on the deployment of elements of prescriptive analytics, structuring that occurs according to these rules will allow the expert council of the enterprise to make informed decisions about the need to change production processes as a preventive response to changing trends. In the future, using simplified formal models of corporate business processes, this structuring will allow us to develop automated mechanisms for adjusting the company's business processes.

III. Research results

In the first stage of creating a unified ontology of elements of corporate knowledge of the enterprise, we will consider the solution to the T1 problem. This will ensure the creation of an ontology of corporate knowledge that provides a reflection of measurable indicators describing the elements of knowledge in understandable terms of the efficiency of production processes and artifacts that characterize the work of the enterprise. Today, most enterprises that use information solutions to manage their business use the description of corporate knowledge in terms of intellectual corporate resources. Such a description is present in the form of macroeconomic categories used by companies to determine the value of the impact of corporate knowledge on the results of the functioning of the enterprise. The most complete intellectual resources are quantified in the company's ERP system in the form of its intangible assets (intangible assets) [29]. At the same time, the analysis of intangible assets well describes the impact of the increment of corporate knowledge, reflected in the form of an increment of intellectual capital, on the economic performance of the company.

At the same time, from the point of view of the ontological description, the intellectual capital of the company, which is actually a valuation of corporate knowledge, can be defined in the form of the following complex ontology [30]:

$$O_I C =< O_{Tech}, O_{HR}, O_{Org}, O_{Rel}, K > \quad (3)$$

where O_{Tech} – innovation capital ontology, O_{HR} – human capital ontology, O_{Org} – organizational (structural) capital ontology, O_{Rel} – relational (social) capital ontology, K – knowledge extraction mechanism (logical inference machine model).

However, the cost definition of knowledge in the form of intangible resources of the enterprise does not make it possible to determine the specific causes and points of occurrence of the increment of new knowledge in the information environment of the enterprise. Therefore, it is necessary to create more detailed reviews linking elements of knowledge with specific business processes of the company. Such elements can be knowledge objects describing the processes of the emergence of new corporate knowledge and which can be isolated from the information arrays of the enterprise [31].

At the same time, intellectual resources taken into account in the enterprise ERP system in the form of intangible assets of the company represent the upper hierarchical levels of the knowledge management system [32]. With this in mind, the root level of the hierarchy of corporate knowledge can be described as a set of the following branches (types of knowledge), presented in Fig. 4:

- corporate object knowledge: knowledge related to the objects of technical and technological or administrative and organizational business processes of the company related to the creation of products or services (branch B1),
- corporate executive knowledge: knowledge, skills, competencies related to the educational level and qualifications of the company's employees (branch B2),
- corporate knowledge of interaction: knowledge about the rules of interaction with customers, partners, suppliers, competitors, performers, contractors, and separate departments within the enterprise (branch B3).

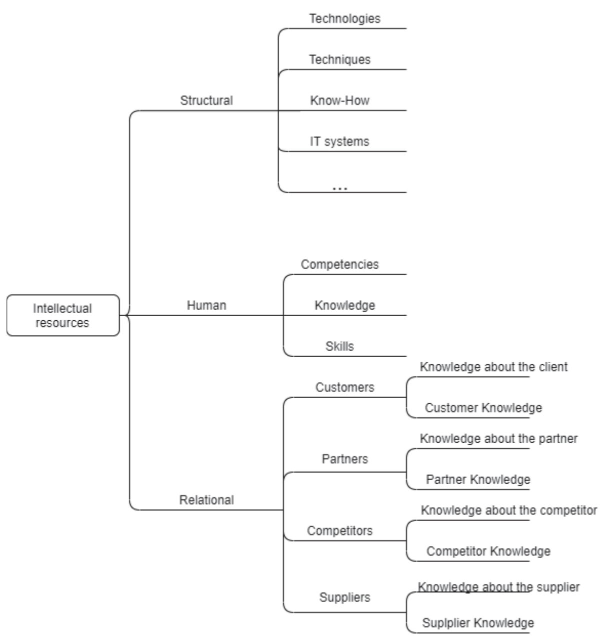

Fig. 3. The root level of the hierarchy of corporate knowledge in terms of intellectual resources

At the same time, the objects of corporate knowledge differ significantly in types, features of occurrence, and accounting in the information systems of the enterprise (see Table 1), and therefore further refinement of their structures should be conducted based on different principles.

Thus, with further refinement of corporate object knowledge describing corporate knowledge that is the property of the enterprise and directly related to its technical and technological production processes, it seems rational to build based on industry terminological ontologies describing the entities, phenomena, properties, and connections of the subject area, based on common industry principles used in the creation of specific product groups. Such ontologies are the most extensive and usually, they number from 200 – 10,000 concepts, depending

TABLE I. TYPICAL TYPES OF CORPORATE KNOWLEDGE

Parameter	Technological part of corporate knowledge	Economic and organizational part of corporate knowledge	Part of corporate knowledge supporting work with the company's staff/clients
The key objective function	Management of technological processes of product/service creation	Economics and management of the company	Human Resources/Customer Relationship Management
Management object	Information	Company	Human
Integral characteristics of key competencies	Natural Sciences, Information Sciences	Economics and Management	Humanities, Pedagogy, Psychology, Sociology
The centrality of tasks	Information processing	Creation of added value	Interaction of people
The main type of processed knowledge	Explicit knowledge	Knowledge – as intellectual capital	Implicit knowledge

on the industry specifics of the subject area. At the same time, the range of tasks to be solved is limited to the selected area.

At the same time, the choice of the basic subject industry ontology that most fully reflects the business needs of a particular enterprise is a solution to the T2 problem and can be carried out based on sets of recommendations specially developed for most industries.

Because within the framework of the described works, the task of creating a unified ontology of knowledge of a pharmaceutical enterprise was solved, Figure 4 shows a fragment of the basic subject ontology of the pharmaceutical industry [33], which is the de facto basic basis for building ontologies of pharmaceutical industry enterprises, based on which each enterprise is based on its own needs can create their own object ontologies (B1).

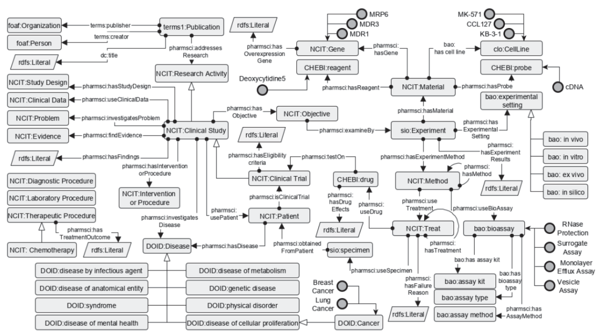

Fig. 4. Fragment of the basic product ontology of the pharmaceutical

To describe corporate executive knowledge: knowledge, skills, competencies related to the educational level and qualifications of the company's employees (branch B2), it is also necessary to use subject-specific industry ontologies, but use educational (competence) concepts common to the education industry. This is explained by the fact that formally performing knowledge is not the property of the enterprise, and it is attracted to perform work only by hiring an employee from the single world labor market, who actually uses competency-based educational ontologies of certain specialties, built based on a conceptual series of training courses [34].

At the same time, to adequately account for the competencies acquired by an employee during his production or other

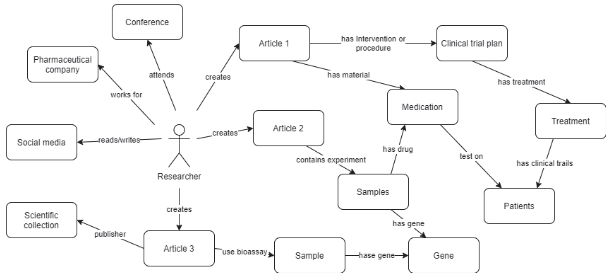

Fig. 5. Fragment of the educational ontology of a pharmacist

activity, it is necessary to carry out an individual account of the growth of competencies for each of the employees of the enterprise, including using the method proposed in [35] and consider the individual competencies of each of the company's employees also as a composite quantity consisting of:

- competencies determined by the operation of the sequential merging of his educational ontologies of the curricula and courses he has completed,
- competencies acquired during the period of production activity and determined by his experience,
- competencies representing the research competencies of the specialist's environment,
- competencies that represent information that is certainly known to all members of the community.

From the point of view of the typology of the ontology of knowledge, B1 and B2 are hierarchically organized systems of concepts of industrial product technologies (a specific industry - B1, and education in general - B2), in which knowledge about the product being produced and the resources necessary for its production (material and human) are formulated and interpreted.

More complex is the development of a branch of knowledge describing the interaction of participants in the creation of a product (branch B3). Based on the ISA-88 standard (Prescription production Management Standard), creating an interaction ontology (branch B3) is quite a difficult task (see Fig. 7)

However, the assembly of the ontology of corporate knowledge objects on the B3 branch of work can be significantly simplified, taking into account that the vast majority of information solutions used by enterprises in their work are based on solutions based on the ISO 10303-11 standard, suggesting unified approaches to organizing the processes of mutual transmission and storage of information approaches to the creation of software products, which in turn are based on even more general descriptions of information about the production of ISO 10303 family standards. At the same time, both the EXPRESS data modeling language (defined in ISO 10303-11) and uml were used as a description language for data on the studied production processes during the study, which make it possible to effectively build a repository of models of the company's key information processes being analyzed (see Figure 8). This set of actions solves task T3.

At the same time, the created repository will contain the

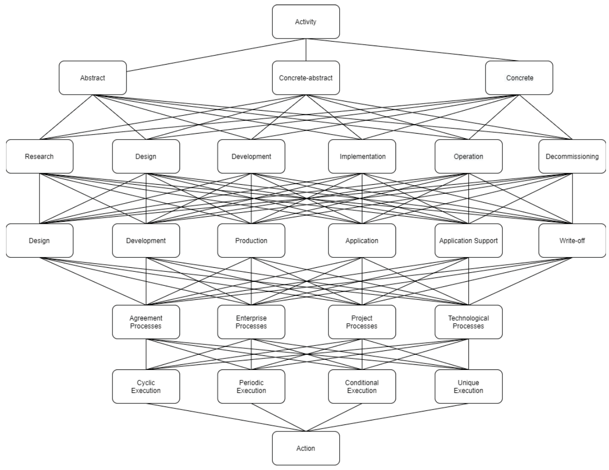

Fig. 6. The relationship of various aspects of the interaction of subjects in terms of the nature of the work

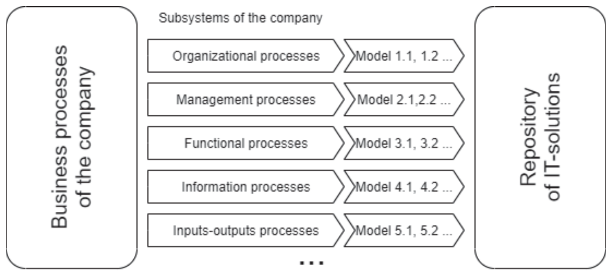

Fig. 7. Block diagram of the formation of a repository of models of key information processes of the company

most significant types of corporate interactions describing all models of the company's key information processes (reflecting its production activities) (Fig.9), based on which it is possible to build a single model of information interactions of the company's key information processes. This set of actions solves task T3.

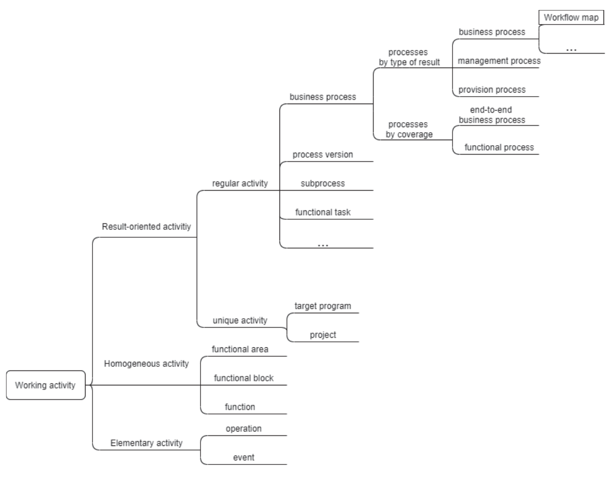

Fig. 8. Mmodel of a key business process

By combining into a single branch of the ontology of objects of corporate knowledge B3 entities describing the processes of relationships of the company's production activities, we will get a hierarchical model of relationships, which is based on the reflection of the company's business processes in its information environment. Through this action, it will be possible to combine the disparate information solutions of the company into a single structure.

At the same time, we will build a unified ontology of corporate knowledge objects, describing in common concepts and relationships the interaction of production facilities, describing the features of technological features of the enterprise and its industry model of functioning (branch B1), the structure of the competencies of its employees (branch B2) and the relationships linking the elements of knowledge into a single whole (branch B3).

The structure of knowledge elements constructed in this way will allow the enterprise to independently build a structure of initial response to the emergence of new market trends, which can be presented in an enlarged way consisting of the following steps:

- definition by external controlled information sources of newly introduced terms related to concepts describing the product produced by the enterprise (using NLP methods),
- definition using a single ontology of the company's knowledge elements of concepts semantically related to newly identified terms (by branch B1),
- determination of the interrelationships of the business processes of the enterprise, which may be influenced by newly identified trends (by branch B3).
- determination of specific employees of the company whose responsibility includes processes in which the emergence of new trends is revealed (by branch B2).

The implementation of these actions will allow us to reasonably identify those parts of the company's production processes that may be affected by reacting to newly identified technical trends, which areas of the company's information system will be affected by these processes, and employees of the company who have the necessary competencies to understand the essence of emerging trends and professionally assess the possibilities of future restructuring of technological processes.

Thus, the task of prescriptive analytics will be solved, which consists of the preparation of structured materials for the development by the expert group of the enterprise of the necessary actions to respond to newly emerging trends.

IV. Discussion and conclusions

As a result of the conducted research, the following conclusions can be drawn that are important for the further development of practical methods and methods for creating prescriptive analytics systems when creating an innovative products by small and medium-sized enterprises:

- it is possible to build a system of prescriptive analytics of small and medium-sized innovative enterprises based on the search for new technical trends, using standard methods of permanent semantic analysis of specialized text corpora using the algorithm described in this paper
- for an adequate response of the company to newly identified market trends, it is necessary to use preliminary systematization of corporate knowledge objects using the principles of partitions based on the concepts of intellectual resources of the enterprise,
- as an instrumental basis for the systematization of corporate knowledge objects, lexical subject ontologies are most effectively used,
- the main groups of systematization of knowledge objects will be: elements of object knowledge, elements of performing knowledge, elements of interaction knowledge, while:
- when constructing a branch of an ontology describing the elements of object knowledge, it is necessary to rely on the universal subject ontologies of the industry to which the enterprise in question belongs,
- when constructing a branch of an ontology describing the elements of performing knowledge, one should rely on educational ontologies,
- when building a branch of an ontology describing the elements of interaction knowledge, it is necessary to use the results of a structural analysis of key business processes of the enterprise based on the review of the repository of models of key information processes of the company,
- the use of the proposed systematization of knowledge objects will provide the expert group of the enterprise with a list of relationships between the newly identified innovative trends of the markets and the elements of the company's corporate knowledge affected by them.

Work on the topic of automated creation of a prescriptive analytics system that allows small and medium-sized companies to constantly monitor the slightest changes in market trends and timely make improvements to their products that anticipate market needs will continue. Upon receipt of the minimum required amount of source material for a detailed response to newly identified trends, it is planned to create and train a specialized neural network aimed at generating sound proposals for introducing innovations into the business processes of the enterprise.

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