Lappeenranta-Lahti University of Technology
School of Engineering Science
Industrial Engineering and Management
Master's Programme in Global Management of Innovation and Technology (GMIT)

Grigory Sadovskiy

Assessing R&D approach methodology and technological trends in fleet management

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ABSTRACT

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Master's Thesis

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Examiners: Professor Ville Ojanen
Professor Ari Happonen

Keywords: fleet management system, data analysis, innovations, economic model, patent analysis, patent landscape, patent information, AHP model, S-curve, decision-making criteria, PMBOK, additive convolution, multiplicative convolution

The cost-effective functioning of automotive industry enterprises is possible due to the strategic planning of R&D, considering the potential of innovation and commercialization of the created technologies in the entrepreneurial sector of the economy. In this thesis, the approaches for strategic planning of R&D refereeing to usage of patent analysis are discussed as a tool for technology forecasts and the investigation of patent metrics. In this project, Fleet Management Systems (FMS) and various dispatching technologies are considered as potential technological solutions to improve flexibility and to monitor development trends in these technology areas. The methodology consists of a decision support system that ranks specific criteria while managing various kinds of resources in

enterprises based on multiple expert evaluations. The implementation of the analytic hierarchy process (AHP) and fuzzy logic can be used to include additional decision variables into the patent retrieval and selection modes. Based on the patent activity of the retrieved patent data, we can predict emerging technologies in the various stages of their lifecycles.

Additionally, proposed technical and IP applicants' analysis for determining current technological trends. Evidence from leads in the development of FMS demonstrates the richness of the methodology for analyzing patent data, respectively. Data-based technologies inventions were examined to establish directions of vehicle fleet using operational research modeling techniques. The thesis describes the methods of modern theory to improve the performance of the fleet managers in conjunction with innovative concepts of fleet management and facilitates the patent retrieval process-related.

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Grigory Sadovskiy

Moscow, 25th of November 2019

TABLE OF CONTENTS

LIST OF SYMBOLS AND ABBREVIATIONS

ERP	Enterprise Resource Planning
FMS	Fleet Management System
LCV	Light Commercial Vehicle
MaaS	Mobility as a Service
PPR	Promising Patent Research
PT	Promising technology
R&D	Research and Development
SCM	Supply Chain Management
TA	Technology Assessment
TI	Technological Innovation
TLC	Technology Life Cycle
TMS	Transportation Management System
WMS	Warehouse Management System
YMS	Yard Management System

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Research background

Starting from the second half of the 20th century, the development of high technologies in various industries and the production of a fundamentally new high-tech products have become critical factors in sustainable economic growth for most industrialized countries of the world. The rapid development of science and technology, global political and technological transformations led to dramatic changes in the international economic system. In the XXI century, the world economy entered a new phase of its development, turning into a knowledge economy, the main driving force of which was knowledge-intensive technology. Most of these tendencies are changing the future of the companies, operation in the automotive industry (Saberi, 2018).

The relevance of the study is emerging due to economic problems in the development of scientific and production enterprises of the automotive industry under intense-changing prevailing conditions happening on the market. The specifics of the activities of these enterprises is the need for a rational combination and balanced development of automotive equipment and technologies used, specifically in the interests of strengthening competitive positions in the international market of automotive and logistics services by commercializing the results of Research and Development (R&D) outcomes as part of the implementation of business agreements between interested parties (Ciechański, 2018).

Apparently, the cost-effective functioning of automotive industry enterprises is possible due to the strategic planning of R&D, taking into account the potential of innovation and commercialization of the created technologies in the entrepreneurial sector of the economy. The most crucial tool for strategic planning of R&D is prospective patent research. Based on the forecast of development trends of scientific and technical areas and objects of technology, it allows us to substantiate target criteria for efficiency and product requirements and evaluate its technical level. Prospective Patent Research (PPR) also supports the generation of competitive intellectual property objects, which directly affects the economic efficiency of R&D results, since intellectual property forms the bulk of the added value of high-tech products and provides revenue from the sale of patents and licenses.

1.2 The aims and objectives of the study

The purpose of the thesis is to develop an organizational and economic mechanism for prospective patent research, which will increase the economic efficiency of fleet industry enterprises. Formed on the analysis of the features of the fleet management industry and the existing approaches to strategic planning of R&D, it is proposed to solve the scientific task of developing an organizational and economic mechanism for promising patent research as a tool for strategic planning of R&D's in fleet management companies, following technological diversification and marketing trends. The research aims not only connect intricate conceptual part of new potential business model approaches for the fleet management organizations but also to develop a forecast model by received of system-forming techniques for the organizational and economic mechanism of promising patent research.

Fleet management is considering as an area of logistics and transportation utilities, where companies are retransferring a series of procedures to fleet companies, including integrated outsourcing, operational leasing, and the possibilities of corporate rental, maintenance, and insurance. Due to technological changes, innovative devices implementation, and a new paradigm in methodologies for solving route problems in vehicle transportation, there is a emerge need to formulate a retrospective analysis of current trends in fleet management.

An efficient operational system is vital for each state of the company's implementation and development process, varying from fleet tracking software to management changes for reducing operational costs. Thus, by studying the specific cases of technology forecasting and modeling principles, this work investigates the use of these technologies in the management of workflow and services through patent data acquisition models.

Therefore, to explain the issues mentioned before and achieve a complete understanding, there is an emerging necessity to answer the following questions. The overall process can be represented in 4 main research questions (RQ) as an analytical basis for the research; the following central questions are:

RQ1: How are the current tendencies affecting fleet management systems technology innovations?
RQ2: How can companies, operating in the fleet management context benefit from utilizing existing datasets and enhance practical business model ecosystem through decision making approaches and patent analysis?
RQ3: Based on patent analytics, in what areas a company should forecast and predict to see disruptive innovations?
RQ4: What are the main predictors and how companies can invest in R&D's and monitor risk indicators for future scenario changes based on patent data and other sources of information?

Technical literature, statistics, case studies, and patent information extracted from multiple sources were used for central research issues, defined goals, and duties. The publications of periodicals and magazines were implemented in order to provide topicality information highly.

1.3 Research outline

Based on the analysis of the fleet management system industry features and the existing approaches to strategic planning of R&D, it is proposed to solve the scientific problem of developing the organizational and economic mechanism of prospective patent research as a tool for strategic planning of R&D at the fleet industry enterprises in the context patent data metrics. It is hypothesized that to predict the economic effect of the implementation of R&D results in the context of automotive and vehicle industry, an integral indicator formed on the basis of patent research (technology forecasting, technology trends, patent landscaping, patent metrics) should be used that takes into account the competitiveness levels relative, the terms of R&D implementation and forecast cash flows from the commercialization of created intangible assets.

The solution of this scientific problem involves the development of an organizational and economic mechanism for promising patent research in the fleet industry, which includes:

- a methodology for substantiating the planning and economic parameters of R&D;
- a methodology for determining the economically optimal scope of prospective patent research for R&D;
- a technique for monitoring promising patent research.

An algorithm for solving research problems is presented in Figure 1.

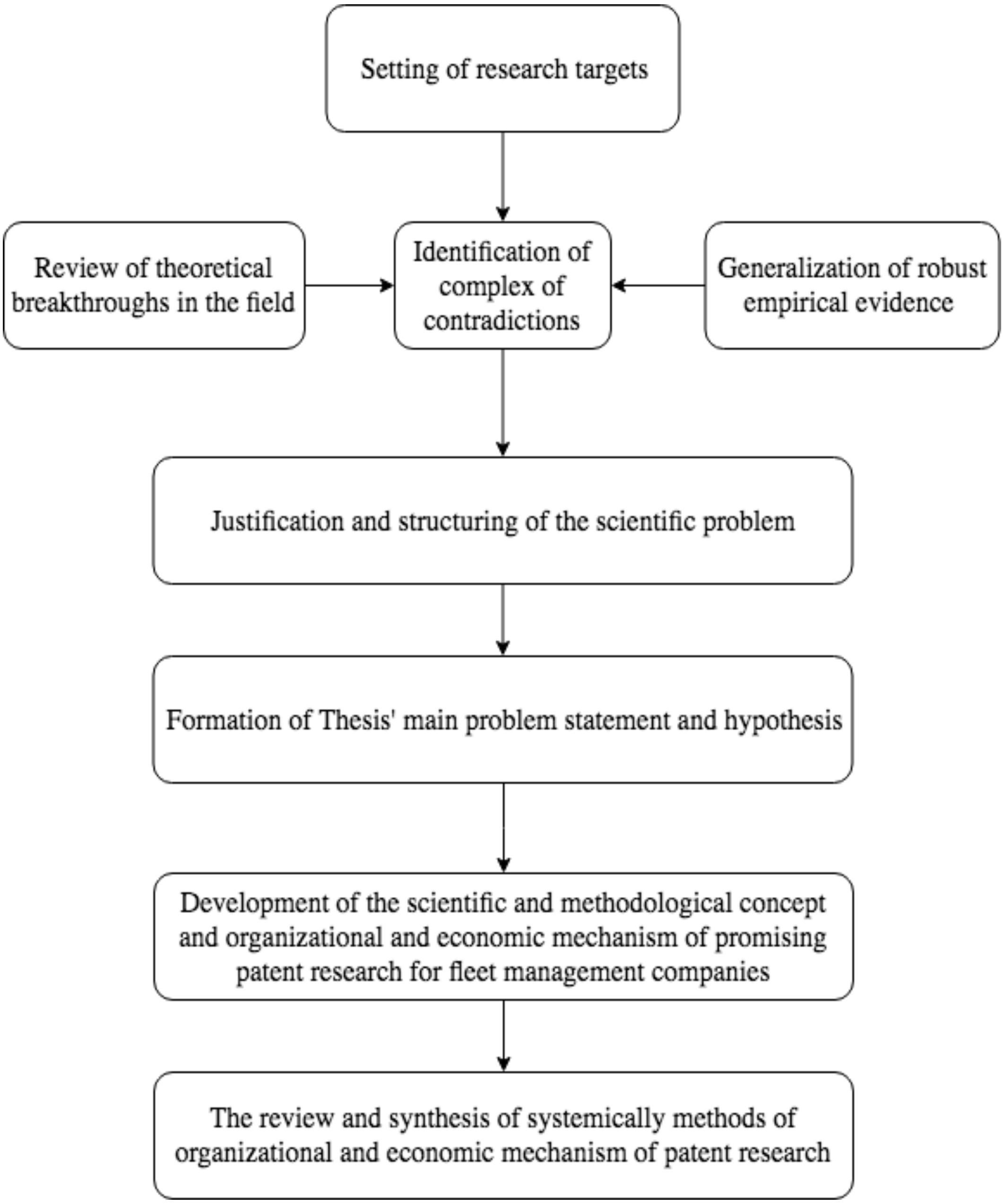


Fig. 1. The logical structure of Master’s Thesis.

2 LITERATURE REVIEW OF TRASPORTATION MANAGEMENT SYSTEMS AND STRATEGIC R&D PLANNING

2.1 Related works review method and work setup

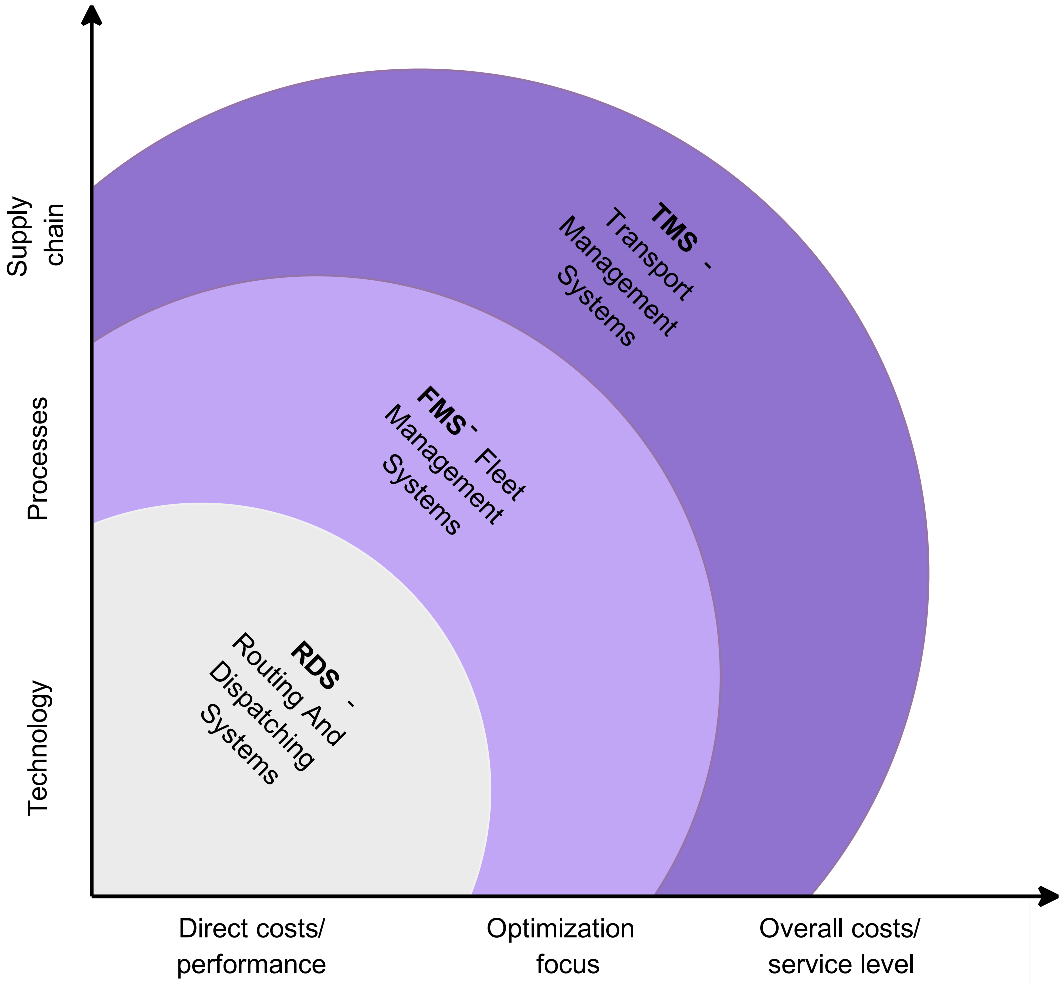
The article search was mainly accessed in LUT Finna, ScienceDirect databases, digital libraries, annual research, and WIPO guides for conducting patent analysis. The search queries that were used included such keywords as «Patent Analysis», «AHP Fleet Management System», «Technological Forecast», «Technology life cycle», «Technology diffusion», «Technology scope», «IPR», «patent», «fuzzy logic» and many others. After such procedures, the most relevant studies and methods were chosen. Mainly for thesis writing purposes, the combination of Markdown and Latex was used as extensions for reproducible research and future minor changes.

2.2 Transportation systems description

Monitoring of motor transport as part of the industry is one of the critical areas of modern industry, the basis of high-tech products in many industries. In any final product, there are either electronic components or electronic components, blocks, modules, devices, systems. Fleet products determine the intellectual capabilities of the entire final product, and it allows you to expand the functionality in the ground space and various methods for determining the location of objects. The following three groups of solutions can be distinguished according to the software market for the automation of transportation processes. Figure 2 representing categories of transportation management information systems (Abvin, 2017; Gris & Goldsby, 2007).

The logistics process is a set of sequential organized actions (operations), the purpose of which is the delivery of material flows from the producer to the consumer, as well as information and financial support for these actions. Typically, this process consists of many actions that you can either personally control or use automated systems. If the first method requires a large number of qualified personnel and time resources, then the second helps to reduce both the time and costs of transport and logistics companies associated with the influence of the human factor. Automation of the production process assumes that certain stages of the production process are performed by automatic or automated equipment, which avoids the implementation of activities that do not add value to the final product. Automated control systems can be used both in transport and in procurement, warehouse, and production logistics, so more and more companies prefer their use.

Fig. 2. The main categories of information systems for managing transportation processes.



(Based on Abvin, 2017)

Local solutions - software products that automate individual tasks as part of a continuous transportation process (optimization of vehicle loading, route planning, scheduling, calculation of transportation tariffs). This category of software products includes transport routing and dispatching systems - a combination of technical means (navigation and communication equipment, sensors), data transmission channels, and software for monitoring key performance indicators and operational vehicle management. Plenty of methodology and online and offline navigation software systems showed in (Horváth, Mátrai, & Tóth, 2017).

Through such systems users can track multiple vehicle parameters, such as on/off-line control of speed, route, driving schedules, mileage and fuel consumption, control of vehicle operation modes (idle time, at high engine speeds, status of the brake pedal and clutch), control of the main parameters the operation of vehicle systems (engine temperature, fuel pressure, on-board voltage, malfunction indicator lamps, engine coolant temperature, fuel temperature, engine oil pressure, torque engine entrant, load system on the vehicle's axles), monitoring the temperature of cargo transportation, monitoring the location of vehicles, cargo, drivers, monitoring the execution of route tasks with an alarm about their violation (Jiang et al., 2019).

Routing and dispatching systems of transport allow you to implement a full cycle of vehicle management at the operational level, according to Zhang (2016):

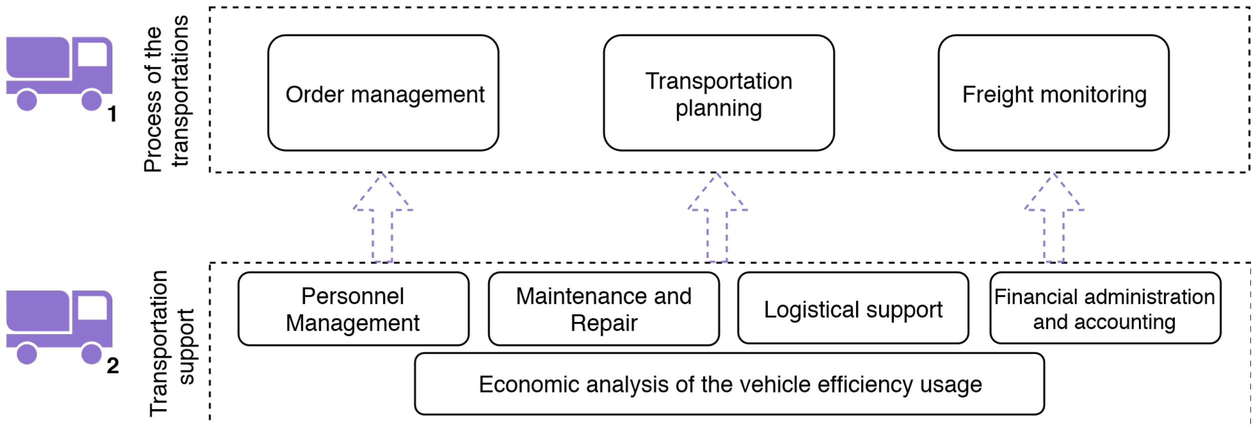
- Assign route tasks manually or automatically according to a specified work schedule
- Track the progress of the route task (determining the location, direction of movement, passing the "control" points - performing certain operations - time and place of loading/unloading of goods);
- Determine the condition of the vehicle, the operation of special systems and equipment based on sensor readings;
- Quickly change route tasks during execution;
- Generate reports on the movement of vehicles, use of working time, forming a statistical base for subsequent analysis and optimization of transportation processes;

In the conditions of a dynamic market and fierce competition, companies seek ways to reduce costs and minimize expenditure on the material base. Thus, most enterprises use motor transport in their activities, and, among other things, car fleet outsourcing becomes one of the ways to optimize costs. The concept of fleet management refers to a range of services, which involves the transfer of its vehicle fleet pool to external management, in order to ensure efficient operation and optimize the cost of its maintenance, as well as leveraging fleet data, expanding globally and implementing basis from mobility as a service

(MaaS) (Gómez, 2019). Besides standard practices, there is also another type of fleet outsourcing - operational leasing. Outsourcing (use of external sources) is the transfer to an outside organization of tasks, business functions or business processes that are not the main activity of the company but are necessary for the full functioning of the business (Twin, 2019).

Fleet management is a complex of services that provides for the transfer of its own fleet to external management in order to ensure efficient operation and optimize the cost of its maintenance (Rouse, 2019). Figure 3 showing the outline schematic of fleet management. A distinctive feature of this type of solution is the creation of a centralized transportation plan: on the basis of order data (internal or external), the system can select the necessary type of transport and a specific vehicle, taking into account the characteristics of the vehicle (for example, data on the average consumption of fuels and lubricants - for planning gas stations and related time and financial costs) and features of routes, already issued tasks, requirements of an external / internal customers.

Fig. 3. Fleet management system outline. Adopted from (Thong, 2007)



The criteria for optimizing the transportation plan may be loading the vehicle and minimizing the cost of transportation, reducing downtime or empty vehicle mileage, etc. When planning, measures for maintenance, and repair of vehicles are also taken into account. It also supports the management of the fleet of vehicles as capital assets (support of transactions for the acquisition of a vehicle into ownership, leasing, rental, commissioning or withdrawal of a vehicle from/to operation, vehicle insurance, depreciation and change in the value of the vehicle in connection with the maintenance and repairs, revaluation, operating costs management). Operational leasing is a financing instrument that opens up great opportunities for business development. The leasing service scheme allows you to purchase vehicles or special equipment for a specified period without using the working capital (current assets) of the company. Upon expiration of the contract, the leased asset is returned to the leasing company, or it can be purchased at a residual value of approximately 30–40% of the original (Alavuotunki et al., 2019). The advantages of operating leasing include the following features:

- Optimization of tax payments. The lessee can consider the expenses of the leasing company payments, therefore limiting the tax base and as well as reimburse value-added tax (VAT) on payments being already made.
- Operational leasing, like other forms, allows you to receive equipment or machines rapidly. The registration duties are the responsibilities of the lessor, as further maintenance and insurance.
- All financial risks are borne by the landlord as a result of which the client becomes protected from unforeseen expenses.
- In fact, when concluding an operating lease agreement, the tenant is able to pay only for the use of the vehicle. When the contract ends, the car will be returned to the owner, and the amount of all leasing payments is reduced by the residual value of the vehicle cost price.

The outsourcing company develops fleet management programs individually for each corporate client, taking into account its requirements and business specifics, analyzing all customer expense items, offers ways to optimize and improves the fleet management system. The experience and professionalism of the outsourcer provide a quick solution to current problems within the framework of the customer’s corporate policy, cost electiveness, and maximum financial transparency. A full range of fleet management services contains many options, and you can choose your specific services, which is relevant to a particular business. In this case, the customer receives regular reports on the operation of the fleet. According to the ReportBuyer (2016) there are the emerging amount of passenger vehicles and LCV in Finland, exceeding over 66,000 leased vehicles by the end of 2014.

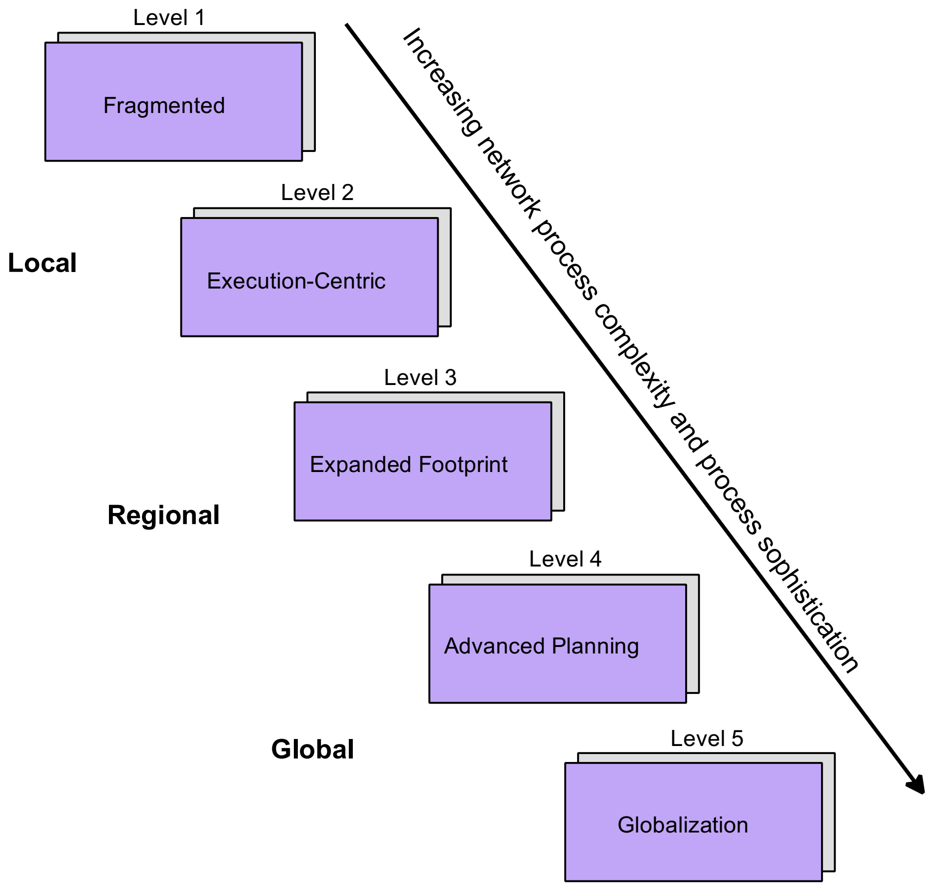


Fig. 4. Levels of TMS complexity according to Garter (2019)

Transport Management (TMS) System has historically evolved from fragmented solutions to end-to-end transportation process management in the value chain within a single platform that integrates various automation applications for transportation management tasks into a single information system. The implementation of TMS is focused on increasing the adaptability and productivity of transportation processes, reducing costs and increasing the level of service in the supply chain (Gris et al., 2015). Regarding the Muynck (2018) and Brock Johns (2019) Transportation Management Systems (TMS) are considered to be part of the Supply Chain Management (SCM) class of systems, which, in turn, are part of Enterprise Resource Planning (ERP) systems.

More precisely the connections between major systems is delighted in the works of Nettsträter et al. (2015) and Figure 4 showing principles related. Transportation management systems is a comprehensive solution that covers the entire transportation process from supporting strategic decision-making procedures, procurement planning and scheduling of transport to delivery and monitoring, cost management and coordination with consumers and providers of transport services. Often TMS-systems act as a separate business application, but the greatest effect is achieved when they are integrated with other subsystems of global products such as ERP or SCM-systems (Wiyonoet al., 2011). The place for the TMS in the Supply Chain Management Information System can be represented in the Figure 5.

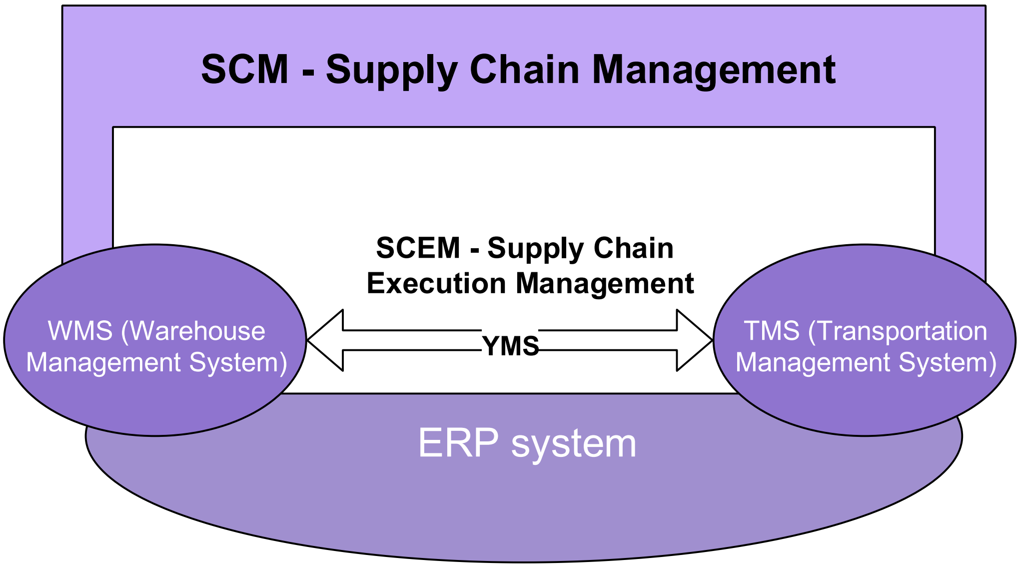


Fig. 5. TMS in the Supply Chain Management Information System

The rapidly advancing growth in society results in an increasing number of urban residents, and therefore an ever-increasing need for transport services created within restricted urban areas. For example, Peng and Lu (2017) forecasts reverse flows and focuses on household deliveries resulting from commercial transactions (most often online shopping) and deliveries needed for the daily business of companies operating within the city (i.e. deliveries of products, materials, parts, consumables, documents, postal delivery services, etc.). This, in turn, leads to a growing number of private and commercial wheeled vehicles.

Any urban environment, therefore, relies heavily on transport, where freight is a particularly important linkage. Urban freight transport focuses on shipments of consumer goods (not only by retailers but also through other industries, e.g., manufacturers) within the city center and suburban areas, including reverse flows of clean waste used goods (Lindholm, 2010). There are also interpretations in the specialist literature that further narrow down the area of practice covered by the term. This does not, however, affect the fact that the quantity of cargo flows produced in cities is immense and continues to grow due to the growing urban populations.

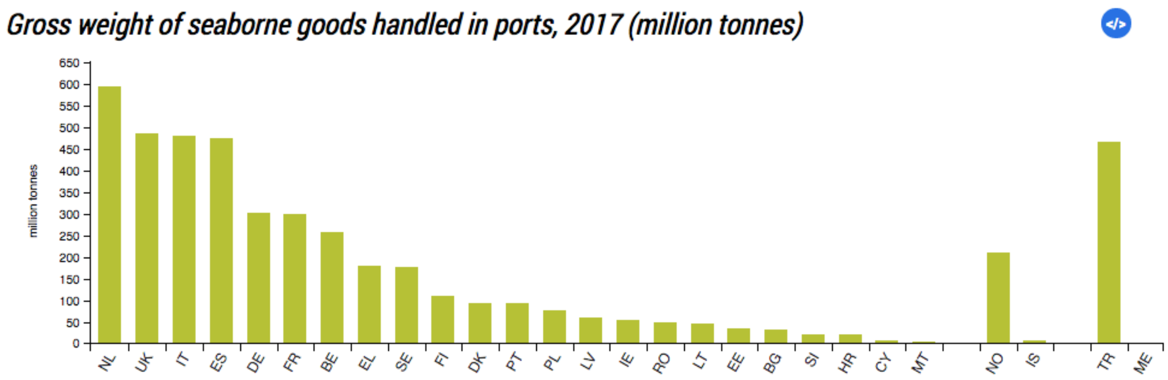


Fig. 6. Freight transport statistics (EuroStat, 2019)

On the one hand, freight transport in cities is a determinant of the attractiveness of city life, but on the other hand it adds an element of chaos to city dwellers' lives (Ruescha, 2012; Quak, 2008). The increasing number of wheeled vehicles also leads to a reduction in transport capacity. In addition, the side effects of industrial deliveries include noise, air pollution, and vibrations caused by heavy goods vehicle traffic, which exacerbate the deterioration of urban areas, particularly historic buildings that are usually located in city centers. Due to this congestion is responsible for increased air pollution, higher energy consumption, and also extending travel time. Every year, 1% of the EU's GDP is destroyed. The implications also include the worsening of the wellbeing of urban dwellers.

Transportation-related emissions accounts for 70% of cancer cases as stated by Silva (2009), respiratory and circulatory diseases, and other diseases (Badyla et al., 2009). Sustainable urban logistics networks have been developed over the past few years to reduce these adverse effects. Many of them are focused on the use of telematics and flow control systems for vehicles (Małecki et al., 2017).

To solve all of this important issues urban logistics is basing solutions formed on the implementation of telematics technologies and intelligent control elements, the most important are (FMS), which are integrated solutions for the management of both freight flows themselves as well as many vehicle-related elements, including electric vehicles, transport operations (Wątróbski et al., 2017). Figure 7 represents the generic outline of telematics solutions used for FMS systems.

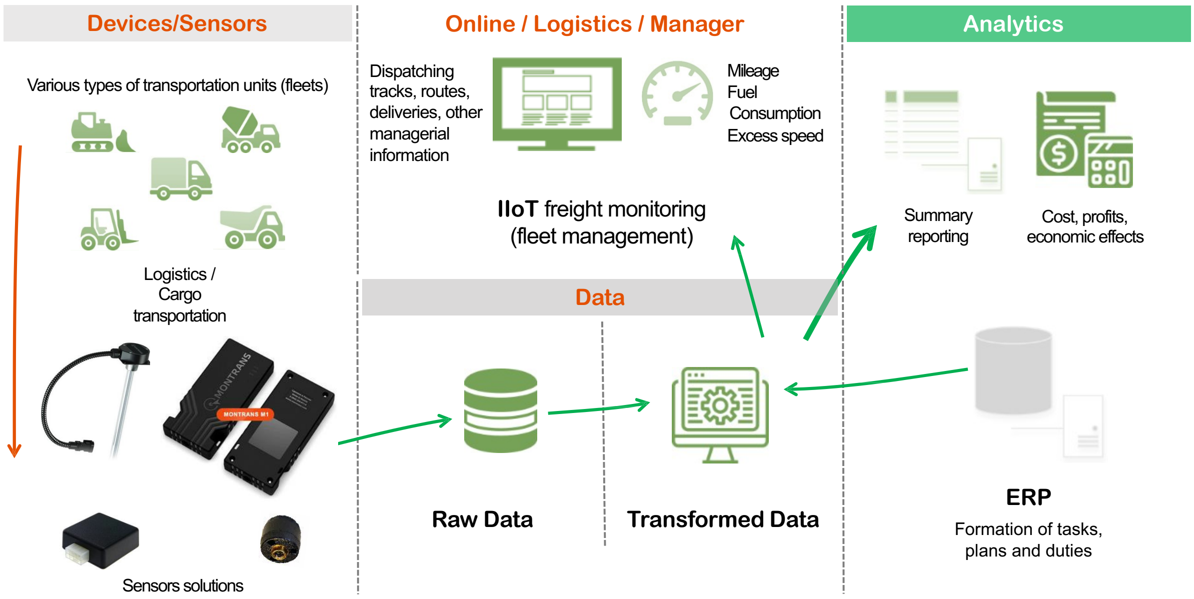


Fig. 7. Telematics solution via fleet management system. Adopted from (Iwan et al. 2018)

2.3 Obstacles in strategic planning of R&D at industrial enterprises

In the rapidly developing post-industrial economy, a key factor in the effectiveness of doing business in high-tech industries, including in the transportation systems, is innovative activity based on scientific achievements and the practical implementation of these achievements. The potential of intangible assets of an enterprise is directly related to the competitiveness of a high-tech enterprise. The costs of Research and Development (R&D) of world leaders in high-tech industries are measured in billions of dollars and euros. The logistics sector of the global economy and its' scientific and industrial base are often considered as one of the main engines of technological progress. This became apparent back at the beginning of the 21st century when there was an emerging need for fleet operations. Currently, the industry is developing dynamically and stably, which is primarily due to the processes in disruptive technologies in the automotive industry and the era of new mobility services under the circumstances of the digital economy. "Zion Market Research" (2018) reported that the global market for fleet management systems in 2017 was USD 11.9 trillion and that by 2024, the global market is expected to reach 43.5 trillion USD, at CAGR of around 20.3 percent between 2018 and 2024.

Thus, the technological development and the level of competitiveness of a company operating in high technology industries, including the fleet industry largely depends on the effectiveness of its scientific and technical activities and patent activity (Deepak, 2013). The technical level of high-tech products is ensured, among other factors, by the degree of legal protection of the technologies underlying it, since the legal protection of products gives the enterprise a legal monopoly on its production and sale in the countries where the patent is valid.

Intellectual property (IP) rights are a special type of property, which is characterized by both characteristics related to tangible property and a number of specific properties. Among the characteristics relating to both material and intellectual property, the following can be distinguished:

- the possibility of carrying out such legal operations as purchase and sale, leasing gratuitous transfer with the property;
- the owner has the right to prevent the unauthorized use or sale of the property.

The main differences of intellectual property are immaterial and inexhaustibility. The inexhaustibility of intellectual property means that the rights to it cannot be alienated mechanically, as its carrier, for example, a flash drive with a program recorded on it. It is possible only with the help of the legislative mechanism to prohibit an individual or legal entity from using a specific scientific and technological achievement, access to which this person received legally or illegally. The system of protecting the results of intellectual activity existing in the world today not only gives the creators of innovations significant competitive advantages, but also poses a number of serious problems for them. One of these problems is patent wars. Figure 7 represents increasing number of patents worldwide during the period from 1990 to 2017.

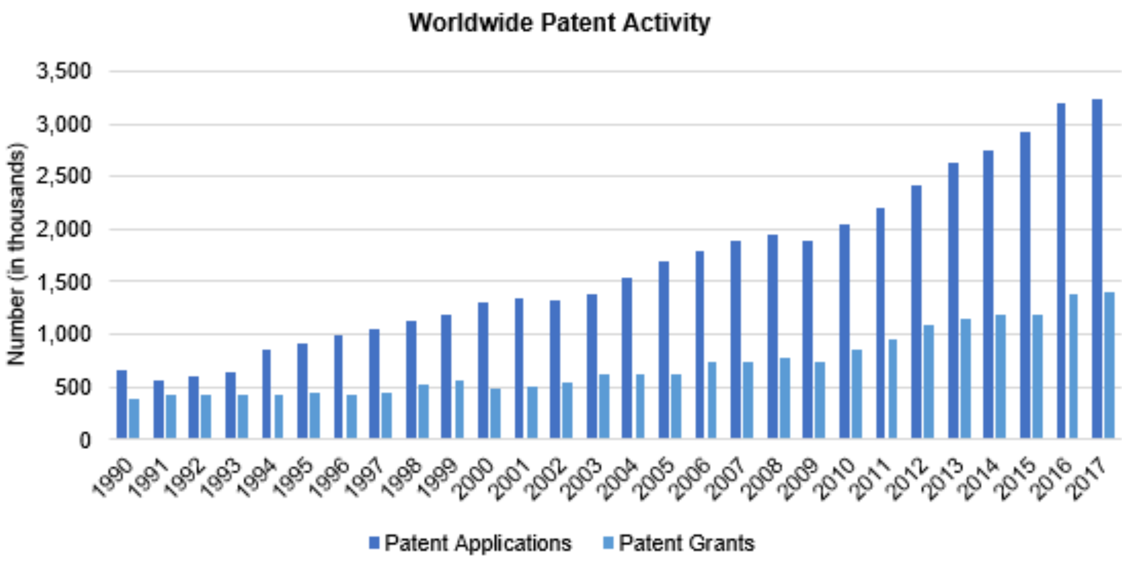


Fig. 8. Number of patents worldwide. (WIPO, 2017)

One of the strategies used by companies in patent wars is the use of blocking patents, which are a specific technological area and prevent the use of other patents in it. Patents are also widely used to protect the maximum number of technical solutions within a single document. As noted above, one of the key factors for successful innovation is the focus of R&D on the creation of promising results of intellectual activity. In the market of high-tech products, usually it is the presence of finalized results of intellectual activity that provides most of the added value to the product and resulting in high profits. In addition, patent protection allows you to bring products to the world market and makes them competitive.

The terms of reference for the development of new products are mainly focused not on current trends in the development of the fleet industry, but on the actual capabilities of enterprises (Guellec, Martinez, & Zuniga, 2008). The key to high competitiveness in these conditions is the effective implementation of R&D, leading to the creation of patentable scientific and technical solutions with world novelty, since patenting of developments provides the company with a natural monopoly.

Fleet enterprises have high scientific and technical potential, which is often not fully realized due to inefficient management and R&D planning, which is not aimed at creating patentable technologies and, as a result, does not allow companies to compete at the global level and effectively solve social and economic problems. Planning is one of the five management functions formulated by A. Fayol and implies as setting goals, finding ways to achieve them and determining the directions in which the company should move. Planning provides the basis for other functions that, in turn, are focused on the implementation of the plans of the organization (Vliet, 2014).

Depending on the goals of planning, baseline information, regulatory framework and final planned indicators, various planning methods are used. The work considers the classification of planning methods according to the stages of the development of plans. Depending on the goals of planning, strategic planning, tactical (business planning) and operational planning are distinguished (Misni & Lee, 2017). According to the work of Eisner, Rahman, & Korn (2009), strategic planning is a set of actions and decisions of the leader leading to the development of specific strategies designed to achieve the goals of the company, and the strategy includes the entire set of global ideas for the development of the company, and not just focused on a specific period. Some academics describes the strategic planning process as a tool to help make management decisions and ensure innovations and changes in the company. They identifies four main types of management activities in the strategic planning process:

- Resource allocation
- Adaptation to the external environment
- Internal coordination
- Organizational strategic foresight

Concerning the research of Meyersdorf & Dori (1997) that R&D is a dynamic control object, and therefore any R&D planning system must have the flexibility and mechanism for continuous analysis of incoming information that ensures sound management decisions through object-process analysis (OPA). According to numerous works - planning of innovation and investment activities, including the organization of R&D, should be considered in the overall system of strategic planning and management of the organization, which implies the application of the following principles of strategic planning of innovation:

- The principle of consistency, providing communication of all aspects of management activities.

- Scientific principle, ensuring the development of methods and tools for managing innovation.
- The principle of flexibility, which implies the ability of the company to quickly respond to changes in the external and internal environment.
- The principle of selection of qualified personnel, ensuring the effectiveness of innovation at all levels.
- The principle of risk minimization in the management of innovative investment projects.
- The principle of ensuring the competitiveness of created innovative products.
- The principle of obtaining maximum income with minimum investment.

Taking into account these principles, the company's innovation strategy is a set of measures by the management to develop innovative ideas and concepts in the implementation of innovation and investment projects in accordance with the goals and objectives of this company. The methods of strategic planning in high-tech industrial enterprises are explored in several academic works and the system of economic indicators is examined to ensure long-term goal-setting and scenarios of innovative strategies in the high-tech industry.

From the standpoint of the concept of knowledge management, the strategic planning of scientific and technical programs of organizations is considered. A comprehensive scientific and technical program is defined as a form of organization of research and development in a company aimed at a single result. The program provides actions for the development, production and use of high-tech products and is a set of innovative projects that are united in purpose, themes, deadlines and funding mechanism.

Strategic planning methods for small high-tech industrial enterprises are studied in by Berry Maureen (1998) in particular, the author considers a system of economic indicators to ensure long-term goal-setting and innovative strategy scenarios in the high-tech industry. The program provides for the development, production and application of high technology products and represents a set of innovative projects that are combined by purpose, subject, deadlines and financing mechanism (Shannak, Masa'deh, & Akour, 2012). The most important functions of the strategic planning of scientific and technical programs are:

1. Information support for developers, investors and organizers in the form of strategic data bases relating to environmental conditions that affect strategic decisions in the organization.
2. Analytical activity that allows you to assess the current situation, make assumptions about the most likely areas of scientific and technical development of the future and choose the structure of the program, the principles of its implementation, requirements for program participants.
3. Prediction of the scientific and technological development of the country's economy in the field of the program being formed in order to study alternative development options.
4. Technical and economic function, consisting in the development of a system of plans containing all types of planned indicators at the end of the corresponding period.

Nieto (2003) in his work considers innovation management as one of the tasks of strategic management of the company, which can be view from the position of macro and micro changes related to technological innovation (TI) within different economic units. Strategic planning methods at high-tech industrial enterprises are studied by multiple authors (Berry, 1998; Ernst et al., 2003, Kang et al, 2013); in particular, the authors consider a system of economic indicators to ensure long-term goal-setting and scenarios of innovative strategies in the high-tech industry. From the standpoint of the concept of knowledge management in Trappey et. al (2008) consider the strategic planning of scientific and technical programs of organizations. A comprehensive scientific and technical program is defined by the authors as a form of organization of research and development in the company aimed at a single result. The program provides for the development, production and application of high technology products and represents a set of innovative projects that are combined by purpose, subject, deadlines and financing mechanism.

Shim, Kim, & Altmann (2016) considers innovation management as one of the strategic management objectives of the company, however, he notes that the R&D sphere, despite the many-sided relations with other areas of the organization's activity, is usually relatively isolated, due to the uncertainty of the R&D process and the specifics of R&D activities. This factor, according to the author, provides a "managerial gap" between the positions and motivation of R&D leaders and other managers, which, in turn, determines the problems of managing the R&D process in the areas of marketing approach to R&D, R&D strategies as part of a firm's overall strategy and etc. A functional analysis of the intellectual property management process is given in the work of Terzic, Eremija, & Terzic (2016) and Terzic et al. (2016). Features of the R&D management sphere are also considered by Matthews (2003). In accordance with these features, according to the authors in the field, the R&D planning system should include a flexible system for monitoring the actual state of work and a mathematical apparatus for assessing the situation, as well as be linked to objective methods of scientific and technical forecasting and a system of feasibility studies for ongoing projects.

Within the framework of this method, the tasks and methods of thematic R&D planning are of great importance. Portfolio is formed on the basis of competition, comprehensive targeted scientific and technical programs and forecasts, direct contracts with customers and initiative proposals of researchers and developers. However, the scientific feasibility of thematic R&D planning can only be ensured by fulfilling the following conditions:

- identification of promising ideas and research directions in the field of technology;
- the introduction of scientifically based methods for assessing the scientific and technical level and the effectiveness of the created equipment;
- development of a system of qualitative and quantitative assessment;
- development of a mathematical model for determining the priority of topics;

Also, thematic planning should take into account economic criteria such as internal rate of return, profitability index, development costs, payback period, expected sales, etc. To assess the novelty of the development, the criteria of prospects, patentability, scientific and technical level, etc. are used.

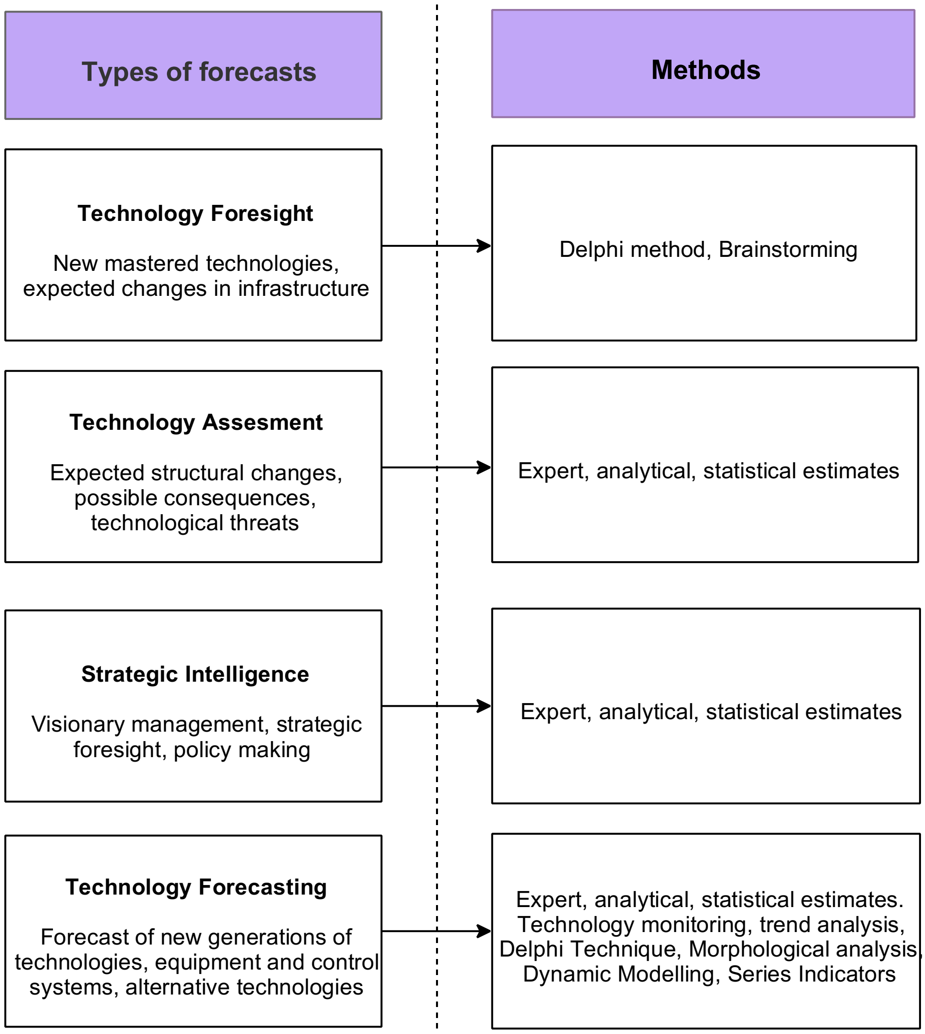


Fig. 9. Classification of types of forecasts.

Malhotra, Das, & Chariar (2015) defined the classification of types of forecasts and corresponding methods, presented in Figure 8. Thus, one of the tools for strategic planning of R&D is scientific and technical forecasting. Foresight-type forecasting methods are widely used, which involve the study of the development prospects of markets and industries for the production of high-tech products and the substantiation of managerial decisions (Farrington, 2012; Porter, 2011). The Technology Assessment (TA) methodology provides for a combination of technological development monitoring and forward-looking assessments and develops mainly in the direction of social and political choice related to technological development. Strategic Intelligence is a knowledge-based decision tool. In the scientific and industrial environment, traditional technology forecasting is most applicable. In domestic practice, as the author notes (Farrington, 2012), complex forecasts combining different types are mainly used. Technological forecasting varies from the economic and socio-economic uncertainty of the content and characteristics of the object in the future. This uncertainty is overcome by using methods of high-quality forecasting, in particular, methods of target management and information-logical models. The basis of information-logical models are phased and hierarchical models. Phased models are formed by constructing successive states of the predicted object from the initial state to the final one, which is determined by the development goals of the object. Hierarchical models consider development prospects at different levels of detail and are most often presented in the form of a “goal tree”. The following classification of technological forecasting methods is given in (Yoon, 2011):

- qualitative methods
- survey work

Methods by which new technological information is generated (extrapolation method, morphological study, scenario method); Methods by which the available technological information is ordered and processed (historical analogy, scenario method, probabilistic transformation methods, operational models). There are such approaches as normative methods (such as network methods and system analysis). However, it should be noted that many traditional methods of scientific and technical forecasting are more focused on the industry level and less applicable for forecasting at the micro level. Dudin et.al (2017) noted that the dynamic development of high-tech enterprises requires the improvement of methodological foundations and tools for predicting their development. The issues of technological forecasting and determining product requirements based on patent research in their works are considered many academics. The prognostic potential of patent information is associated with two factors (Dou, 2012):

1. The outstripping nature of patent information - it becomes available to a wide circle of users several years before the appearance of the corresponding products on the market.
2. A direct relationship between the intensity of patenting and the cost of R&D associated with the creation and improvement of products.

One of the most effective methods for analyzing trends in the development of scientific and technical areas related to the improvement of a product is the method of analyzing inventive activity, based on the assumption that a constant increase in R&D costs leads to an increase in inventive activity associated with the development of this direction. Description of the invention contains a section that analyzes the previous state of development of an object of technology and formulates requirements for improving this object. The analysis of this section allows you to compile a list of technical requirements for the product, since the technical requirements formulated by the inventors largely reflect the real requirements of consumers. Thus, the analysis of patent information significantly complements the traditional methods for identifying product requirements based on following mathematical approaches and managerial decision-making solutions.

Based on the foregoing, it can be concluded that R&D planning is an integral part of the innovation management system in a high-tech company and is carried out at strategic, tactical and operational levels. The objective of strategic R&D planning is to substantiate the subject of R&D in the long term, taking into account the results of scientific and technical forecasting and patent research, tactical planning ensures the direct formation of the R&D portfolio within existing resources; operational planning of R&D provides a refinement of the system of indicators identified at the stage of tactical planning.

3 RESEARCH DIRECTION IN PATENT ACTIVITIES

3.1 Patent search tools

The second object of the research is the tools for analyzing and searching for patent information, the subject is the applicability of existing tools for analyzing and searching for patent information in relation to innovation technology management in the development of technical solutions. The purpose of this part research is to review the search and analysis tools for patent information. Basically, the use of patent information to search for new solutions using special tools is possible when conducting patent research, which includes such basic steps as:

1. Development of patent research regulations;
2. Conduct a patent search;
3. Analysis of relevant patent information;
4. Preparation of a report on patent research.

In this research, the stage of development of the patent research regulations is clearly defined and connected with the tasks of finding solutions that have practical significance for product development. Preparation of a report on patent research is only a consequence of the work carried out in accordance with the regulations. Therefore, the analysis of tools at stages 1 and 4 is not of interest in this study. The tools of conducting a patent search and analyzing relevant patent information are strictly related to the objectives of conducting patent research, so their choice has a significant impact on the quality of the final report on patent research, as well as the applied significance of the results obtained. Thus, to achieve the goal of the article, those tools, tools for searching and analyzing patent information will be considered. The use of such theoretical models of patent forecasting and planning greatly facilitates this task and allows you to concentrate financial, material, labor and other resources to solve current and most promising areas for further development, reduce the time for research, development and production of new equipment, increase its life cycle to ensure maximum profit from the sale of either service or complete products.

Such tools as semantic expansion of the search query search based on the analysis of citations of patent documents formation of functional search queries were highlighted as the most valuable tools for conducting a patent search (Michel & Bettels, 2001, Verhaegen et al., 2011). The semantic extension tools of a search query, in general, represent a search for a variety of interpretation options for the purpose of reducing the risk of “losing” relevant patent documents due to the use of specific terminology in them (Valverde, P Nadeau, Scaravetti, & F Leon, 2014). The divergence in the terms used can be caused by various factors, the main ones of which include the language barrier, the field of technology, the abuse of generic terms. Such an approach is often used in patent searches, however, in its implementation, they are limited to searching for synonyms, while modern tools allow reaching a much higher level in the search for options for interpreting signs (Sharma et al., 2015; Yanagihori et al., 2014).

The materials presented in publications of reveal the possibility of using for this purpose software based on the electronic thesaurus / semantic network. This network allows you to carry out a qualitative search of hyperonyms, hyponyms and synonyms in English, thereby expanding the search query with different variations of the interpretation of terms. Special attention is also paid to such information resources as Wikipedia, since the interface presented on this resource allows you to quickly identify terms in different languages, and based on the research, it can be concluded that both the first and second options are applied (Sharma et al., 2015). It is also worth highlighting about the tools of semantic analysis that relate to the extraction of terms from patent information. To broaden the search query using semantic analysis of patent information, it is necessary to sample patent documents and create a table containing the names and abstracts of these patent documents, then it is necessary to conduct a semantic analysis of this table, which will reveal the semantic core and the most frequently repeated terms that may be will reveal important terms to increase the completeness and depth of the search query. Tools based on the analysis of patent document citations, along with their simplicity, make it possible to significantly increase the efficiency of searching for patent information aimed at solving the same technical problem, as well as to trace the development dynamics of its solutions. The essence of these tools lies in the analysis of patent documents, which can be divided into the following groups:

- cited in an information search conducted by a patent office expert on a relevant patent document;
- specified in the description section of the "prior art" relevant patent document;
- in which the relevant patent document is given in the description section of the "prior art";
- in which the patent examiner cited the relevant patent document as relating to the subject matter of the search

It is worth considering that the patent documents of the first and second groups can be found when analyzing the relevant patent document, its bibliography and description, while the detection of the third and fourth groups of patent documents will require the use of special tools. Such tools include open digital libraries of patent information, such as Google Patents and Espacenet, Lens which provide the ability to view patent documents from the third and fourth groups (WIPO Manual, 2019). When analyzing citations of patent documents, it becomes possible to detect a multitude of patent documents that are directly related to the object under investigation without the use of search queries in a short period of time. However, this tool represents the greatest efficiency when analyzing patent documents of the United States, European countries, regional patent offices and international patent applications, while citation chains for Asian patent documents make it possible to obtain a fairly small amount of relevant patent documents. The tool for the formation of functional search queries is based on TRIZ, therefore, unlike the earlier mentioned tools, it can be used exclusively for product development. It is based on an in-depth analysis of the object of research, during which the functions that it performs to realize its purpose, or rather physical phenomena that occur during the implementation of these functions, are highlighted (Albers, et al., 2014; Mann & Dewulf, 2011).

The physical phenomena detected are structured by type of energy, time and phase variables, their functional interrelation. Exploring the functional relationship of time and phase variables of physical phenomena, it becomes possible to objectively identify the indicators that need to be changed to improve the object under study. Having determined these indicators, as well as the vector of their improvement, it is necessary to determine the processes by which they improve. After that, include this process in the search query. Further search is carried out taking into account the discovered patent documents, namely, the new processes discovered in them, which can affect the indicators of interest, as well as by a combination of the detected processes. Further search is carried out taking into account the discovered patent documents, namely, the new processes discovered in them, which can affect the indicators of interest, as well as by a combination of the detected processes. On the basis of conducting a patent search with the use of this tool, it also becomes possible to build a kind of "target-funds" matrix in the form of "function-funds". The tool for generating functional search queries allows to consider the most unobvious options for replacing a particular element of the object under study in order to increase its output characteristics, since it is not tied to structural elements and technological operations or variants of their execution, so there is the possibility of finding a solution to a technical problem in those areas technology that, in the classical patent search, would not be subject to consideration.

Having examined these tools, it is possible to draw certain conclusions about their applied significance for the development of a new product:

- Tools for semantic expansion of a search query can reduce the risk of losing relevant patent documents, as well as simplify the process of expanding and narrowing the search area by using hyperonyms or hyponyms as keywords in a search query.
- Tools based on the analysis of citations, without search queries, to conduct a quick, narrowly focused search for patent documents aimed at solving one technical problem.
- The functional search query generation tool may allow detection of non-obvious ways to solve technical problems based on identifying indicators that affect the output characteristics of the object under study

3.2 Patent Information Analysis Tools

Effective analysis of patent information requires the use of software, since most of the modern analysis tools are based on Natural Language Processing technologies, so the use of tools considered in this chapter without software is very comprehensive (Souili, Cavallucci, & Rousselot, 2015). As the most interesting tools, such tools as improvement analysis, product "DNA" analysis and statistical analysis are considered (Dewulf, 2011). Analysis of further improvements allows to determine the direction of patent documentation. Analysis of improvements is made by identifying certain sections of the description in a patent document using Natural Language processing technology, such sections include the name, abstract, level of technology, technical problem. After identifying the quality characteristics, they are grouped into “increase”, “decrease” and “preservation and change”; based on the obtained table, you can select interesting samples of patent documents, which will be aimed, for example, at increasing reliability or reducing material intensity. There is also a modification of this tool, based on a figurative representation of quality characteristics in the form of an equation for the representative value (capital V) of a technical solution (Blois, 2003).

$$\mathrm{V} = \mathrm{P} - (H + I + C) \qquad (1)$$

where the P - efficiency, H - harm, I - interface, C - cost. From the formula it can be seen that the table is grouped into columns of “effectiveness”, “harm”, “interface” and “cost”. The use of the tool also implies a grouping of qualitative characteristics, but the grouping approach “directs” to combining existing technical solutions with the aim of “improving the ideality of the system” by reducing harmfulness, constructive complexity and cost, therefore this tool allows you to immediately identify those patent documents require deep study.

The analysis of the “DNA” of the product is aimed at finding common points of contact for technical solutions from various areas. This analysis is performed by building a petal diagram based on a comparison of quality indicators and adjectives, or verbs, and the subsequent comparison of a petal diagram of another technical solution with the same quality indicators. This allows you to determine the proximity or difference of certain indicators of technical solutions from multiple areas. The tool for statistical analysis of patent information is the most common, as it is fully automated and does not require the use of specialized software. However, despite this, this tool is very useful for obtaining overview information about the object of research, identifying key inventors, companies and other indicators that are contained in the bibliographic data of any patent document.

3.3 Analytics based on patent statistics

The number of registered patents has become a familiar indicator of the innovativeness and success of an economy in a country. Among the main areas of research using patents, three groups can be distinguished: technological progress, industry development, and cross-country comparisons. The first group of works focuses on the consideration of patents as an economic category and the possibilities to evaluate with their help the dynamics of technological development, primarily technological breakthroughs. The second group of studies draws attention to the dynamics of the development of one or several industries, comparing them using patent statistics. The third group proposes to compare the results of the innovative activities of countries, for example, in order to determine the level of their competitiveness. In this research, the only specialized quantitative methods were chosen for further analysis.

Beforehand, it is vital to have a brief explanation about the patent notion itself. A patent is a legal document certifying the authorship of an invention, utility model or industrial design and the exclusive right to use them. However, it is a unique source of scientific and technical information, which is not limited to the description of the invention, but reflects the level of current research and innovation, and long before the product enters the market. To assess current trends and select areas of support in the field of fleet management systems, statistical analysis of patent activity can be utilized in the form of a comparison of the number of applications by region, application, citation, etc. One way to study and characterize patent activity around a particular technology in a particular region or globally is the analysis of the patent landscape, or patent mapping (Kim, 2017). This method consists of statistical processing of bibliographic data and intellectual analysis of a large array of patent information, followed by visualization of the results as in Figure 10 (Streletskiy et al., 2015).

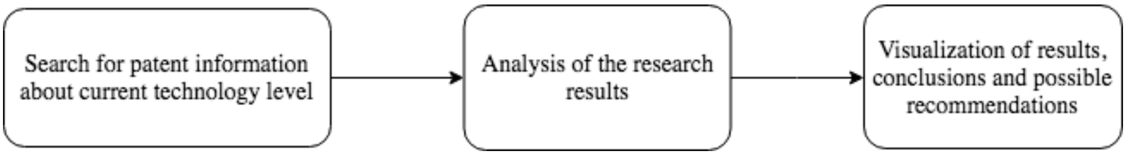


Fig. 10. Steps in patent analysis and visualization processes.

3.4 Methods of using patent landscapes in the study of technological trends

The most crucial advantage of patent research is that the data from patent documents are open and provide the completeness of the technical component, since the completeness of information disclosure is the most important principle of the patent system (Frietsch & Schmoch, 2010). With the help of patent analysis, you can determine trends in the industry, as well as the competitive advantages of companies or countries (K. Chakrabarti & Dror, 1994). So, in particular, the research of David Popp (2011) was about the state of the energy industry and a surge of patent activity was noticed on alternative methods of energy production after the first energy crisis (Popp, 2001).

Patents are an objective indicator of the activity of a company or a country in R&D. Thus, Petra Moser (2013) revealed a history outlook and pattern between the number of patents and the productivity of the company (Moser, 2013). With the help of patent information, researches also can define objectives and vectors of research in companies, technical means or weaknesses (Noh, Jo, & Lee, 2015). H. Ernst and J. Soll (2003) assessed the technical capabilities of companies in the field of mechanical engineering, analyzed their patent strategies, and showed that patent information allows us to identify and study competitors, evaluate technologies, plan R&D goals and proposed a set of indicators for strategic technology management (Ernst & Soll, 2003). Some authors also point out the expediency and effectiveness of using patent analysis for planning the managerial part of intellectual property and research activities of the company (Griliches, Hall, & A Hausman, 1986). The use of the possibilities of quantitative computer analysis in combination with the high-quality intellectual study of this information by an expert gives advantages in competitive exploring.

One of the tools designed to determine future paths of development is technological forecasting. The current master thesis is proposed to use one of the most effective methods of technological forecasting - analysis of patent information. Models were based on the example of a foreign patents databases, acquiring data from 1976 to 2019 period time series for subgroups were built, through and The International Patent Classification (IPC) for the fleet management patent subgroups classes. The obtained diagrams allow extract and evaluate the dynamics of published patents over the past 10, 20, 30 years, to get an idea of the further development of research topics classified according to the IPC's patent data. Based on the obtained results, it is possible to create a methodology for identifying specific promising and breakthrough innovative technologies at the industry and corporate levels. The European Classification code system was used to obtain only patents related to fleet management technologies. All data gathered mostly from WIPO IPC website, and it contains the full text of the Classification in English and French of the current version or edition, as well as previous versions or revisions.

3.5 S-curves as models of innovation

Applying mathematical principles within the managerial framework gives the ability to predict the flow of the innovation life cycle and form an accurate innovation model. Hence, over time, the performance of any system and the value of its primary production function naturally changes. Dynamics of a precise evolving indicator goes through several stages in its development. These changes are described by an empirical dependence, having the form of a stylized S-shaped curve. These changes are described by an empirical dependence, having the form of a stylized S-shaped curve. By using the S-shaped curve, we can visualize the processes of transition of a socio-economic system from one stable state to another, processes of radical changes accompanying its innovative activity as well as processes of growth and development during crisis stage and other phenomena. The practical application of the S-shaped logistic curve in the study of innovation was investigated by Foster (1986). The concept of technology S-curves suggests that the amount of improvement in the characteristics of a product or technology over a given period of time or due to a given volume of intellectual costs changes as it grows older/mature. In the early stages of development, product quality improves relatively slowly.

With the development of technology, the pace of technological improvement is growing. However, at the stages of maturity, the technology will asymptotically approach the natural or physical limit and for further improvements more and more intellectual and time costs will be needed. The essence of strategic technology management is to determine when the inflection point on the S-curve of technology has already been passed, and then identify and develop next-generation technologies that ultimately change the current one. Thus, the most important thing is to change the technology in time at the intersection point of the S-curves of the old and new technologies. According to the definition given in Kasztler et al. (2012), at the emergence stage, a new technology has practically no competitive influence and is poorly integrated into products or processes.

During the period of "growth", the pace of technology diffusion accelerates, its competitiveness increases, while its integration into new products or processes is still small. Having reached "maturity", a number of common technologies acquire the status of key ones and integrate into products or processes, consolidating their highly competitive potential. With the loss of competitive influence, the technology becomes basic, enters the saturation stage, and can be replaced by new technology (Tidd, 2018).

As can be seen from Figure 11, the most critical factors are Technology Limit and Change in Productivity Ratio. A change in productivity coefficient is defined as a turning point due to the emergence of a new opportunity. Another factor is the technological limit. This is manifested when the technology, having exhausted the potential for improvement, reaches maturity. It is at this level that process innovations often take place (Gao et al., 2013). S-curves are formed using a regression model that describes the non-linear relationship between the dependent variable (prediction object) and time (showed in Equation 2). The most commonly used equation presented in works of Sepúlveda, Paternina, & Suarez (2014) and outlined the relationship between invested in R&D activities.

$$Y_t = \frac{L}{1 + a \cdot \ ae^{-bt \cdot}} \qquad (2)$$

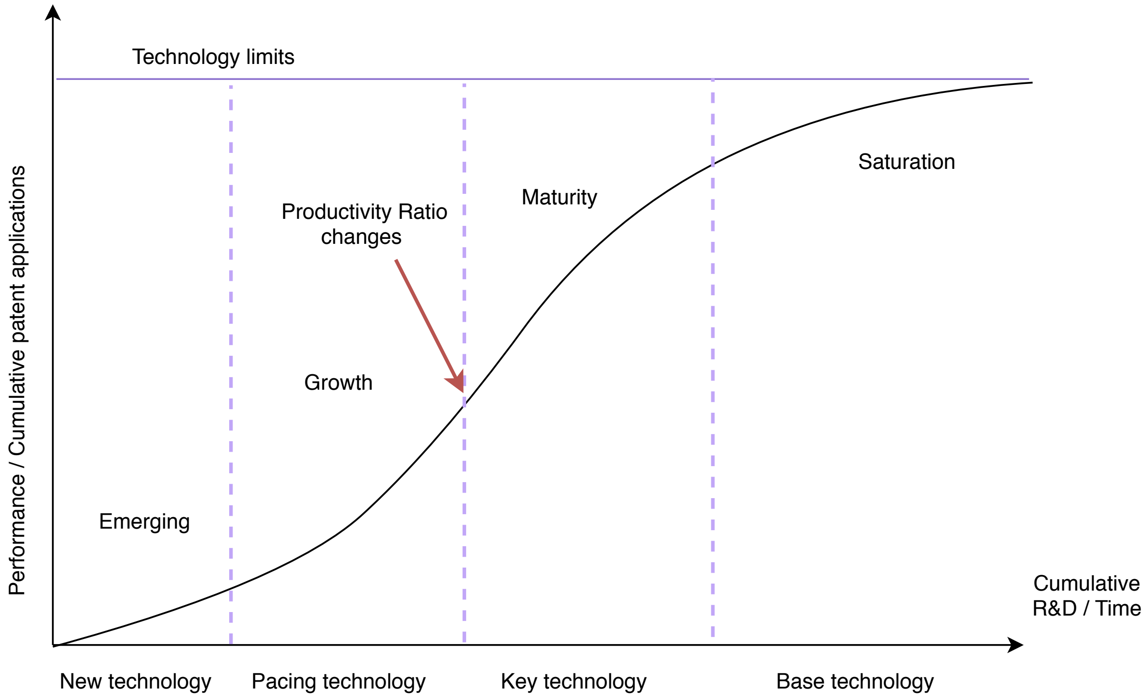


Fig. 11. The S-curve concept of technology life. Adapted from Gao et. al (2013)

where parameter a determines the position of the curve along the time axis, parameter b characterizes the steepness of the middle part of the curve (both responsible for location and curve shape). L characterizes the upper limit of growth (asymptotic maximum of the function Y_t). Currently, quite a lot of materials have been published in which the analysis of the S-curve is presented as a tool for describing and predicting the system development and it is linked with knowledge concept in form of patent citations. Giving that, a knowledge spillover arising from a patent citation is known when addressing innovation diusion (Altuntas, Dereli, & Kusiak, 2015). Smojver, Storga, & Potovcki (2016) defines the patent diusion speed (PDS) showed in Equation 3.

$$PDS = \frac{n}{m} \qquad (3)$$

where n is the total number of forward patent citations, m is the total number of examined patents that are considered for diffusion (due to other formula, variables are changed and not like in original resource). High diffusion speed may mean a higher market value for the innovation defined as an invention in patents. In general, it ensures that such innovation can in the near future affect certain innovations, making it a seemingly good investment. Also, Altuntas et al. (2015) define that the innovation has connections with many different technologies when this scope is broad. Two metrics, patent power (PP) and expansion potential (EP), combined is the innovation scope. Patent authority is defined by the formula:

$$PP = \frac{x}{y} \qquad (4)$$

where x is the total number of IPC codes included in the set of examined patents and y is the total number of examined patents. A high-tech innovation has a potentially greater economic impact. In general, higher patent power (PP) is considered to have a strong connection with other technologies and a greater chance of creating new technology sectors. The engineering (EP) potential capacity decreases as the amount of IPC codes listed in the patent under scrutiny rises.

3.6 Technology Forecasting (TF) based on patent documentation

Patents play a significant role in the development of technologies, since they give exclusive rights to inventors and assignees, and provide legal protection. However, given that the patenting process is expensive and can take several years, filing a patent application usually indicates optimistic mood in the economy or the importance of patented technology. When a patent is referenced in other patents, the same patent is expected to be of interest and thus to have a higher probability of eventual distribution as well as innovation that is focused on the invention. Patent analysis is used to obtain information about a particular industry or technology that can be used in forecasting (Ranaei et al., 2016; Cho et al., 2017).

The growth rate for technology patents usually follows a similar trend, in a trajectory resembling an S-curve. In the early stages of technology development, the number of patents granted is limited, then a period of rapid growth begins, when both the number of patents granted and the range of their applications increase, and finally, the development potential is exhausted (Chen et al., 2012; Madvar et al., 2019). Using the data on the number of patent applications, grants, as well as revoked or expired patents, an idea of the stages of technology development can be made. This process consists of several stages, starting with intellectual activity and ending with entering the market. Initially, the primary idea is formed, then R&D is carried out, which may become the basis for filing a patent application.

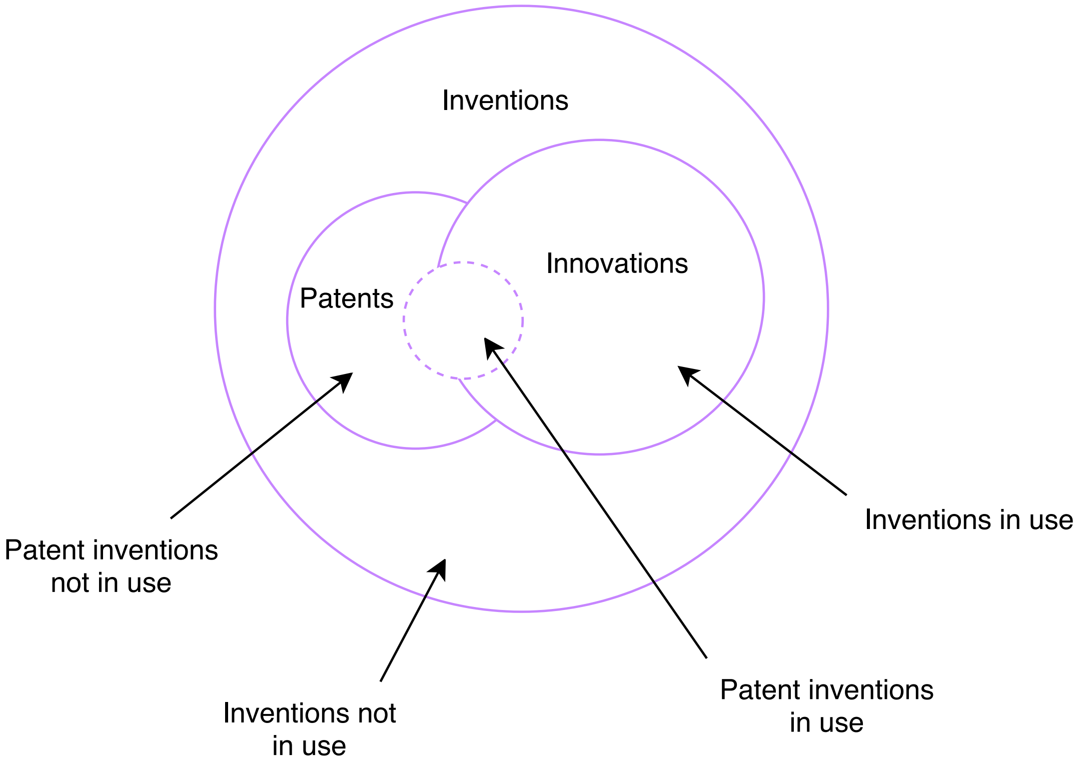


Fig. 12. The relationship between patenting, inventions and innovations. (Basberg, 1987)

According to the results of R&D, a patent is registered, after which the product is ready for commercialization and entering the market (Figure 12). In most models, patenting refers to the phase of invention, and R&D is considered an indicator of the effectiveness of the latter (Figure 13). The positive relationship between R&D intensity and the number of registered patents is invariably traced. The number of citations received by a patent may correlate with its economic and technological value. Note that, in contrast to scientific articles, it is preferable for patent authors to keep their citations as low as possible in order to avoid claims for duplication by regulatory authorities. Despite this, the number of citations present in the patent also retains its significance as an indicator of technological development.

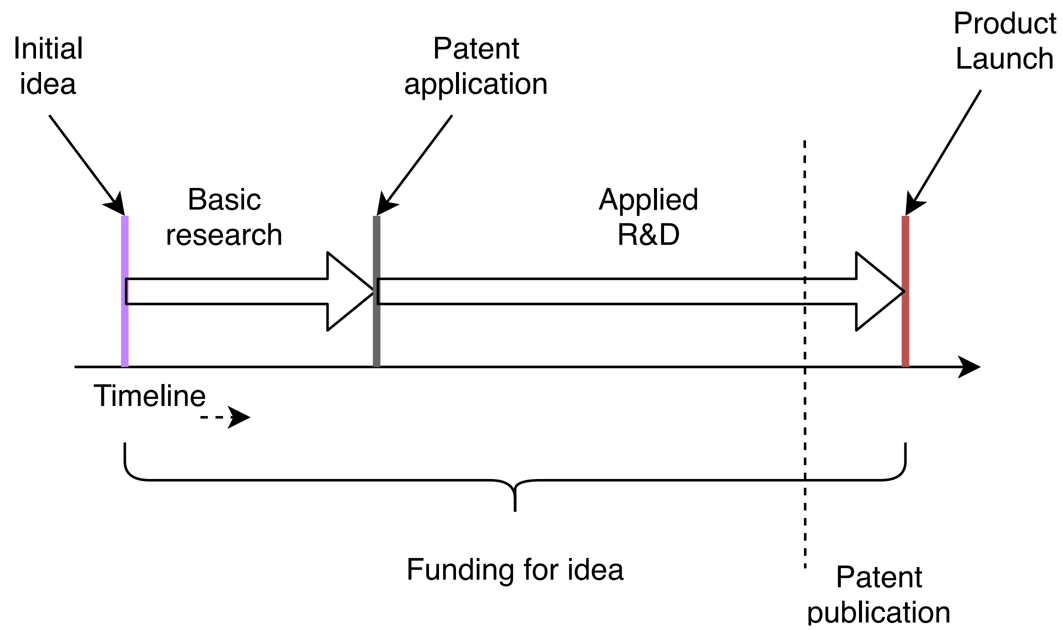


Fig. 13. Stages of technological development and patenting. (Madvar, 2017)

3.7 Example of patent analysis of fleet management systems

From the standpoint of modern strategic management approaches, it is necessary to go on to consider the strategic justification of the patent method and directions of possible application areas. Despite the fact that technology is becoming the main competitive advantage in many markets, a number of managers and decision-makers still have insufficient information about the possible effects of technological changes on the competitiveness of their organization.

Providing such missing information is the main function of patent analysis, the value of which lies in the ability to provide most of this information using bibliometric methods. Patent analysis uses bibliometrics to analyze the set of data found in patent databases in order to identify leading indicators of technological change. The number of times that a patent is cited provides strategic information on which technologies reach critical mass. In addition, such an analysis determines which competitors and industries actively follow these technologies.

As noted earlier, one of the goals of the Master’s Thesis is the patent analysis of the development of fleet management systems as a starting point for assessing the patent density and level of cooperation of leading companies in this field, including determining the circle of their strategic partners and the latest registered inventions. The basis of this study was a specially developed scientometric methodology for assessing technological progress through patent analysis using the principle of system design, consisting of two interrelated steps (Figure 2.10). At the first stage, the initial collection of patent information on the technology under consideration is carried out through various specialized databases, including USPTO, Espacenet, PatBase, Lens.org (the purpose is to eliminate duplicate and irrelevant information).

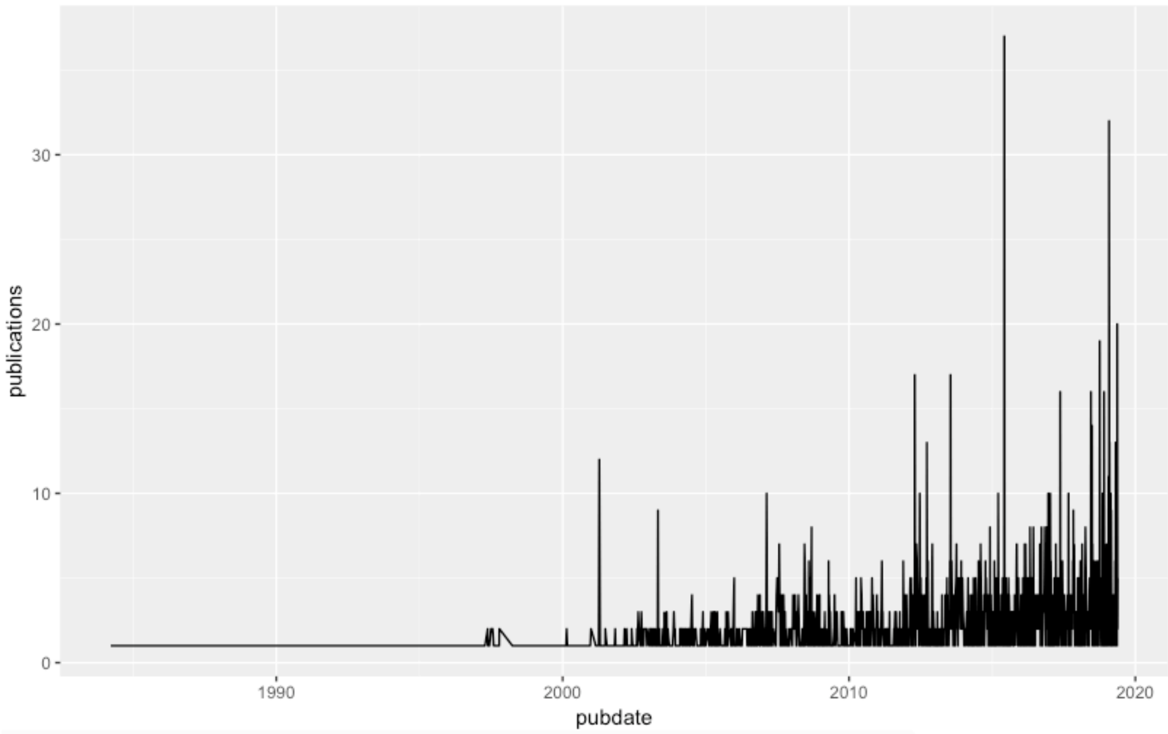


Fig. 14. Patent extract from databases related to fleet management systems (raw data).

In the second stage, scientometric patent analysis is performed using special software, which, in turn, is divided into two stages. First, a group of analysts determines the key areas and categorical apparatus of the study (taking into account various standard patent classifications); leading patenting companies; joint patents of the most active applicants and examples of their technological cooperation. Then, patent activity for various technological systems is evaluated, in this case, different types of fleet technologies units. The posterior analysis undertaken in the future is designed to integrate a specific variable, in our case, the telematics system, leasing, multi-source data connection hub, depending on the purpose of the study.

Subsequent substantive analysis of the latest patents based on the variable mentioned includes leading applicant organizations. It is important to emphasize that feedback from experts in relevant fields plays a decisive role for the entire process. Assessing new prospects and summarizing the findings also require the final validation of the results. The constructed diagram of causal loops made it possible to distinguish between the elements that make up the research system. At the first, the total number of patents in the field of creating fleet management systems was established, chronologically limited to the beginning of 1999 and September 31, 2019. The selection was carried out by searching for keywords in the headings. Patents clearly reflect technological advances in the creation of fleet technologies therefore scientometric patent analysis is actively used to evaluate them. In the present study, this analysis was supplemented by a technological approach, for which a causal loop diagram (Casual Loop Diagram, CLD) was constructed, which reflects the elements of the system, their mutual influence, and feedback dynamics (Zemke, 2001) (Figure 16) and more precisely shown as ”Methodology for a systemic technology patent analysis” in Appendix 1.

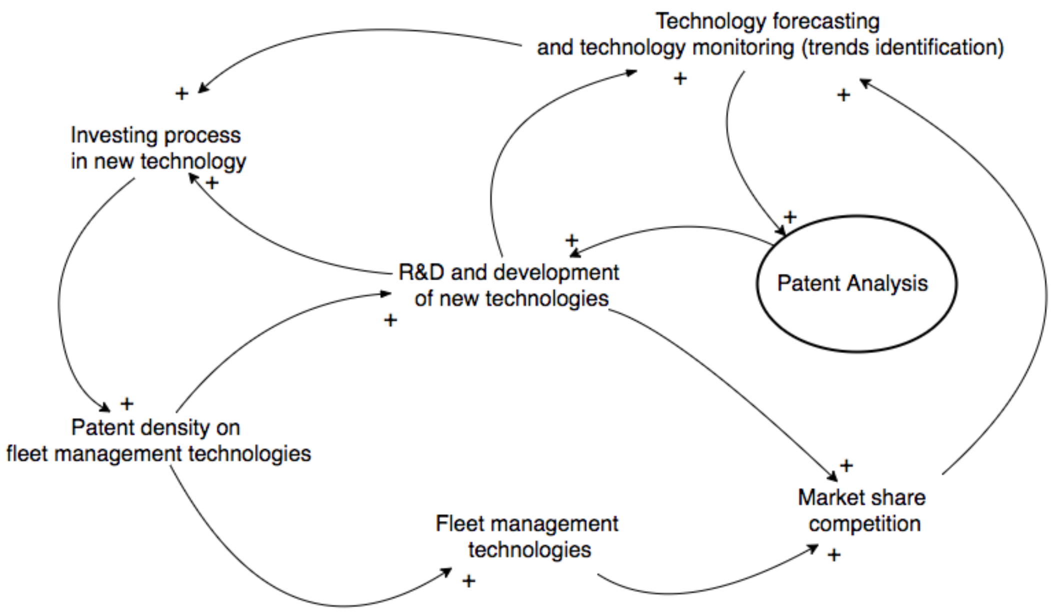


Fig. 15 Casual loop diagram (CLD) for perspective technology activities for fleet management systems. (Adopted from Rodríguez et al., 2015 Appendix A p. 2)

In total, 8234 patents were identified, the filtering of which allowed us to filter out duplicate or irrelevant records and standardize fields (such as the name of the organization). The following are the most globally popular research areas. Based on the International Patent Classification (IPC) and class codes, their focus was established, and leading applicant organizations identified.

Next, the possibility of applying patent analysis to describe the life cycle of technology on fleet systems is investigated. To determine the relevant patents, an expert survey was first conducted, based on which a list of keywords related to the technology under consideration was compiled. This list was then used to extract key codes from patents in accordance with the International Patent Classification (IPC) and the Cooperative Patent Classification (CPC), as well as to identify the relationships between them, which made it possible to identify key and related codes. The search for relationships between key codes (defining patent family codes) was followed by analysis in the Lens patent database.

Most patents related to fleet systems technologies have codes G07C5 and H04L67, and the lowest codes are G08G1, H04W4 and G07C5. As shown above, the code G07c5/008 is one of the most widely applicable technology for fleet systems. It includes five subgroups, and the maximum number of patents relate to subgroup H04l67/12. The lowest rates are in the subgroups G08g1/20 and H04w4/029. Further, patents were highlighted that were most relevant for telematics technology and fuel analytic technology. In total, the sample included 1837 refined patents registered in the period from 1999 to 2019. The results proved the leadership of automakers in the field of technological inventions. Other organizations (universities, research centers, government departments) that carry out their own R&D in this area are less effective. The object of a separate analysis in the form of patent research was joint patents and technological cooperation of companies - leaders of patenting in the fleet sector. The data collected was properly filtered and processed and presented in form of patent landscapes in Appendix 1. Based on this data, experts and company representatives have to measure specific amount of investment in this methodology for determining correct technology to choose.

Table 1. Codes of the International Patent Classification for the fleet management systems

Symbol (Code)	**Classification and description**
G	PHYSICS
G07	CHECKING-DEVICES
G07C	TIME OR ATTENDANCE REGISTERS; REGISTERING OR INDICATING THE WORKING OF MACHINES; GENERATING RANDOM NUMBERS; VOTING OR LOTTERY APPARATUS; ARRANGEMENTS, SYSTEMS OR APPARATUS FOR CHECKING NOT PROVIDED FOR ELSEWHERE (identification of persons A61B5/117; indicating or recording apparatus for measuring in general, analogous apparatus but in which the input is not a variable to be measured, e.g. a hand operation, G01D; clocks, clock mechanisms G04B, G04C; time-interval measuring G04F; counting mechanisms per se G06M)
G07C 5/00	Registering or indicating the working of vehicles (for measuring distance travelled or combinations of speed and distance G01C; engine indicators G01L; devices for measuring speed or acceleration G01P)

4 DEVELOPED METHODOLOGY FOR MANAGING R&D AND PATENT RESEARCH ACTIVITIES

Figure 17 shows the place of Prospective Patent Research activities in the life cycle of commercial products. Prospective Patent Research (PPR) is a tool for strategic planning of R&D at the enterprises of science-intensive industries, which is a set of works providing forecasting the competitiveness of the research object relative to the world level on the basis of patent and other information and focused on the commercialization of the results of intellectual activity in the entrepreneurial sector of the economy. The development of the organizational and economic mechanism of PPR will increase the accuracy of planning at the initial stage of research and substantiation of development, as well as at the stage of experimental design work. Detailed mechanism of organizational and economic mechanism of PPR includes the following methods: - methodology for substantiating the planning and economic parameters of R&D in fleet management; - methodology for determining the economically optimal scope of prospective patent research for R&D - a technique for monitoring promising patent research for R&D.

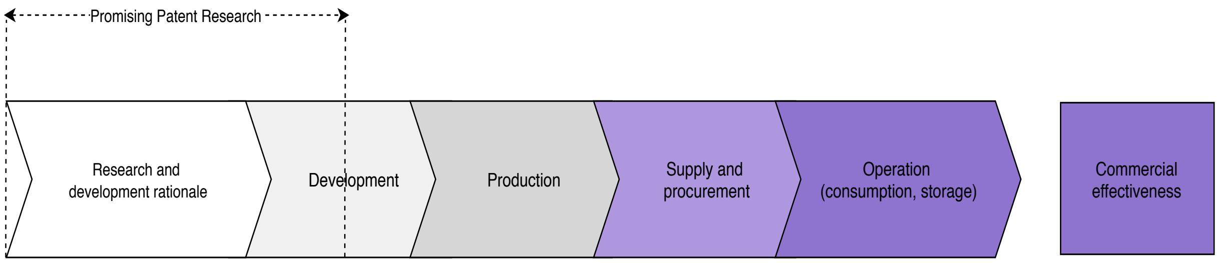


Fig. 16. Perspective Patent Research (PPR) activities.

The methodology for substantiating the planning and economic parameters of R&D is presented in Figure 17. At the stage of research of industry and product development trends by the customer and the R&D executor, this methodology allows one to predict the resulting steps of commercialization in the entrepreneurial sector of the technology of technologies created in the framework of R&D in the form of intangible assets. This technique provides the formation, on the basis of analysis of patent information and data on world industry leaders and other competing companies, of a criterion of economic impact of PPR, which includes:

- scientific and technical indicators;
- time indicator (planning timeframe);
- cost indicator (cash flow from the commercialization of intangible assets (IA) created in the framework of R&D).

The scientific and technical indicator includes the most relevant trends and developments in the research area identified in the analysis of patent information. This indicator serves as a guide when selecting promising R&D topics. The scientific and technical indicator at the planning stage includes a set of target indicators of the technical level of products, formed on the basis of the analysis of the most relevant patent information and allowing to justify technical and economic indicators for the products in the development of technical specifications stages. The R&D planning horizon is formed on the statements of the predicted timelines for the creation of new products and technologies by competitors in the various field of technology. Obviously, only being ahead of the competition can ensure company market leadership. The cash flow from the commercialization of intangible assets created in the framework of R&D characterizes the economic efficiency of R&D of the company.

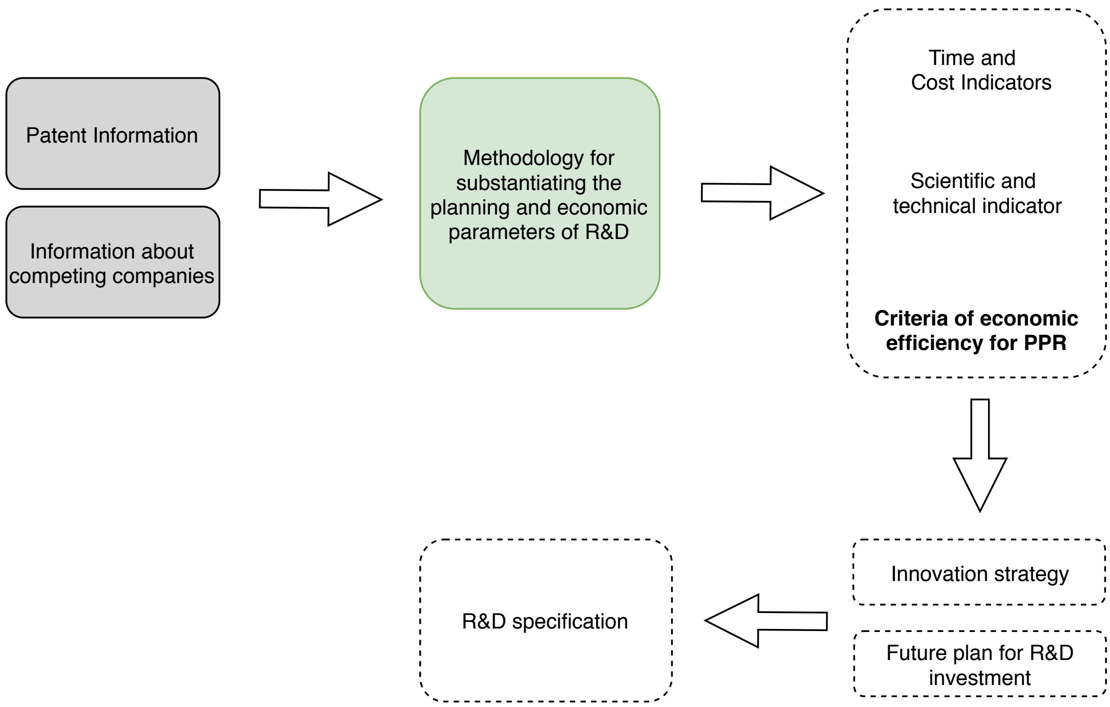


Fig. 17. Methodology for substantiating economic planning parameters.

Updating and clarifying the criteria of economic rationale of prospective patent research in the process of R&D allows timely adjustment of planned technical and economic indicators and thereby ensure the competitiveness of the developed product. Also, this can be used in assessing the novelty and patentability of a developed product and its structural elements. Methodology for determining the economically optimal volume promising patent research, presented in Figure 18. It allows to reduce the duration of those stages of the life cycle at fleet management enterprises. This technique allows to increase the efficiency of R&D planning due to a more accurate assessment and allocation of resources required for patent research, and thereby reduce the cost of patent research. Also, the technique allows you to optimize the application of the methodology described above to justify the planning and economic parameters of R&D, based on the analysis of patent information, and, thus, shorten the period of R&D planning.

The methodology for monitoring PPR is presented in Figure 19. Using feedbacks mechanism, this technique allows you to monitor the implementation of the developed mechanism by comparing actual PPR performance indicators with planned ones and subsequent adjustments. This technique is based on the principles of quality management.

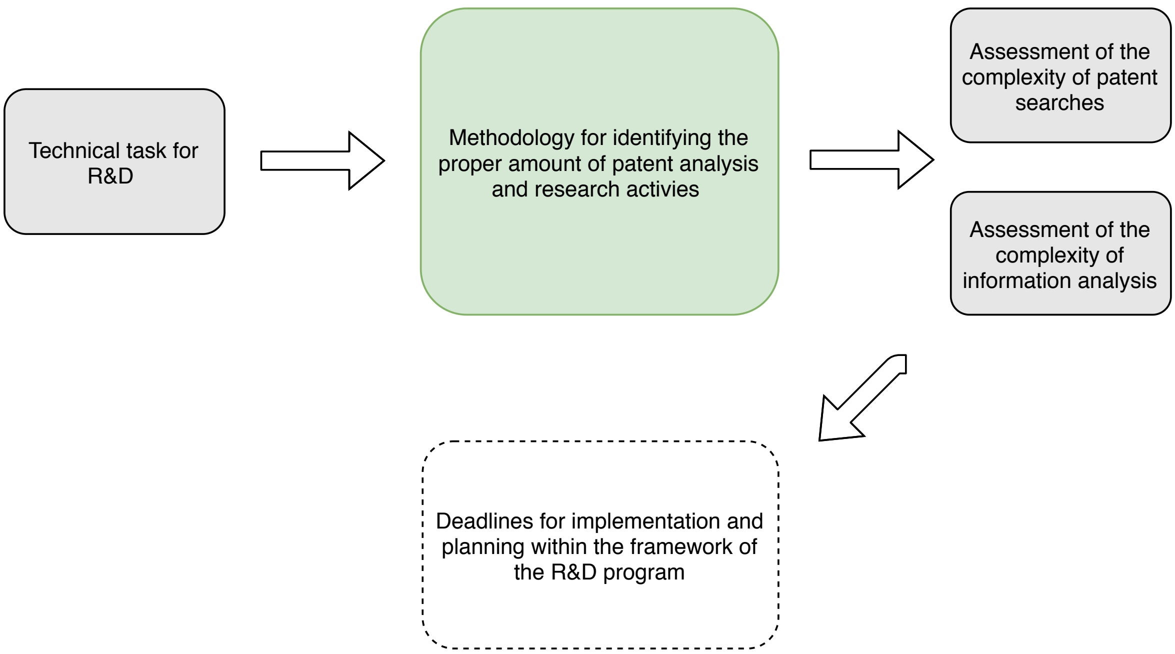


Fig. 18. Methodology for determining the economically optimal volume of PPR.

4.1 Methodology for substantiating the planning and economic parameters of R&D for fleet management technologies

Fleet industry products are high-tech and in most cases unique, unparalleled in the market. Direct analogues on the international market are practically absent due to the characteristics of the industry. Due to such circumstances, traditional methods for assessing and forecasting the technical level of products, based on comparison with similar products, are often ineffective (Jeong & Yoon, 2015). Thus, before conducting the research, it is vital to formulate sequence of proposed structure beforehand. The key to the implementation of the methodology is a taxonomic scientific and technical indicator, which is a synthetic value that summarizes all the characteristics that characterize the object under study. In this case, these marks will be all the technical characteristics that reflect the most relevant trends in the development of the object of study, and allow you to evaluate it from the point of view of compliance with scientific and technological progress and consumer requirements.

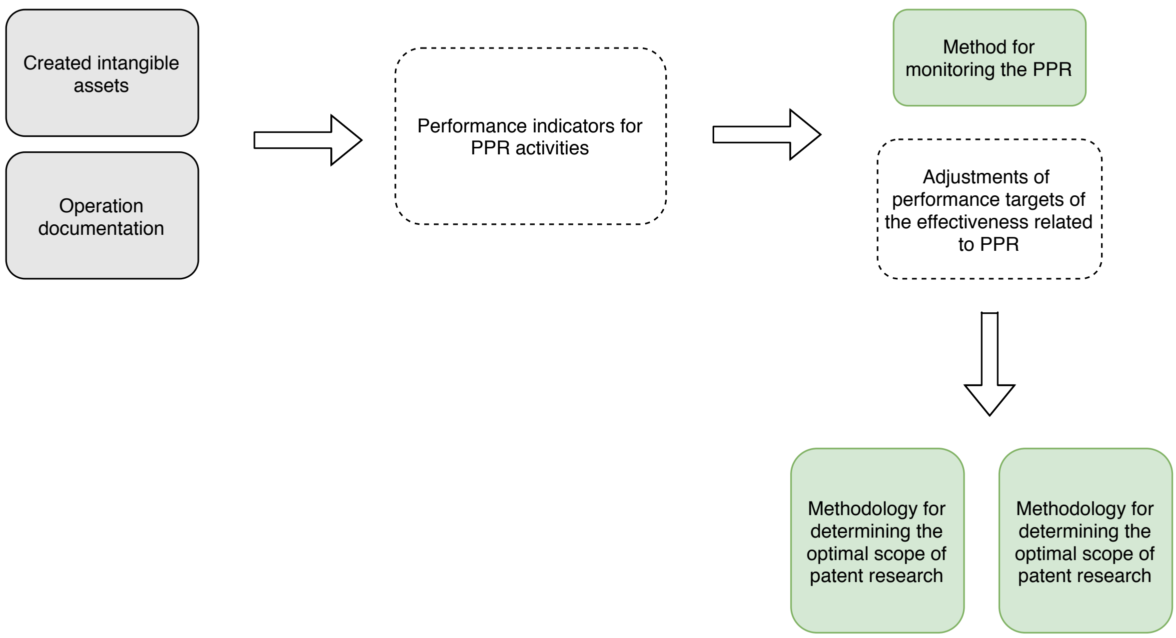


Fig. 19. Developed PPR monitoring methodology.

The peculiarity of the fleet industry is that the same tasks can be solved by radical methods, and the choice of the solution path is determined by the cost, technological base, innovative potential of the developer and a number of other factors.

The taxonomic indicator allows you to create a model that includes all possible technical indicators for the object under study, affecting its quality and technical level. This model will be a kind of standard that you need to focus on when developing R&D programs and terms of reference.

At the first stage of the algorithm, the object of study is determined. In the case of strategic planning, the object will be the scientific and technical sphere, within which the company intends to implement the R&D program. At the level of planning the technical specifications, the object of research will be a product: a device, technology, process, created in the framework of a specific research. The next step is to conduct a patent search in domestic and foreign patent databases in accordance with the chosen object of study. The depth of the search in the general case is determined by similar studies in this area, since the most relevant developments are important for research purposes, however, a patent search must be large enough so that its results allow for the most objective assessment of the development trends of the research object. After the patent search is completed, the formation of a scientific and technical indicator begins. An example of developed structural model of a scientific and technical indicator is presented in Figure 20.

At the strategic level, this is a model that reflects the global level of development in the field of technology, allowing you to evaluate a whole scientific and technical field, and at the stage of developing a technical task for research or development, it is a model that reflects the global level of development of a product that allows you to evaluate a specific product or technology. The structural model of the indicator is two-level. At the first level, it may include the following criteria of a technical level, depending on the nature of the object of study (performance, reliability, system efficiency, complexity of usage and cost of reduction). Types of innovation performance at strategic showed in Figure 21.

Fig. 20. Types of innovation strategies. Adopted from Fernald (2013)

The optimal set of criteria for the first level is determined by experts. Further, for each of these criteria, experts on the basis of a patent search form a set of private criteria of the second level, which are specific qualitative characteristics of the studied object. Since the same technical problem can be solved using various methods, it is necessary to include in the model all alternative options for technical implementation, if it is not yet known which method of solving the technical problem will be implemented in the planned R&D. In the future, when assessing the developed object, it will be necessary to use the corresponding version of the private indicator in the model. Since the same technical problem can be solved using various methods, it is necessary to include in the model all alternative options for technical implementation, if it is not yet known which method of solving the technical problem will be implemented in the planned R&D. In the future, when assessing the developed object, it will be necessary to use the corresponding version of the private indicator in the model.

4.2 Mathematical model for proposed indicators system for FMS

The next step is the assignment of weighting factors for the criteria of the first and second levels. Obviously, the various technical and economic characteristics of the object of fleet systems do not equally affect its technical level, so it is necessary to determine the weight of each criterion included in the model of a scientific and technical indicator (Saaty, 2008). Within the framework of the developed methodology, it is proposed to use for these purposes the method of finding the ranks of criteria based on the matrix of pairwise comparisons and higher. A linguistic scale consisting of nine gradations of assessments of relative importance is presented in Table 2. A typical statement of the AHP problem includes determination of evaluation criteria for decision making and the formation of a hierarchical structure, comparison of paired solutions, assessment of the relative weight of the elements of the resulting solution and assessment of alternatives.

Table 2. Linguistic assessments of relative importance

Qualitative assessment	**Quantitative value a_{ij} (Definition)**
Strictly equivalent (equally significant)	1
Slightly preferable	3
Somewhat preferable	5
Much preferable	7
Strictly Preferred	9
Intermediate Importance Values	2,4,6,8
The comparison between element j and element i (a_{ij}) has the opposite value a_i	$a_{ij} = \frac{1}{a_{ij}}$

The matrix of pairwise comparisons of particular criteria a_1, a_2, a_3 will have the following form, shown below.

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix}$$

After that we are using the comparison matrix to estimate the maximum eigenvalue (a set of numerical weights m_1, wm_2, . . ., w_n which reflects the recorded judgments within each level can be calculated by using the geometric mean method in the comparison matrix represented in Equation (5).

$$m'_n = \sqrt[n]{\prod_{j=1}^{j=1} a} \; ; \; m_i = \frac{m_i}{\sum_{i=1}^{n} m'_i}, \qquad (5)$$

where a_{ij} is the element of the comparison matrix; n is the number of particular criteria; m_i' is the irregular rank of the i-th criterion; m_i is the normalized rank of the i-th criterion.

After the formation of a two-level model of a scientific and technical indicator, it is necessary to determine the values of particular criteria in the form of value intervals. If patent information is not found enough to determine them, then additional sources of scientific and technical information are also used. The presentation of various characteristics in a universal form is the basic problem of formalizing uncertain parameters and particular criteria. In practice, to solve this problem, the following three methods are most often used: representation of uncertain parameters in the form of fuzzy intervals, clear intervals and in the form of probability distributions.

Using the theory of fuzzy sets as a conceptual basis for solving problems of multicriteria choice was proposed by Bellman and Zadeh (Rahimian et al., 2016). Further, the concept was developed in the works of Jager, Dubois and Prad, Diligensky and other scientists. Particular estimates of the object of study for each criterion take values in easily identifiable sets, and the objective function is considered as a fuzzy set that limits the allowable values of the corresponding criterion.

Further in the work, the fuzzy mythology contained in the works of (Collan, Fedrizzi, & Luukka, 2013) .The objective function associated with the criterion C_α will be described by a fuzzy set G_i, defined on X_α, and for any $x \in X_\alpha$, $\mu_{Ga}\,(x)$ is the degree of compatibility between the value of the estimate x, characterizing the object and the desire of the decision maker. The range of values [0,1] was selected for the proposed system. The membership function $\mu_{Ga}\,(x)$ for each particular criterion will vary from 0 in the region of undesirable values of the criterion to 1 in the regions of the most preferred values of the criterion (showed in Equation (6)).

$$\mu_{Ga}\,(x) = \begin{cases} \alpha, & x \in X_a \\ 0, & x \notin X_a \end{cases} \qquad (6)$$

Depending on the admissible values of the criteria and the fixed points determined fleet management experts, the piecewise-linear membership functions $\mu\,(x)$ can have different forms. Reference points for constructing the membership function $\mu\,(x)$ for each particular criteria are determined on the basis of the analysis of patent and other technical information. These are the minimum and maximum possible values for each particular criterion. Thus, the criterion of economic efficiency of PPR allows you to compare the object of study with both existing analogues and a conditional standard that combines the best values of all the criteria included in the scientific and technical indicator.

Membership functions for each i criterion of the standard is equal to 1, but taking into account weighting criteria, their final values are different. A thorough analysis of the reference model and models built for existing analogues allows us to build a model of a scientific and technical indicator for the research object, in which the values of particular criteria correspond to the desired characteristics of the studied object.

The overall goal (scientific and technical indicators) is expressed as a hierarchy of sub goals, at the lower level of which there are q particular goals associated with q particular criteria C_i that allow you to evaluate the object under study. Then the fuzzy set D of objects compatible with the common goal can be obtained by convolution of fuzzy sets with membership functions μ_i. For the purposes of the proposed methodology, it is advisable to use the additive version of coagulation (Chiu & Chen, 2003).

Determining the value of a scientific and technical indicator takes place in two steps. The first is the calculation of the values of the criteria of the first level (Equation (7)):

$$K_i = m_1\mu_1(x_j^1) + \cdots + m_j\mu_j(x_j^i) + \cdots + m_q\mu_q(x_q^i), \qquad (7)$$

where: K_i - i-th criterion of the first level; m_j is the rank of the jth criterion of the second level; μ_i is the membership function of the jth particular criterion x_j^i; q - the number of private criteria of the second level.

The second step is the summation of the values of the criteria of the first level (Equation (8)):

$$U_{sum} = \beta_1 K_1 + \cdots + \beta_i K_i + \cdots + \beta_n K_n, \qquad (8)$$

where: β_i is the weight coefficient of the i-th criterion of the first level; n is the number of criteria of the first level. After calculating the scientific and technical indicator, it is also necessary to determine the time and cost indicators.

A temporary indicator allows you to evaluate during what period it is necessary to implement a project in order to get ahead or at least keep up with competitors. This indicator is predicted using expert methods based on the analysis of patent activity of competitors in the studied scientific and technical field. At the strategic planning level, it determines the R&D planning horizon, and at the tactical level, the effective term for the implementation of specific R&D. The cash flow from commercialization of the created intangible assets characterizes the real return on R&D costs, since it is intellectual property that is the key asset of high-tech business, provides it with competitiveness and sustainable innovative development. In high-tech industries, including the fleet and automotive industry, the value of intangible assets is largely involved in shaping the market value of a business.

The value indicator is expressed in cash flow from the commercialization of intangible assets obtained in the development of promising technologies Equation (9):

$$V_{IA} = \frac{CF_t^{IA}}{(1+r)^t}, \qquad (9)$$

where: CF_t^{IA} - cash flow from the commercialization of intangible assets in the period t; r is the discount rate.

The cost indicator is predicted by experts based on an analysis of the prospects for the commercialization of intangible assets, the value of existing intangible assets of a company, the average number of intellectual property created as part of R&D, and also taking into account data on intangible assets of competing companies, operating in transportation systems sector.

Presence of the time (T) and cost (V_{IA}) indicators in the form of fuzzy intervals allows for an additive or multiplicative convolution of the criterion of economic efficiency of PPR depending on the rigidity of the requirements for the implementation of the plan (Equations (10) and (11)).

$$P^A = \tilde{U} + \tilde{T} + \tilde{V}, \qquad (10)$$

$$P^M = \tilde{U} \cdot \tilde{T} \cdot \tilde{V}, \qquad (11)$$

where: $\tilde{U}$, $\tilde{T}$, $\tilde{V}$ - Intangible Assets of Fuzzy estimates of indicators. The criterion formed using the additive convolution is less stringent and is applied when the absolute achievement of the planned targets is not mandatory. Multiplicative convolution, in contrast, allows you to create a more stringent criterion. Thus, the methodology for substantiating the planning and economic parameters of R&D allows us to determine the criterion of economic efficiency of prospective patent research, which includes scientific, technical, time and cost indicators, and forms a set of key elements based on prospective patent research (Kamble, Singh, & Kharat, 2017). This criterion is associated with the long-term development of the company and is intended to be used in the development of the company's innovative strategy and long-term R&D plan, as well as the development of specific products and technologies and is the basis for the development of technical tasks for R&D (Choi, 2018).

The methodology for substantiating the planning and economic parameters of R&D, discussed above, is based on patent research. It is obvious that in order to identify and objectively interpret all current trends in the development of various objects of space technology, it is necessary to systematize and analyze a significant amount of patent information. Thus, in the work of Guderian (2019) the author recommends, within the framework of research on industry development trends, to analyze patents issued over 10 years, as well as to form patenting series characterizing the growth of the total number of patents, to build dynamics curves of inventive activity. The procedure for conducting patent research, described in the, is quite simple, as you can see and it can distinguish two main stages:

- patent search;
- analysis of the information received.

The implementation of these works is time-consuming and requires the participation of highly qualified specialists who have sufficient knowledge of the research subject. Obviously, the accuracy of the forecast of the criterion of economic efficiency of the PPR depends on the number of relevant patents found, but with an increase in the selection of the analyzed patents, costs increase. At the same time, the number of relevant patents does not increase in proportion to sample growth. In this regard, it is necessary to evaluate the optimal amount of work.

$$I = log_2N \qquad (12)$$

The amount of information received is estimated by the Hartley formula (variation of Shannon's formula), where: I is the amount of information; N is the number of messages (Rioul & Magossi, 2014). In this case, N is the number of selected patents, can be replaced by an economic value - the cost of patent research. Then the information content of patent research and, accordingly, the criterion of economic effectiveness of PPR:

$$I_{info} = log_2S, \qquad (13)$$

where: I_{info} the information content of patent research; S - the cost of patent research. Prospective patent research carried out as part of R&D planning should not take a long period of time and not waste human resources on itself, otherwise the practical implementation of the PPR mechanism will be impossible due to the high complexity and cost. Thus, it is necessary to optimize the approach to planning patent analysis and bring it into line with the goals of the methodology for assessing the efficiency of strategic planning of R&D.

Such optimization is possible due to the correct justification of the needs for time and human resources required for patent research. Therefore, the task of the methodology for substantiating the optimal volume of PPR for R&D is to determine the optimal resources that need to be spent on these works. When developing a task for patent research and patent search regulations, the following parameters are determined that characterize the amount of work:

- Indices of the International Patent Classification;
- depth of search;
- countries of patenting.

The technical nature of the object of study determines which indices of the International Patent Classification (IPC) should be searched. IPC is a uniform hierarchical classification of patent documents, covering all scientific and technical fields. Each patent has at least one IPC index. For the correct determination of the indices of the IPC by which the search will be carried out, it is necessary to formulate the goals as accurately as possible and describe the object of study.

In addition to the methods mentioned and explained above, a number of authors use specialized analysis techniques to study patent data. As a rule, they are resorted to as additional tools in order to expand the opportunities provided by the basic methods. For example, to evaluate the effect of a qualitative factor on patent activity without using dummy variables in a model or to conduct simulation modeling. The most notable of the specialized methods, in our opinion, are the gravity model, the Cox proportional risk model, the Poisson regression model and the CDM model (Wang et al., 1998).

Gravity models got their name for their resemblance to the universal gravitation formula. Their application allows us to evaluate the effect of the distance between the studied objects on the interaction between them. Initially, this method was developed to study foreign trade and its dependence on the distance between trading entities (countries). In this capacity, he was used by one of the founders of econometrics J. Tinbergen (Tinbergen, 1962). However, at present, this approach is also applied in other areas of economic research.

The Italian economist L. Picci used the gravitational model, modified for use in regression analysis, to study the degree and factors of internationalization. Development of research on innovative processes based on patent statistics on the internationalization of inventive activity in Europe, estimated by the statistics of international patents (Picci, 2010). At the same time, a new set of indicators was developed to measure international patent applications. The latter refers to applications in which at least one of the inventors or applicants for a patent (which may be not only the inventors themselves, but also companies) is a citizen of another country than other inventors or applicants. According to the results of the study, it was found that the level of internationalization of inventive activity in Europe remains at a low level but is growing steadily.

International cooperation in the field of research and development is positively influenced by the presence of a common language and a common border between countries whose residents are inventors and applicants, but the distance between the capitals of countries participating in the research process is negatively affected. However, the effect of these distances is weaker than in the international trade model. In the study of the relationship between patent statistics, reflecting either the value of the invention or the uncertainty of the business environment, and commercialization indicators of inventions (products) (for example, the pharmaceutical industry), a Cox proportional risk regression model can be used, which represents an equation of the form:

$$h_i(t) = H(t)exp(b_i X_{i1} + \cdots + b_n X_{in}) \qquad (14)$$

where $h_i(t)$ is the risk of object i at time t; $H(t)$ is the basic risk for all objects at time t; b_i, ..., b_n - coefficients for risk factors; X_{i1}, ..., X_{in} are risk factors.

4.3 PMBOK in procurement of patents and risks management

It is proposed to study procurement activities related to patent in industry in the form of a set of milestones and their management tasks, in accordance with the project management standards of the Project Management Body of Knowledge (PMBOK) (Niemann et al., 2014). The project approach to procurement management is the most rational in the high-tech industry, where complex innovative technical systems for civilian and dual-use complexes are created. The figure shows the five main groups of PMBOK processes and their respective project procurement management processes. Further, I will proceed from the fact that risk management in procurement is an end-to-end subprocess, which is necessary in the formation of complex cooperative ties between finalists and suppliers of components, assemblies (shown in Figure 22)).

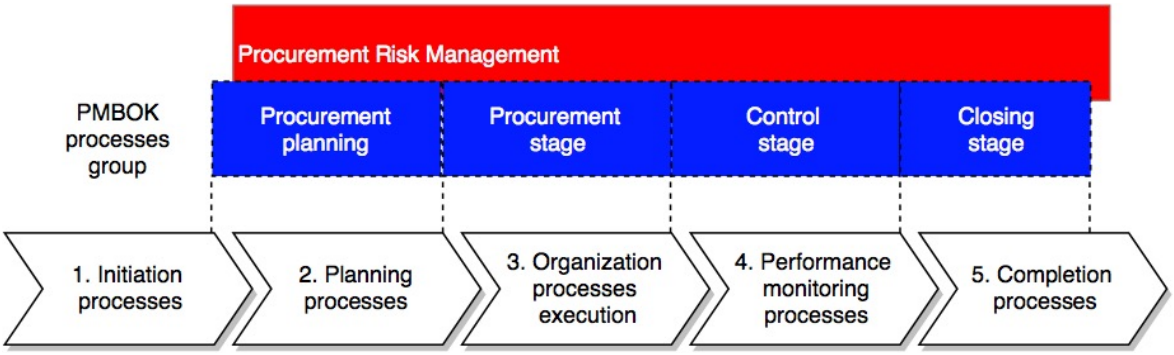


Fig. 21. The main stages of procurement in industry according to PMBOK.

As a generalized indicator characterizing the risks of interaction with suppliers, the indicator of the degree of trust (or coefficient of trust) on the part of the customer is most often used. The degree of trust in an enterprise in most works is understood as a subjective conditional assessment characterizing the ability of an enterprise to deliver components, components, modules and components in a timely manner and with a given quality, provided there is no technical risk, that is, if all technical problems are resolved.

Thus, when assessing risks, indicators should be taken into account that characterize, on the one hand, the scientific and technical and production and technological capabilities of the supplier, and on the other, its financial and economic condition. The mathematical model of the indicator of the degree of trust of the enterprise-customer to the enterprise-supplier can be represented as the following dependence Equation 15:

$$K = f(R_t, R_e, w_t, w_e) \qquad (15)$$

where R_t, R_e - coefficients characterizing the degree of technical and economic risk of interaction with the supplier acquiring the patent, respectively; w_t, w_e— importance factors of indicators of technical and economic risks, respectively. Given that the coefficient of trust of the enterprise and risk indicators are antagonistic in sign, we obtain the following expressions:

for additive convolution of risk indicators (Equation 16)

$$K = w_t(1 - R_t) + w_e(1 - R_e); \qquad (16)$$

for a multiplicative convolution of risk indicators (Equation 17)

$$K_1 = (1 - R_t)^{wt},$$

$$K_2 = (1 - R_e)^{we},$$

$$K = K_1 \cdot K_2 \qquad (17)$$

Risk factor importance factors w_t, w_e, are usually determined by expert methods taking into account the normalization rule $w_t + w_e = 1$. For their analysis, the AHP method considered earlier can be used. It should be noted that when managing procurement in the commercial sense, the preferred option is to use a multiplicative convolution. This is a rigorous approach in which mutual compensation of aggregated risk factors is not possible. Thus, when making purchases, it is necessary to ensure at the same time strict compliance with the requirements of the technical specifications and price limits. Accordingly, when managing the procurement of commercial projects, it seems possible to use additive convolution. For example, in the case of compensation for the risks of quality reduction by price discounts.

The enterprise risk indicators represented by the values (R_t, R_e), as well as a generalized indicator of the degree of confidence K are of a fuzzy-interval nature. To formalize this feature, we write the following:

$$R_t = R_t(\xi);$$

$$R_e = R_e(\xi);$$

$$K = K(\xi), \quad (18)$$

where (ξ) is a variable characterizing uncertainty factor.

Thus, the risk indicators of the supplier enterprise are presented in a more general form compared to the traditional approach and can be expressed not only as determinate (point), but also as fuzzy interval values. Uncertainty is one of the basic concepts of the theory of decision-making and means that the decision-maker cannot absolutely accurately determine the development of the project in the future. Uncertainty is always evaluated both positively and negatively, for example, the future financial flow of a project may turn out to be more or less than predicted. The rational behavior of the head of the enterprise is that his position is not passive, and he has the ability to change procurement management decisions depending on the market situation, while striving to increase the efficiency of his business and analyze the patent activity of technologies. At the same time, he tries to take advantage of the favorable economic situation and avoid losses in the unfavorable. Then, it is necessary to distinguish between two types of uncertainty, which have opposite effects on the optimality condition for decision-making:

- economic uncertainty, which is associated with correlation dependencies with the state of the economy or industry and is exogenous (external) with respect to the decision-making process;

- technical uncertainty that is not related to the state of the economy or industry and is endogenous (internal) with respect to the decision-making process.

It is technical uncertainty that characterizes procurement of components and modules for the production of complex high-tech products. The degree of technical risk of the supplier enterprise R_t is an indicator characterizing the presence of the necessary scientific and technical backlog, security and the level of professional preparedness of scientific and technical personnel (researchers, designers, technologists, mock-up workshops and pilot plants), technical equipment (level of technology and technology), composition production assets of the enterprise (machine tool fleet, modern technologies, instrumentation, etc.), production capabilities and technological base, the use of new technologies and construction materials, as well as the availability of necessary labor resources. To assess the degree of technical risk of the supplier's enterprise, it is proposed to develop a system of private indicators reflecting its scientific, technical and industrial-technological potential. An integrated assessment of the degree of technical risk of a supplier enterprise can then be obtained by compiling particular indicators using known convolutions.

The analysis of various approaches to the formation of indicator systems used in the practice of making managerial decisions made it possible to identify the following groups of indicators that directly or indirectly assess the degree of technical risk of the supplier enterprise:

- indicators of scientific and technical reserve;
- indicators of production and technological reserve;
- indicators of innovation activity;
- indicators of staffing.

The scientific and technical reserve is understood as a complex characteristic indicating the potential scientific and technical capabilities of the enterprise for the successful implementation of innovative projects on a given topic. The main forms of scientific and technical backlog are:

- new knowledge about phenomena, effects, laws and laws of an applied nature;
- new (improved) materials and substances;
- elemental base, components, modules and blocks;
- Algorithms and computer programs;
- laboratory experimental base;
- experimental and prototype models;
- conceptual, regulatory, technical, methodological and other documents.

Under the production and technological reserve is understood a comprehensive characteristic that reflects the potential of the enterprise to ensure the successful implementation of production and technological stages and innovative projects on a given topic. The main forms of production and technological backlog include:

- production technologies;
- machines, equipment, tools, inventory;
- production, technological and testing equipment;
- measuring instruments;
- means of automation of production.

To characterize the innovative activity of the enterprise, such private indicators are used as the number of patent applications and patents received, the number of licenses for intellectual property objects realized, the number of process and product technological innovations, etc. The indicators of the staffing of the enterprise are the staffing of the enterprise with employees of the main specialties, the turnover of staff of the main specialties and the average age of specialists. To assess the private indicators of the technical risk of the enterprise, it is proposed to use the method of point estimates, which is characterized by relative simplicity and clarity.

The degree of economic risk of the supplier enterprise R_e is an indicator that characterizes the possible influence of the parameters of financial and economic stability, stability of the financial and economic activity of the enterprise on the successful implementation of supplies. The analysis of existing indicator systems allowed us to propose the use of the following indicators:

- financial stability;
- liquidity;
- turnover.

An indicator of financial stability is the equity multiplier, which characterizes the ratio of funds invested in the assets of the enterprise to equity. It reflects independence from external sources of financing and the degree of formation of assets from equity. This ratio allows you to evaluate the increase (decrease) in the financial independence of the enterprise (Equation 19):

$$k_{\text{multiplier}} = \frac{\text{A}}{\text{OC}} \qquad (19)$$

where A - assets; OC - equity (own capital).

Liquidity indicators allow us to assess the solvency of the enterprise - its ability to timely repay its short-term obligations. To analyze the liquidity indicators and assess the solvency of the enterprise, the calculated values of the indicators are compared with the recommended (normative) values, as well as industry average data. The absolute liquidity ratio shows how much of the short-term debt obligations an enterprise can pay for with available funds. Exceeding the recommended value indicates that the company has more money than is necessary to meet needs, and an excess of funds brings little profit or does not bring at all:

$$k_{\text{liquidity}} = \frac{\text{FR}}{\text{SL}} \qquad (20)$$

FR - financial resources and cash equivalents; SL - short-term liabilities.

Important to note that the quick liquidity ratio reflects how much of the short-term debt obligations an enterprise can pay without resorting to selling inventories. The ability of an enterprise to repay its debt obligations depends on the buyers, therefore, it is necessary to study the conditions of commodity loans granted to customers. In the presence of overdue receivables, the ratio will be overstated:

$$k_{\text{urgent}} = \frac{(\text{FR} + \text{AR})}{\text{SL}}, \qquad (21)$$

where FR - financial resources and cash equivalents; AR - accounts receivable; SL - short-term obligations.

The current liquidity ratio shows the multiplicity of current assets exceed the short-term liabilities of the enterprise. If the indicator is greater than the recommended value, then this indicates that the company has more current assets than can effectively use them for patenting. A low current liquidity ratio may indicate the presence of high financial risk, as well as difficulties in marketing products or poor organization of logistics.

$$\mathrm{k_{tec}} = \frac{\mathrm{CA}}{\mathrm{SL}}, \qquad (22)$$

where CA - current assets; SL - current liabilities.

Turnover indicators allow us to assess how quickly the funds invested in assets turn into real cash. Accelerating the turnover of current assets with the same sales volume allows you to release part of the funds from the turnover, or with the same amount of working capital to increase sales (if there is demand for products, work, services of the enterprise). Turnover ratios characterize the number of turns made by assets as a whole or a certain type of assets (the speed of their turnover as a whole or a given type of assets):

$$\begin{aligned} \mathrm{k_a} &= \mathrm{R} / \mathrm{A}, \\ k_{ca} &= R/CA, \\ k_{st} &= R/ST. \qquad (23) \end{aligned}$$

where R is the revenue; A - assets; CA - current assets; ST - stocks.

For the effective implementation of the procedure for analyzing the technical and economic risks of the supplier for patenting purposes, it is proposed to use a combination of linguistic and fuzzy interval estimates. The advantage of this approach is that in the case of applying fuzzy numbers to the forecast of parameters, the analyst is required not to specify the calculated corridor of the values of the predicted parameters. Then the expected effect is estimated by the expert as well as a fuzzy number with its degree of fuzziness.

The proposed system of indicators for assessing risks in management of procurement activities for patenting in industry is focused on the analysis of suppliers of components, modules, components, assemblies and assemblies in the context of cooperation in the production of complex high-tech military, civilian and dual-use products. It can be used at various stages of the procurement process in accordance with the project management approach: for preliminary competitive selection of applicants, during competitive procedures, for monitoring the activities of suppliers in the course of fulfilling contractual obligations, as well as for auditing the results of cooperation and preparing proposals for subsequent projects and programs.

The scorecard is based on the proven methods of the theory of management of organizational systems, hierarchy analysis, regression analysis and is distinguished by the use of a complex coefficient of degree of trust in the supplier company, taking into account potential technical and economic risks of interaction in the procurement process. A further development of the described approach to the construction of such a system of indicators is the development of methods and procedures for analyzing technical and economic risks in procurement using criteria convolution methods, linguistic and fuzzy-interval assessments, taking into account decision-making features in organizations of the state and business sectors of the economy.

In this chapter, a scientific and methodological modelling apparatus was developed. Organizational and economic mechanism of prospective patent research are including the following methods:

1. The methodology for substantiating the planning and economic parameters of R&D, which allows us to predict the effect of the commercialization of technologies created in the framework of R&D in the business sector of the economy by forming, based on the analysis of patent information, the criterion of economic efficiency of R&D.
2. The methodology for determining the economically optimal volume promising patent research, which reduces the cost of patent research.
3. The methodology for monitoring promising patent research, which allows monitoring the implementation of the organizational and economic mechanism of PPR through the application of the principles of fuzzy intervals, risks management and PMBOK.

5 DISCUSSION AND CONCLUSIONS

5.1 Discussion

The main goal of this paper was to provide an overview of patenting activity and mathematical model affecting right amount of investments into R&D process for following trends in fleet management. This was done by addressing the following research questions:

Table 3. Research questions and discussion chapters

Chapter	Question
2.2 TMS, FMS and RDA systems	How the current tendencies in technology sector are affecting fleet management systems technology innovations?
2.3 Obstacles in strategic planning of R&D at industrial enterprises	How can companies, operating in the fleet management context benefit from utilizing existing datasets and enhance practical business model ecosystem through decision making approaches and patent analysis?
4 Developed methodology for managing R&D and patent research activities	Based on patent analytics how can company predict to see perspective technology directions and make correct investment into R&D and how it should be implemented?
4.2 Mathematical model for proposed indicators system	What are the main predictors and how companies can invest in R&D's and monitor risk indicators for future scenario changes based on patent data and other sources of information?

The research questions are answered in the order depicted in Table 3. In the chapters of the thesis, the problem of the practical implementation of the developed organizational and economic mechanism of prospective patent research at the fleet industry enterprise was solved:

A project of a set of mathematical tools that implement the mechanism of promising patent research was proposed, and appropriate algorithms were developed.

An important role in expanding research areas using patent data was played by a significant enrichment of their methodological apparatus. The emergence of large patent information databases allowed researchers to use advanced methods of quantitative analysis, and the appearance of specialized computer programs made it possible to process large amounts of data in a short time. In these conditions, instead of simple quantitative analysis methods that were used earlier (counting the number of patents for a particular research object and their distribution in time and industry affiliation) and often based on bibliometric methods developed for the analysis of scientific texts, more complex methods such as S-curve analysis, correlation analysis, fuzzy logic analysis, gravity model, and also regression analysis.

The latter is currently one of the most common tools for evaluating patent data, since it allows solving problems inaccessible to other methods. In particular, with its help it is possible to establish not only the presence of a stable relationship between the dynamics of the number of patent applications and its alleged factors, but also to evaluate the strength of the influence of each of them on the appearance of patentable inventions. In addition, it became possible to determine the degree of influence of the obtained patents on various industries. This allows us to consider fuzzy logic method as one of the most promising modern methods of quantitative analysis of patent statistics and R&D planning. However, this method is not without drawbacks and involves a number of difficulties. In particular, there is a risk of the absence of significant factors in the model, which can lead to distorted research results and a general deterioration in the quality of the model.

Despite the fact that there are certain methods for detecting such errors, it is still necessary to choose factors manually, which requires a deep knowledge of the object under study and its relationships with the external environment. The economic interpretation of the obtained mathematical results, in particular, the insignificance of certain factors of the model, can also present difficulties. The authors solve these and other problems in different ways. Regression analysis of patent statistics can be supplemented by other methods: the Cox proportional risk model or Poisson regression. However, this method has a certain potential, which is currently poorly implemented in the study of patent data. Among these opportunities include the ability to give short-term forecasts of the dynamics of the studied indicators. Most of the other methods used in the study of patent statistics do not have the ability to give mathematical forecasts, but in a regression analysis this is more than possible.

In particular, it becomes possible to calculate the future values of difficult to predict targets, such as the market value of the company, labor productivity, if the function of its dependence on more easily predicted factors, including patent data, is determined. Similarly, one can predict patent activity, if we consider it as a reflection of the innovation activity of the firm itself or the industry as a whole, if there are forecasts on the factors of patenting. At the same time, none of the works that we examined using regression analysis contained quantitative forecasts. In my opinion, researchers should try to consider the possibilities of applying this method for prognostic purposes.

5.2 Summary of the work

As a result, an analysis of the current economic conditions for the functioning of the scientific and production enterprises of the fleet industry made it possible to justify the need for further development and improvement of the methods of strategic R&D planning, taking into account the effects of technology commercialization and patent analysis in the entrepreneurial sector of the economy. The analysis of methodological issues of the organization and economics of patent research activities was carried out in the thesis as a tool for planning R&D at research and production enterprises in the fleet industry revealed specific features of the automotive industry that determine the insufficient effectiveness of traditional methods of planning R&D, including patent research methods and decision making methods.

A hypothesis of the thesis was put forward, consisting in the fact that to predict the economic effect of the implementation of R&D results, an integral indicator formed on the basis of patent research should be used, taking into account competitiveness relative to the world level development, the terms of R&D implementation and forecast cash flows from the commercialization of created intangible assets.

In order to solve the scientific problem posed, a new methodological approach to the organization of preventive maintenance at the initial stages of research and development is proposed and justified:

- in the predictive assessment of the economic effect of the commercialization of technologies created during the development of fleet technologies in the entrepreneurial sector of the economy;
- in substantiating the planning and economic parameters of R&D based on patent datasets on the creation of technology fleets industry trends taking into account the forecast effects of technology commercialization in the form of cash flow from intangible assets and PMBOK methodology.

To implement the proposed methodological approach, a new organizational and economic mechanism of PPR has been developed. The following author’s methods have been developed as part of this mechanism: a methodology for justifying the planning and economic parameters of R&D within modern mathematical modeling frameworks from literature and expert opinions.

The present study offers an initial perspective through a systematic patent review of work on fleet vehicles system. To obtain more in-depth perspectives, because the study area is so broad, it is important to focus on specific topics. It would be interesting in future research to determine the correlations between the variables that characterize the trends and the evolution of technical advances through mapping of technology related to FMS. Furthermore, it is important to remember that patent analysis only covers one part of the strategic complexity of the industry; further analysis of the market is required.

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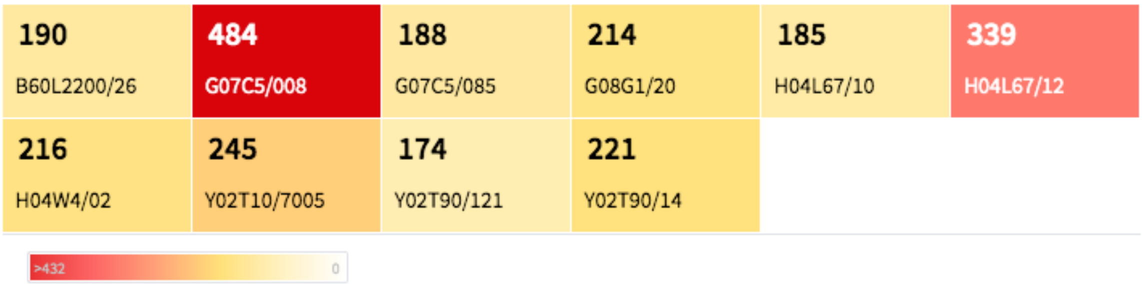
APPENDIX 1: CPC Subgroups, Inventors, Years of publishing

Figure 1. Fleet management technology heat map (CPC patent code ranking)



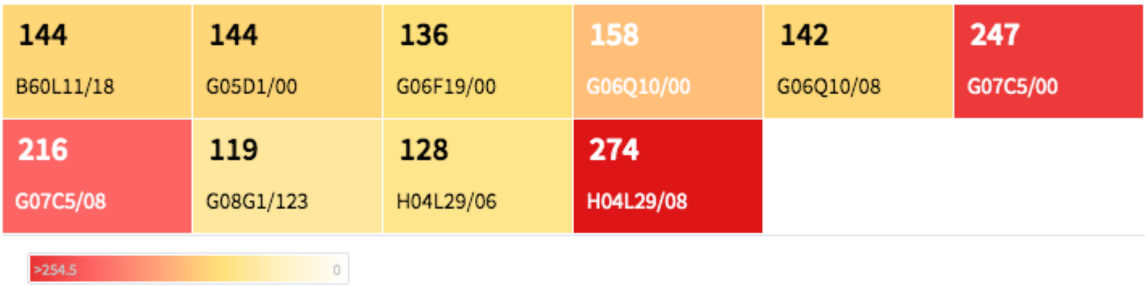
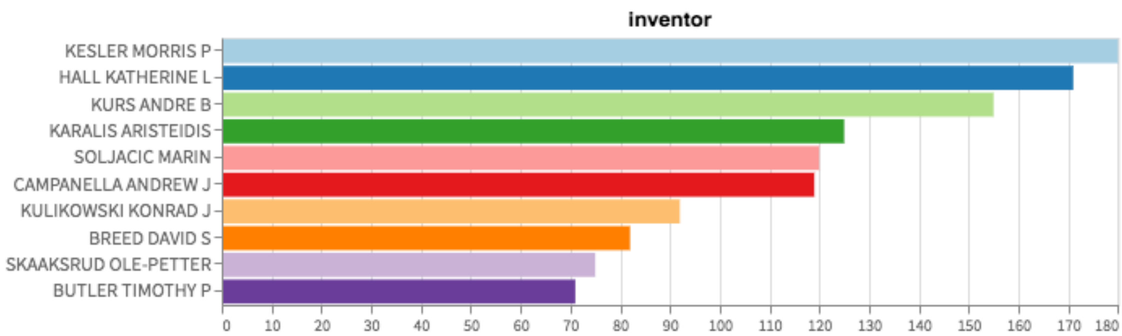


Figure 2. Inventors ratio for patents scope (CPC patent code ranking)




Fernandez Dennis S (17)
Hti Ip L L C (14)
Verizon Patent & Licensing Inc (18)
Chengalvarayan Rathinavelu (19)
State Farm Mutual Automobile Insurance Co (19)
Strongforce Iot Portfolio 2016 Llc (23)
Talwar Gaurav (25)
Concaten Inc (17)
Tomtom Telematics Bv (28)
Argus Cyber Security Ltd (31)
Flextronics Ap Llc (20)
Ford Global Tech Llc (45)
Madhavan Sethu K (47)
Peirce Kenneth L (21)
Deere & Co (15)
Eaton Corp (16)
Cummins Inc (32)
Geotab Inc (52)
Gormley Joseph (15)
Automotive Tech Int (59)
Allstate Insurance Co (61)
Nnt Inc (7)
Moj Io Inc (8)
United Parcel Service Inc (70)
Yi Ki Hak (48)
Telogis Inc (59)
Zonar Systems Inc (93)
M2md Tech Inc (15)
Hti Ip Llc (25)
Gm Global Tech Operations Inc (77)
Davidson Mark J (19)
Autoconnect Holdings Llc (19)
Swiss Reinsurance Co Ltd (17)
Caterpillar Inc (15)
Hartford Fire Insurance Comp (16)
Hyliion Inc (15)


Cited By Patent Count
600
500
400
300
200
100
0
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
Publication Date
Number of Patents
15
10
5
0
1986 1990 1994 1998 2002 2006 2010 2014
Filing Date
Document Type
Granted Pat...
Patent Appl...
Relevance
0.0
0.5

APPENDIX 2. Logic sequence of patent analysis and mathematical modelling for fleet management system

Figure 3. Approach used for the patent analysis

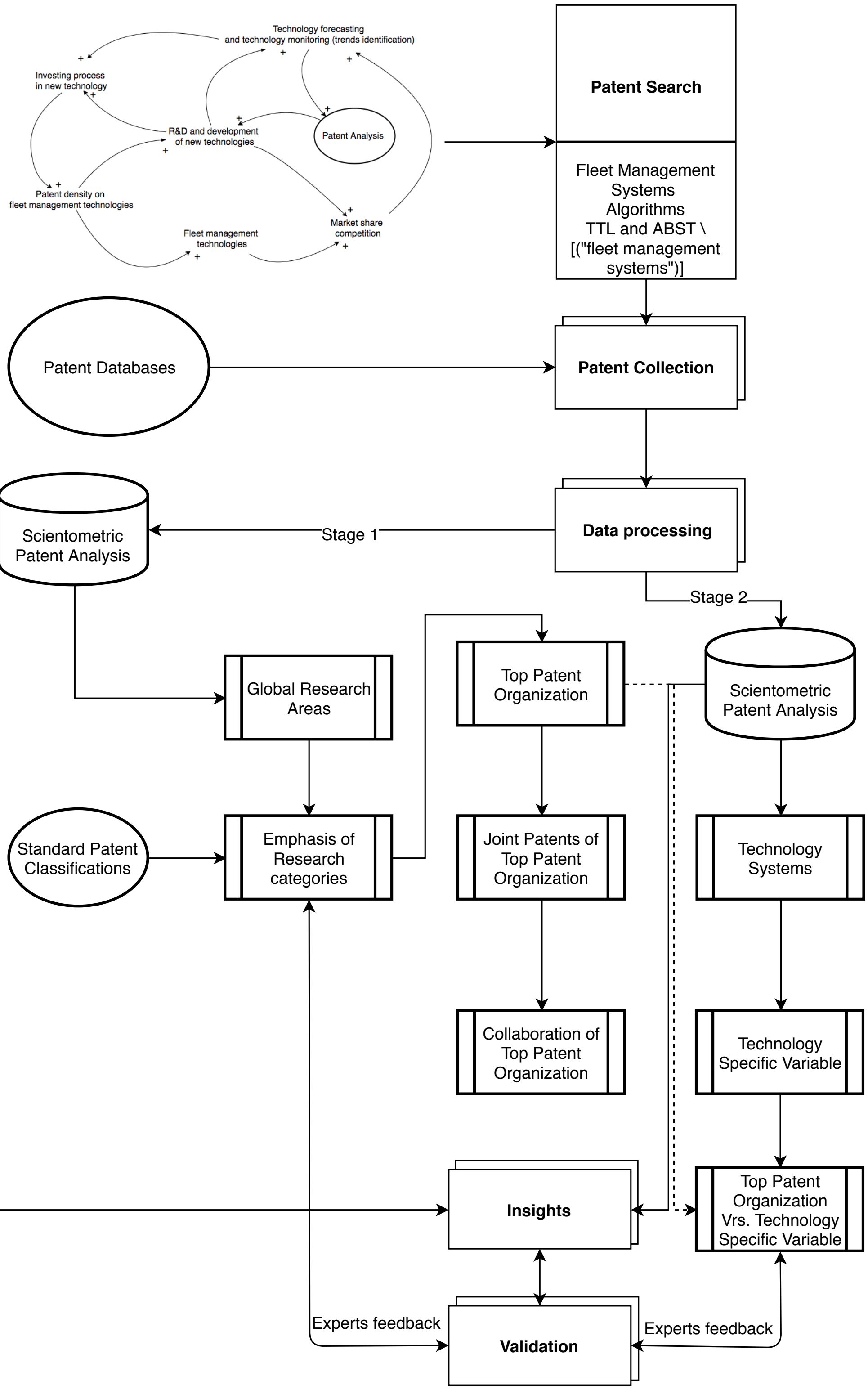


Figure 4. Approach used for the mathematical evaluation