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Patent analysis methodology for validating and developing the Trends of Engineering Systems Evolution

certification work for the degree of TRIZ Level 5 Specialist
in accordance with the requirements of The International TRIZ Association (MATRIZ)

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ABSTRACT

This certification work is devoted to the development of a methodology for patent search and analysis, taking into account the key concepts used in the modern Theory of Inventive Problem Solving (TRIZ). The methodology being developed is the first stage of a more ambitious project to test the hypothesis of a connection between the trends of engineering system evolution (TESE) and the stages of the S-curve analysis of engineering system development. The hypothesis is that at different stages of the S-curve, some TESE are active, while others remain passive or act partially.

The proposed methodology includes a sequence of interrelated stages. When identifying patents for the engineering system (ES) under study, its main function and one of the Main Parameter of Value (MPV) are determined. The MPV is a key factor that determines consumer choice and influences the decision to purchase a given TS at all stages of its development in accordance with the S-curve. For each engineering system, a historical and technical overview is created based on its name and the selected main parameter of value using open sources. Next, the historical material is divided into time periods corresponding to the stages of the S-curve, based on the characteristic features of each stage. Based on the name of the engineering system, its main function, MPV, and stage characteristics, a preliminary glossary of terms is formed for patent search. A preliminary patent analysis is conducted, and a sample of patents is formed for each stage in order to identify the terminology corresponding to the main function of the ES, MPV, and characteristics of the stage. The refined dictionary is used to enhance the patent search and form the most relevant sample of patents.

The scientific novelty of the methodology lies in the creation of the first systematic, repeatable approach to patent search formation, taking into account the terms and concepts used in modern TRIZ. The practical significance of the work lies in the possibility of applying the developed methodology to form a relevant selection of patents for any further research where patents are a key source of information about the development and/or change in the ES.

This work is a first step toward empirical verification of TESE and their correlation with the stages of the S-curve. To form a reliable statistical base and increase the accuracy of conclusions, further research is needed, including a greater number and variety of engineering systems. Only at this level is it possible to definitively verify the universality of the patterns identified in this work. The results of the study can be used by engineers, patent experts, innovation researchers, and companies to improve the efficiency of engineering system lifecycle management and strategic planning in the field of technological development.

Certification work for the degree of TRIZ Level 5 Specialist

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List of abbreviations

FPV – Physical Value Parameter.
TESE – Trends of Engineering System Evolution.
TRIZ – Theory of Inventive Problem Solving.
MPV – Main Parameter of Value.
MFPV – Main Functional Parameter of Value.
CRT – Cathode Ray Tube.
ES – Engineering System.
IP – Internet Protocol.
IPC – International Patent Classification.
CPC – Cooperative Patent Classification.
USPTO – United States Patent and Trademark Office.
EPO – European Patent Office.
WIPO – World Intellectual Property Organization.
SI – Système International d'Unités (French).
CGS – Centimeter – Gram – Second (in English: CGS – Centimeter – Gram – Second system).
VR – Virtual Reality.
AR – Augmented Reality.
LCD – Liquid Crystal Display.

1. Patent search methodology using using the modern TRIZ conceptual framework

1.1 Relevance of the research topic

In today's world of technological progress, effective patent search is critical for analyzing and forecasting the development of engineering systems. Patent information, which is one of the most comprehensive and structured sources of data on technical solutions, forms the basis of many studies in the field of innovation and technological development.

Classical TRIZ, created by Genrich Saulovich Altshuller, was originally based on the systematic analysis of a large number of patent documents. The author used specially developed patent analysis techniques that made it possible to identify the fundamental patterns of engineering system evolution and formulate the Trends of Engineering System Evolution (TESE). However, these initial patent analysis techniques have not survived to this day in a formalized form, remaining only as general principles and approaches. Over the decades since TRIZ was created, the methodology itself has evolved significantly. New analytical and decision-making tools have appeared, the conceptual apparatus of the theory has expanded, and new classes of engineering systems have emerged – information technology, biotechnology, nanotechnology, and quantum systems – which did not exist in Altshuller's time. At the same time, the possibilities for working with patent information have changed dramatically, with the emergence of powerful digital databases, automated search systems, and big data analytics tools.

In these conditions, there was an urgent need to develop a modern systematic and algorithmic approach to patent search that takes into account the concepts and ideas used in modern TRIZ. A methodology is needed that would organically integrate the modern TRIZ conceptual framework with the capabilities of modern patent databases and take into account the specifics of new technological areas. However, existing patent search methods have significant limitations when working with TRIZ concepts and terminology. Traditional approaches to patent search do not take into account the specifics of TRIZ concepts and are not adapted to work with key concepts of the theory, such as the main function of a technical system, the main parameter of value, and the characteristics (indicators) of the S-curve stage. This creates serious methodological obstacles when conducting research on the development of engineering systems based on patent data. Existing research in the field of patent analysis and TRIZ often uses disparate approaches. For example, work on creating a patent landscape and technological forecasting is based on standard search methods without taking TRIZ terminology into account, while TRIZ research is often limited to analyzing individual examples without systematic patent searches. This leads to incomplete use of the potential of patent databases and reduces the quality of TRIZ research.

Thus, there is a significant gap in the patent search methodology for TRIZ research. The lack of a systematic approach to searching and analyzing patent information, taking into account the modern TRIZ conceptual framework, leads to:

1. Inefficient use of patent databases in TRIZ research.
2. A decline in the quality of the empirical base for verifying TRIZ theoretical propositions.
3. Limitations in the possibilities for analyzing the historical development of engineering systems.
4. Difficulties in forming relevant patent samples for researching the manifestation of TESE with the aim of developing them and identifying new laws.

Moreover, the lack of a methodology for accounting for the historical evolution of technical terminology creates additional problems:

1. Loss of relevant patents from early periods of engineering system development due to the use of outdated terminology.
2. Distortion of the results of the analysis of the stages of development of engineering systems.
3. Incompleteness of the picture of technological evolution when studying S-shaped development curves.
4. Limitations in the possibilities of comparative analysis of different stages of technology development.

All of the above indicates a real need to create a specialized patent search methodology that would allow for effective work with TRIZ concepts and take into account the historical dynamics of the development of technical terminology. The creation of a systematic patent search methodology based on the TRIZ methodology and its modern framework will allow for:

1. Increase the effectiveness of TRIZ research through a higher-quality empirical base of patent data.
2. Ensure correct accounting for the historical evolution of technical terminology when analyzing the development of engineering systems.
3. Create a basis for the systematic verification of TRIZ theoretical propositions based on patent data.
4. Expand the possibilities for applying patent analysis in the context of researching trends of engineering system evolution.

The development of patent search methods is particularly important in the context of empirical verification of the trends of engineering system evolution. In order to verify and refine the TESE, identify patterns of their manifestation at various stages of the S-curve, a reliable empirical database of patent data covering the entire life cycle of engineering systems from inception to decline is necessary. However, existing patent search methods do not provide for the formation of such a base due to the lack of consideration of TRIZ terminology and historical dynamics of system development. Existing methods, which are focused on modern terminology, systematically omit relevant patents from the early stages of development, when technical solutions were described using different concepts, which distorts the picture of technological evolution and makes it impossible to correctly analyze the manifestation of

TESE at various stages. Thus, the creation of a specialized patent search methodology becomes a necessary condition for the restoration and development of the empirical foundation of TRIZ, laid down by Genrich Saulovich Altshuller. The developed methodology will allow, at a new level, taking into account modern digital technologies and the expanded framework of the moder TRIZ, to continue systematic patent analysis to strengthen the scientific basis of the theory and ensure the possibility of quantitative verification of theoretical propositions.

1.2 Research objectives and tasks

The purpose of the research is to develop a comprehensive patent search methodology that takes into account the key concepts used in modern TRIZ, including algorithms for analyzing, selecting, and forming relevant patent samples for researching the development of engineering systems.

To achieve this goal, the following tasks must be solved:

1. Conduct a systematic analysis of existing approaches to patent search, including:

    - Researching traditional patent search methods and their limitations when working with TRIZ concepts.
    - Analyzing modern patent analysis tools and platforms.
    - Evaluating the effectiveness of existing search methods for TRIZ research.

2. Investigate the specifics of applying TRIZ concepts in the context of patent search:

    - Analysis of key TRIZ concepts (main function, MPV, resources, ideality) in terms of their reflection in patent terminology.
    - Study of the features of formalizing TRIZ concepts for search queries.
    - Research on the problems of terminological compatibility between TRIZ concepts and patent classifications.

3. Develop a methodology for accounting for the historical evolution of technical terminology:

    - Identifying patterns of change in technical terminology in various fields of technology.
    - Creation of principles for periodization of the development of engineering systems for the purposes of patent search.
    - Developing an algorithm for comparing historical and modern terminology in patent documents.

4. Systematize the process of forming TRIZ-oriented dictionaries of terms:

    - Analysis of methods for identifying the main function of an engineering system and its reflection in patent terminology.
    - Development of an algorithm for determining and formalizing the main parameter of value for patent searches.
    - Creation of a procedure for forming stage-specific dictionaries of terms, taking into account the S-shaped development curve.

5. Create an algorithm for conducting iterative patent searches:

   - Development of a procedure for initial patent search based on a basic dictionary of terms.
   - Creation of a methodology for analyzing the results of the initial search to identify additional relevant terminology.
   - Develop an algorithm for refining term dictionaries and conducting a refined patent search.

6. Conduct practical testing of the developed methodology:

   - Select an engineering system that has fully passed all stages of development along the S-curve for detailed testing of the methodology.
   - Application of the developed methodology to the selected engineering system with the creation of a complete set of term dictionaries.
   - Analysis of the test results and validation of the methodology's effectiveness by comparison with traditional approaches to patent searches.

Solving these tasks will allow us to create a comprehensive patent search methodology adapted for working with TRIZ concepts, which will significantly increase the effectiveness of forming an empirical basis for research into the development of engineering systems and verification of TRIZ theoretical propositions.

1.3 Research methodology

The following methods will be used in the course of the research:

1. System analysis – for a comprehensive study of patent search and TRIZ concepts as interrelated elements of a unified methodology for researching engineering systems. This method will allow us to examine the interaction of traditional patent analysis methods with the modern TRIZ conceptual framework in the context of a comprehensive approach to studying the development of engineering systems.
2. Terminological analysis – to study the evolution of technical terminology and identify correspondences between TRIZ concepts and patent terminology. This method will be used to create glossaries of terms and ensure the correct translation of TRIZ concepts into search queries.
3. Comparative analysis – to evaluate the effectiveness of the developed methodology in comparison with traditional approaches to patent search. This method will be used to validate the results and demonstrate the advantages of the TRIZ-oriented approach.
4. Historical and technical analysis – to study the evolution of engineering systems and related terminology at various stages of development. This method is critical for correctly accounting for the historical dynamics of technical concepts when forming search queries.
5. Iterative modeling method – to develop and improve the patent search algorithm through cycles of "search → analysis of results → correction → repeat search". This method will ensure the creation of a self-improving search methodology.
6. Expert validation – to assess the quality and relevance of patent search results with the involvement of specialists in the field of TRIZ and patent analysis. The involvement of experts will increase the practical applicability of the developed methodology.

7. Method of specific examples – for a detailed study of the application of the developed methodology using an example of a specific engineering system. This method will be used at the testing stage to verify the effectiveness and versatility of the proposed approach.
8. Content analysis of patent documents – to identify terminological patterns and regularities in the description of technical solutions. This method will help in the formation and refinement of dictionaries of terms for search.
9. Statistical methods – to process data on search performance and analyze the completeness and accuracy of patent samples. These methods will help in the quantitative assessment of the effectiveness of the developed methodology.
10. Theoretical generalization method – for formulating the principles and algorithms of the methodology based on the research results obtained. This method will be used to create a comprehensive theoretical basis for TRIZ-oriented patent search.

The comprehensive application of these methods will ensure a comprehensive study of the problem and allow the development of a scientifically sound patent search methodology that takes into account TRIZ concepts.

Research limitations: This study focuses on engineering systems and does not consider the application of the methodology for searching patents in the field of software, business methods, or social innovations. In addition, the effectiveness of the developed methodology may vary depending on the specifics of a particular technological field and the completeness of patent databases for different historical periods.

It should be noted that this is the first attempt to create a systematic patent search methodology specifically adapted for TRIZ research, so modifications and improvements to the methodology are possible in the course of further research and practical application.

1.4 Scientific novelty

The scientific novelty of the research lies in:

1. The creation of the first systematic patent search methodology specifically adapted for working with key concepts of modern TRIZ. This represents a new integrated approach to patent analysis that fills a gap in existing research, where patent search and TRIZ concepts were considered as separate, unrelated tools.
2. Development of a methodology for accounting for the historical evolution of technical terminology in patent search. For the first time, a systematic approach has been created for comparing the terminology of different historical periods of engineering system development, which solves the problem of losing relevant patents from the early stages of technological development.
3. Formulation of an algorithm for creating TRIZ-oriented dictionaries of terms for patent search. A procedure has been developed for converting TRIZ concepts (main function, MPV, S-curve stage characteristics) into structured search queries that take into account the specifics of patent terminology.
4. Creation of an iterative patent search model with a self-improvement mechanism. For the first time, an approach has been proposed: "initial search → terminology analysis → dictionary refinement → refined search", which ensures progressive improvement in the quality of results.

5. Development of a methodology for periodizing the development of engineering systems for the purposes of patent analysis. An algorithm has been created for dividing the history of an engineering system's development into stages corresponding to an S-curve, with characteristic terminology identified for each period.
6. Systematization of the principles of integrating modern digital patent databases with classical TRIZ approaches. For the first time, a methodological link has been established between the capabilities of modern search platforms and the fundamental principles of engineering system analysis laid down by G.S. Altshuller.
7. Creation of a methodology for validating the results of TRIZ-oriented patent searches. Criteria have been developed for assessing the completeness and relevance of patent samples specific to the tasks of researching the development of engineering systems in the context of TRIZ.

Thus, the scientific novelty of this research lies in the creation of a comprehensive methodological framework that integrates TRIZ principles with modern patent analysis capabilities. This allows overcoming the limitations of existing methods of searching for patent information and opens up new opportunities for empirical research in the field of development of engineering systems.

For the first time, it is now possible to systematically apply patent analysis to verify the theoretical propositions of TRIZ on the basis of a historically accurate and terminologically adequate search for relevant technical solutions.

1.5 Practical significance

The practical significance of the research consists in:

1. Increasing the effectiveness of TRIZ research by creating a high-quality empirical database of patent data. The developed methodology allows for the formation of relevant and complete patent samples for researching the development of engineering systems, which is critically important for:

   – Verifying TRIZ theoretical propositions based on real technical solutions.
   – Identifying new patterns in the development of engineering systems.
   – Analyzing the manifestation of the Trends of Engineering System Evolution in patent solutions.
   – Researching correlations between the stages of the S-curve and the nature of innovative activity.

2. Providing a methodological basis for patent experts and innovation researchers when working with engineering systems in the context of their historical development. The methodology provides:

   – An algorithm for systematic patent search, taking into account the evolution of terminology.
   – Procedures for forming search queries based on TRIZ concepts.
   – Criteria for assessing the completeness and relevance of patent samples.
   – Tools for analyzing technological trends based on patent data.

3. The creation of tools for engineers and inventors that allow them to more effectively analyze the prior art and identify directions for technological development. The methodology is particularly valuable for:

   - Companies developing technological development strategies based on patent analysis.
   - Research centers studying the patterns of innovation processes.
   - Patent attorneys who need a deep understanding of technological evolution.
   - Venture capital funds evaluating the prospects of technological directions.

4. Expanding the possibilities of using patent analysis for educational purposes. The methodology can be used in training programs on TRIZ, patent law, and innovation management to:

   - Teaching students the principles of technological development analysis.
   - Practical mastery of TRIZ tools using real patent data.
   - Developing skills in working with historical sources of technical information.
   - Forming systematic thinking in the field of technical innovation.

5. Providing a methodological basis for further research in the field of empirical verification of TRIZ. The developed methodology creates a foundation for:

   - Large-scale research on the manifestation of TESE in various technological fields.
   - Comparative analysis of the development of engineering systems in different industries.
   - Quantitative research into the patterns of technological evolution.
   - Developing predictive models for the development of new technologies.

6. Improving the quality of patent research in industry by taking into account the specifics of engineering system development. The methodology allows for:

   - More accurately assess patent landscapes, taking into account historical dynamics.
   - Identify gaps in patent protection based on an analysis of the stages of technology development.
   - Forecast patenting trends based on the patterns of technological evolution.
   - Optimize intellectual property management strategies.

7. Create a methodological basis for empirical research on the trends of engineering system evolution. The developed methodology provides:

   - The formation of a reliable empirical basis for verifying and refining the TESE based on a systematic analysis of patent data covering the entire life cycle of engineering systems.
   - The possibility of quantitative analysis of the manifestation of various TESE at specific stages of the S-curve through the formation of representative patent samples for each period of development.
   - Tools for identifying correlations between TESE activity and stages of engineering system development based on statistical analysis of patent solutions.

- A methodological basis for large-scale studies of the patterns of technological evolution in various fields of technology with the possibility of comparative analysis of the manifestation of TESE in different technological domains.
- A basis for empirical testing of the hypothesis of uneven activity of different laws at different stages of system development, which will allow us to move from qualitative descriptions of TESE to quantitative models of technological evolution.

Thus, the practical significance of the work lies in the creation of a universal methodological tool that can be applied to a wide range of tasks related to the analysis and forecasting of the development of engineering systems based on patent information. The methodology provides a bridge between the theoretical provisions of TRIZ and the practical tasks of patent analysis in modern conditions.

1.6 Propositions to be defended

The following propositions are put forward for defense:

Proposition 1. Methodology for accounting for the historical evolution of technical terminology in patent searches

A methodology for periodizing the development of engineering systems for the purposes of patent analysis has been developed, based on the application of 30 characteristics of the stages of an S-shaped development curve (9 characteristics of the initial stage, 4 characteristics of the transition stage, 6 characteristics of the intensive growth stage, 8 characteristics of the maturity stage, and 3 characteristics of the decline stage). The methodology includes:

- An algorithm for dividing the history of an engineering system's development into five stages, with the time limits for each period determined based on the characteristic features of the stages.
- The procedure for identifying and systematizing terminological changes for each historical period of the system's development.
- The principle of historical accuracy, ensuring the adaptation of search terminology to the characteristics of each stage, excluding anachronistic concepts.
- A mechanism for comparing historical and modern terminology through the analysis of the evolution of technical concepts in patent documents from different periods.

The application of this methodology ensures an increase in the coverage of the early stages of engineering system development from 20% to 90% compared to traditional patent search methods that use only modern terminology.

Proposition 2. Algorithm for forming TRIZ-oriented dictionaries of terms for patent search

A systematic algorithm has been developed for creating dictionaries of terms for patent search, integrating three key elements of TRIZ: the main function of an engineering system, the main parameter of value, and the characteristics of the stages of the S-curve. The algorithm includes:

- A procedure for formalizing the main function of an engineering system in terms of patent terminology, highlighting the object of influence, the type of action, and the method of implementing the function.

- A methodology for converting MPV through physical formulas and cause-and-effect relationships into a set of measurable technical parameters that can be traced in patent documents.
- A structure of the glossary of terms consisting of four interrelated blocks: basic terminology of the main function, MPV terminology, stage-specific terminology, and logical connectives.
- A procedure for adapting the basic dictionary to the historical features of each stage of development, replacing modern terms with historical equivalents, adding specific terms of the period, and excluding anachronisms.

The application of the algorithm ensures the formation of stage-specific dictionaries covering the functional, parametric, and historical aspects of the development of an engineering system.

Proposition 3. Iterative patent search procedure with a self-improvement mechanism

A four-cycle iterative patent search procedure has been created, ensuring progressive improvement in the quality of results through successive cycles of analysis and correction:

- Cycle 1 (broad search) – use of basic terms of the main function to form a general picture of the patent landscape and identify the main directions of system development.
- Cycle 2 (focus on MPV) – inclusion of the main parameter of value terminology to narrow the search area to technical solutions aimed at improving key system characteristics.
- Cycle 3 (stage specialization) – adaptation of queries to the specifics of the development stage using historically correct terminology and taking into account the characteristics of the S-curve stage.
- Cycle 4 (detailing and verification) – in-depth analysis of the patents found to identify missed technical solutions and final adjustment of the sample.

Each cycle includes an analysis of the results of the previous stage to identify additional relevant terminology and refine the dictionaries. The procedure ends when the saturation criterion is reached, when new cycles do not lead to a significant increase in the number of relevant patents.

The use of the iterative procedure increases the accuracy of the patent search from 45% to 85% while reducing the noise level in the results by 60% compared to a traditional one-step search.

Proposition 4. Results of practical testing of the methodology using the example of facsimile communication

The developed methodology was tested in practice using the example of six engineering systems. The paper presents the example of facsimile communication (1843-2020+), an engineering system that has completely passed all five stages of the S-shaped development curve. Testing using the example of fax included:

- Creating a historical and technical overview of the development of fax, identifying the evolution of technical terminology from "electric printing telegraph" (1843) to "IP fax" (2000s).
- Determination of the time boundaries of the five stages of development based on 30 characteristics of the S-curve: initial stage (1843-1862, 19 years), transition stage (1863-1923, 60 years), intensive growth (1924-1979, 55 years), maturity (1980-1997, 17 years), decline (1998-present, 26+ years).
- Formation of stage-specific glossaries of terms for all five stages of development, taking into account the main function (to inform the user) and MPV (speed of transmission of one page).

- Conducting iterative patent searches with the formation of a sample of 850 highly relevant patents with 85% accuracy versus 45% accuracy of traditional searches.

A comparative analysis with traditional patent search methods demonstrated an increase in the completeness of coverage of the early stages of development (1843-1923) from 20% to 90%, which confirms the effectiveness of the developed methodology for forming a high-quality empirical base when researching the development of engineering systems.

The results of the testing confirm the effectiveness of the methodology and its applicability for forming relevant patent samples necessary for conducting TRIZ research and verifying theoretical propositions about the patterns of development of engineering systems.

2. Analysis of existing patent search methods

2.1 Traditional patent search methods

Modern patent search methods are based on the use of structured patent databases and standardized classification systems. The main approaches are:

2.1.1 Keyword search

The most common method, based on searching for text matches in patent documents. Includes searching in:

- Invention titles.
- Patent abstracts.
- Invention descriptions.
- Formulas of inventions.

Advantages: ease of use, wide availability, ability to search in natural language.

Disadvantages: high level of noise in results, dependence on the terminology used, difficulty in accounting for synonyms and historical changes in terms.

2.1.2 Search by classification indices

Based on the use of international patent classifications:

- International Patent Classification (IPC) - a hierarchical system that divides technical fields into sections, classes, subclasses, and groups.
- Cooperative Patent Classification (CPC) - a joint system of the USPTO and EPO, a more detailed version of the IPC.
- US Classification (USPC) - a historically established system for classifying American patents.

Advantages: structured, searchable by technical field, independent of the language of description.

Disadvantages: requires in-depth knowledge of classification systems, static classification in the face of dynamic technological development, difficulty in reflecting interdisciplinary solutions.

2.1.3 Search by patent numbers and applicants

Targeted search for specific patents or patent portfolios of specific companies and inventors.

Application: competitor analysis, tracking activity in specific technological areas, studying companies' patent strategies.

2.1.4 Citation analysis

A method based on analyzing references between patent documents and scientific publications.

Capabilities: identification of technological connections, determination of basic and derivative inventions, analysis of technological trends.

2.2 Modern patent search tools and platforms

2.2.1 Commercial patent databases

Google Patents is a free, publicly accessible patent platform that provides broad coverage of patent offices in over 100 jurisdictions, including the USPTO, EPO, WIPO, and national patent offices. The system provides access to the full text of patent documents with the option of machine translation into major languages and simple text search by title, abstract, and description of inventions. The interface is designed for a broad audience, including researchers, inventors, and professionals without specialized training in patent search. The platform is integrated with Google Scholar, providing a link between patent documents and scientific publications.

Limitations of Google Patents in the context of TRIZ research:

- Lack of tools for working with TRIZ concepts, which requires manual formulation of all search queries without methodological support from the TRIZ methodology.
- Basic search capabilities without semantic analysis. The search engine works on the basis of textual keyword matching, without providing an understanding of context, functional relationships, or technical solutions, which leads to a high level of noise in the results.
- Lack of tools for periodization and historical analysis. The platform does not provide tools for systematically tracking the evolution of terminology or dividing results by historical periods of engineering system development.
- Limited analytical capabilities. The system does not include tools for building patent landscapes, analyzing technology trends, or visualizing patent activity dynamics, which are necessary for researching the development of engineering systems.

PatSnap is a comprehensive commercial analytical platform for patent research and intellectual property management. The system provides access to a database of more than 170 million patent documents from more than 170 patent offices with advanced semantic search tools using natural language processing and machine learning technologies. The platform includes modules for creating a patent landscape, competitive analysis, technology monitoring, and data visualization in the form of maps, graphs, and timelines. PatSnap is aimed at corporate users, including research and development departments, patent departments, and strategic planning divisions of large technology companies.

Limitations of PatSnap in the context of TRIZ research:

- Lack of tools for working with TRIZ concepts, which requires manual formulation of all search queries without methodological support from the TRIZ methodology.

- Limited support for historical terminology. Semantic search is optimized for working with modern technical terminology, which makes it difficult to identify relevant patents from earlier periods of engineering system development when different technical concepts were used.
- Focus on business analytics rather than research into development patterns. The platform's analytical tools are aimed at solving corporate tasks (competitive analysis, patent portfolio, technological trends of engineering system evolution) rather than the systematic study of the manifestation of the trends of engineering system evolution.
- Proprietary semantic search algorithms. The closed nature of the machine learning algorithms used to rank and classify results limits the transparency and reproducibility of research that is critical to scientific work.

Derwent Innovation (Clarivate) is a professional patent analysis system based on the unique Derwent World Patents Index (DWPI) database, which includes expert processing of patent documents since its creation in 1963. The database covers more than 29 million patent families with manual indexing, terminology standardization, and structured abstracts created by professional patent analysts. The system includes advanced search capabilities for chemical structures, biological molecule sequences, and technical classifications. Derwent Innovation is aimed at professional patent researchers, patent attorneys, and researchers in the pharmaceutical, chemical, and biotechnology industries who require high-precision patent searches.

Limitations of Derwent Innovation in the context of TRIZ research:

- Lack of tools for working with TRIZ concepts, which requires manual formulation of all search queries without methodological support from the TRIZ methodology.
- Limited applicability to mechanical and electronic systems. The system is optimized for chemical and biotechnological inventions, while for many engineering systems of interest to TRIZ research (mechanical devices, electronic systems, information technology), expert processing is less detailed.
- High cost of access. The professional system requires a corporate subscription with significant financial costs, which limits its availability for academic TRIZ research and independent researchers.
- Lack of tools for phased analysis of system development. The platform does not provide the means for periodizing patents according to the phases of pragmatic S-curve analysis or systematically recording the historical evolution of technical terminology, which are necessary for analyzing the patterns of engineering system development.

Orbit Intelligence (Questel) is a professional platform for patent analysis and intellectual property management, providing access to over 120 million patent documents from 100+ patent offices. The system includes advanced semantic search capabilities using artificial intelligence technologies, tools for building technology maps and patent landscapes, citation analysis and patent activity monitoring modules. Orbit Intelligence integrates various data sources, including scientific literature, technical documentation, and business information, providing a comprehensive analysis of the technological context. The platform is aimed at corporate users, patent firms, and intellectual property management specialists.

Limitations of Orbit Intelligence in the context of TRIZ research:

- Lack of tools for working with TRIZ concepts, which requires manual formulation of all search queries without methodological support from the TRIZ methodology.
- Limited support for historical analysis of terminology. Semantic search is configured to work with modern technical concepts, which makes it difficult to systematically search for patents from early periods of engineering system development using historical terminology.
- Focus on competitive analysis and IP strategy. The platform's analytical tools are optimized for solving business problems (analyzing competitors' patent portfolios, identifying gaps for patenting, assessing freedom of action), rather than for empirical research into the patterns of technological evolution.
- Closed semantic analysis algorithms. The proprietary nature of the artificial intelligence algorithms used to rank results and build semantic connections limits the transparency of the methodology and the reproducibility of research results.

GoldFire (Accuris, formerly Invention Machine, then IHS) is a specialized platform for engineering research that integrates patent search with elements of TRIZ. The system uses patented semantic analysis technology to search a database of over 83 million patents and 72 million technical documents. The GoldFire semantic processor is capable of interpreting the context of search queries, identifying cause-and-effect relationships, identifying functional relationships between components of engineering systems, and proposing solutions based on TRIZ principles. The system is designed to support engineering problem-solving processes, including defect analysis, functional modeling, root cause analysis, and technology trend forecasting. GoldFire is the most interesting of the commercial systems due to its integration with the TRIZ- methodology. It is worth noting that the semantic search and analysis in the program was built on the basis of Markov chain analysis.

Limitations of GoldFire in the context of TRIZ research on the development of engineering systems:

- Closed proprietary architecture with opaque query processing logic. Patented semantic analysis algorithms function as a "black box," which makes it difficult to understand the mechanisms of result formation and excludes the possibility of search process control by the researcher, which is critical for ensuring scientific reproducibility.
- The absence of mechanisms for adapting search dictionaries to the specifics of a particular engineering system and its stages of development. The system uses predefined semantic models and knowledge bases that cannot be modified by the user to take into account the characteristics of the technology under study, the main function of a particular system, or the characteristic features of the stages of the S-curve.
- The inability to systematically take into account the historical evolution of technical terminology when forming search queries. GoldFire is optimized for working with modern technical documentation and does not provide tools for periodizing the development of systems and adapting terminology to historical periods, which leads to the loss of relevant patents from the early stages of engineering system development.
- Functional orientation towards solving engineering problems, rather than systematic analysis of the development of engineering systems for TRIZ research. The main focus of the platform is on supporting the design and defect elimination processes in current products, which does not correspond to the tasks of empirical verification of the trends of engineering system evolution and analysis of the patterns of technological evolution.

- High price for individual users.
- According to the developers from Minsk, in the latest version of GoldFire, all TRIZ tools have been removed from the program, leaving only a few modules: analysis of the cause-and-effect chain of defects, a database of scientific effects, and semantic search.

An analysis of the capabilities and limitations of existing commercial patent databases shows that, despite advanced semantic search technologies and analytical tools, none of the systems are adapted for systematic TRIZ research into the development of engineering systems. The lack of support for TRIZ terminology, the inability to take into account the historical evolution of concepts, and the focus on solving business tasks or current engineering problems rather than analyzing the patterns of technological evolution create a methodological gap that is eliminated by the patent search methodology developed in this study.

2.2.2 State patent databases

Espacenet (EPO): the official database of the European Patent Office with access to patents from more than 100 countries.

USPTO Patents Database: database of the United States Patent and Trademark Office.

WIPO Global Brand Database: international database of the World Intellectual Property Organization.

2.2.3 Capabilities of modern systems

- Semantic search – the use of natural language processing algorithms to understand the context of queries.
- Machine learning – automatic classification of patents and identification of similar documents.
- Data visualization – construction of patent landscapes, technology maps, and networks of connections.
- Multilingual search – automatic translation and search in different languages.

2.3 Limitations of existing methods when working with the TRIZ methodology and its terminology

2.3.1 Terminological incompatibility

Existing patent search methods are not adapted to work with the specific terminology of TRIZ.

The problem of conceptual gap – key TRIZ concepts (main function of a technical system, function, main parameter of value, signs of a stage of development in accordance with the S-curve, and many others) have no direct equivalents in standard patent classifications.

Lack of a functional approach – traditional searches focus on the structural and technological characteristics of inventions, while TRIZ emphasizes the functional purpose of technical solutions and their evolution in accordance with TESE.

Ignoring systematicity – existing methods treat patents as separate documents, without taking into account the systemic connections between technical solutions, which are critical for TRIZ analysis.

2.3.2 Insufficient consideration of historical dynamics

Static terminology – modern search engines do not take into account the evolution of technical terminology, which leads to the loss of relevant patents from early periods of technology development.

Lack of stage differentiation – traditional methods do not provide for the division of search results by stages of engineering system development, which is necessary for pragmatic S-curve analysis.

The problem of historical accuracy – the use of modern terms when searching for historical patents leads to a distorted picture of technological development.

2.3.3 Limitations in the analysis of engineering system development

Fragmentary results – traditional methods do not provide a comprehensive picture of the development of an engineering system over time.

Lack of connection with theoretical models – existing approaches are not integrated with TRIZ's theoretical ideas about the laws of technological development.

Insufficiency for empirical research – the quality of patent samples formed by traditional methods is insufficient for statistically significant research on the manifestation of TESE.

2.4 Conclusions from the analysis of existing methods

An analysis of the current state of patent search methods shows:

1. Technological perfection of tools with methodological limitations for specific TRIZ research tasks.
2. The need to create a specialized methodology that would organically integrate the capabilities of modern patent databases with the modern TRIZ conceptual framework.
3. The critical importance of solving the problem of the historical evolution of terminology to ensure the completeness and correctness of patent analysis in the context of the development of engineering systems.
4. The need to develop new approaches to the formation of search queries based on functional analysis and taking into account the systemic nature of technical solutions.

Thus, there is an objective need to create a patent search methodology specifically adapted to work with the TRIZ methodology, its conceptual framework, and the tasks of researching the development of engineering systems.

3. Theoretical foundations of the TRIZ-oriented patent search methodology

3.1 The main function of an engineering system in the context of patent search

The main function of an engineering system is its primary purpose, for which the engineering system was created, determining its existence and differences or similarities with other engineering systems. In the context of patent search, the main function serves as the fundamental basis for:

- Forming function-oriented search queries – the main function determines the key terms and concepts, as well as their synonyms, which must be present in relevant patent documents.
- Identifying relevant technical solutions – patents aimed at implementing or improving the main function are of primary interest for analyzing the development of an engineering system.
- Ensuring the integrity of the analysis – the main function serves as an invariant criterion for combining various technical solutions within a single system at all stages of its development.

Examples of main functions, provided that the user is a component of the supersystem:

- Pager – informs the user.
- Car – transports people and cargo.
- Typewriter – moves ink.

The immutability of the main function over time is a key principle for patent search. Despite radical changes in design and operating principles, the main function remains unchanged throughout the entire life cycle of an engineering system.

3.2 Main Parameter of Value (MPV) and its role in patent search

The main parameter of value (MPV) is a key measurable characteristic of an engineering system that determines its consumer value and influences user choice.

3.2.1 Functions of MPV in patent analysis

The basis for forming search queries – MPV determines the directions of technical improvements that are reflected in patent solutions through descriptions of technical results and achievable effects. It should be emphasized that it is not always possible to identify MPV directly in patents, therefore it is necessary to transition to MFPV.

Patent relevance criterion: patents aimed at improving MPV directly or through MFPV are of greatest interest for analyzing the development of an engineering system.

The tool for tracking evolution—changes in the ways and methods of improving MPV allow us to trace the technological evolution of the system through patent solutions.

3.2.2 Examples of MPVs for various engineering systems

- Fax – document transmission speed (minutes/seconds per page).
- Cars – fuel consumption (liters per 100 km).

- Mobile phones – battery life (hours/days).
- Digital cameras – image resolution (megapixels).

3.2.3 Formalization of MPV for patent search

MPV itself is rarely found in patents. To solve this problem and conduct an effective patent search, it was proposed to express or transform MPV into MFPV through:

- Physical formula or dependence.
- Technical synonyms and equivalent concepts.
- Units of measurement and quantitative characteristics.
- Causal relationships with other system parameters.

3.2.4 Signs of stages of an S-curve for patent analysis

The work is based on the signs of the stages of the S-curve developed by GEN3 Partners and used in the daily work of the company "Algorithm", described in the book "Trends of Engineering System Evolution" by A. Lyubomirsky and S. Litvin.

3.2.5 Initial stage (9 characteristics)

1. The engineering system is new and has not yet entered the market or occupies small, strictly limited market niches.
2. Improvements in functionality significantly reduce costs.
3. The engineering system adapts technologies from other engineering systems.
4. The engineering system integrates with elements of the supersystem.
5. The engineering system is combined with leading alternative systems already on the market.
6. The engineering system uses supersystem resources not intended for it.
7. The variety and scale of system modifications increase, then decrease.
8. Costs exceed revenues.
9. MPVs change slowly.

3.2.6 Transition stage (4 characteristics)

1. MPVs grow rapidly.
2. The engineering system is almost ready for the market, but is vulnerable to external factors.
3. Attempts to implement the system in various areas have limited success.
4. The engineering system begins operating on the market, but in a niche.

3.2.7 Intensive growth stage (6 characteristics)

1. The engineering system moves into mass production.
2. The engineering system is adapted for use in various applications.
3. Variations of the system become more widely differentiated.
4. The system's applications become more widely differentiated.
5. System modifications slow down and become less diverse toward the end of the stage.
6. The system begins to use resources specifically designed for it.

3.2.8 Maturity stage (8 characteristics)

1. The engineering system has reached certain limits of development.
2. The engineering system is successfully being implemented in new applications and market niches.
3. Incremental improvements to the system require disproportionate resources.
4. The system uses highly specialized resources.
5. Supersystem components are being intensively adapted to interact with the system.
6. System generations differ mainly in design and functionality.
7. The system acquires functions that are not closely related to its core function.
8. MPVs change slowly.

3.2.9 Decline stage (3 characteristics)

1. The engineering system is no longer utilitarian—it becomes entertainment, decoration, a toy, or sports equipment.
2. The engineering system remains utilitarian, but only in highly specialized areas.
3. The system exists only as part of a supersystem.

3.3 Integration of the main function, MPV, and stage signs in patent search

Below are the general principles for forming patent requests using TRIZ terms.

3.3.1 Principles for forming search queries

Effective patent search for TRIZ research is based on the integration of three key elements:

- Main function → defines the area of technical solutions and basic terminology.
- MPV → specifies areas for improvement and technical results.
- Stage characteristics → clarify the nature of technical solutions and historical context.

3.3.2 Algorithm for creating stage-specific dictionaries

Step 1 – formulate the main function in terms appropriate to the historical period.

Step 2 – Identify ways to describe and measure MPV in patents from this stage.

Step 3 – Include terminology that reflects the specific characteristics of the stage of development.

Step 4 – Form complex search queries that combine all three elements.

3.3.3 Terminology dynamics by stage

Each stage of an engineering system's development is characterized by specific terminology:

1. Initial stage – experimental terminology, borrowings from other fields.
2. Transitional stage – formation of basic terminology, emergence of standard terms.

3. Intensive growth – established terminology, technical specialization.
4. Maturity – terminological differentiation by field of application.
5. Decline – archaization of terminology, transition to descriptive constructions.

3.4 Conclusions on theoretical foundations

Theoretical analysis shows that an effective patent search methodology for TRIZ research should be based on at least three key elements:

1. Main Function as an unchanging basis for technical solutions.
2. MPV as a dynamic criterion of relevance and direction of development, as well as an unchanging basis for analysis at all stages of pragmatic S-curve analysis.
3. Stage characteristics as a contextual and historical framework for interpreting technical solutions.

The integration of these three elements, the conditions of immutability, creates a methodological foundation for the development of a practical patent search methodology adapted to work with the TRIZ methodology and its conceptual framework, ensuring the correct accounting of the historical dynamics of the development of engineering systems.

4. The developed patent search methodology taking into account the modern TRIZ conceptual framework

4.1 General algorithm of the methodology

The developed patent search methodology, taking into account the TRIZ methodology and its conceptual framework, is a systematic approach consisting of six interrelated stages:

4.1.1 Methodology structure

Step 1 – Preparatory analysis:

- Selection of an engineering system for research.
- Determination of the main function of the ES.
- Identification of MPV.
- Translation of MPV through physical formulas or cause-and-effect relationships into MFPV, which can be found in patents.

Step 2 – Historical and technical review:

- Collecting historical information on the development of the TS.
- Analysis of the evolution of MPV/MFPV over time.
- Identification of key milestones in technological development.
- Identification of a list of key market players producing the TS.
- Compiling a chronology of the system's development.
- Identifying and analyzing the impact of force majeure circumstances (wars, government agreements and decisions, changes in the macroeconomic structure, natural disasters, etc.).

Step 3 – Periodization of development:

- Application of the characteristics of the stages of the S-curve.
- Dividing the history of the TS into five stages of development.
- Determining the time limits for each stage.
- Identification of the characteristic features of each period.
- Identifying a list of key market players producing ES for each stage.

Step 4 – Creating glossaries of terms:

- Creation of a basic dictionary based on the main function and MPV/MFPV.
- Adapting terminology to the historical characteristics of each stage.
- Forming stage-specific glossaries.
- Inclusion of cause-and-effect relationships and technical synonyms.

Step 5 – Conducting a patent search:

- Initial search using basic term dictionaries.
- Analysis of results and identification of additional terminology.
- Revision of dictionaries based on patents found.
- Iterative refinement search.

Step 6 – Analysis and validation of results:

- Assessment of the completeness and relevance of the patent sample.
- Verification of the compliance of patents with development stages.
- Analysis of the quality of the formed patent base.
- Documentation of results.

A structural diagram of the patent search methodology, taking into account the modern TRIZ conceptual framework, is provided in Appendix 1.

4.1.2 Principles of the methodology

The principle of functional invariance – at all stages of the search, the main function of the engineering system remains the unchanging basis for forming queries.

The principle of invariance of the main parameter of value – at all stages of the search, the selected main parameter of value of the engineering system remains the unchanging basis for forming queries.

The principle of historical correctness: the terminology of search queries is adapted to the characteristics of each historical period of TS development, taking into account the timing of the appearance (creation) of certain TS names. Here and further, this refers to the name of an engineering system, such as a pager, which did not exist in the early stages of development. The same applies to marketing names, such as Walkman, which existed only and exclusively in advertising and commercial materials.

The principle of iterative improvement: the results of each search cycle are used to improve subsequent queries.

The principle of stage specificity – each stage of ES development requires a specialized approach to the formation of search queries.

4.2 Selection of engineering systems for comprehensive analysis

4.2.1 Criteria for selecting engineering systems for comprehensive analysis

For effective testing and application of the methodology, engineering systems must meet the following criteria:

1. Life cycle completion criterion – the engineering system must go through all five stages of the S-shaped development curve to enable a full analysis.
2. Patent representation criterion – the development of the system must be sufficiently reflected in patent documents at all stages of development.
3. Functional certainty criterion – the main function of the system must be clearly formulated and remain unchanged throughout its life cycle.
4. Main parameter of value certainty criterion – the main parameter of value of the system must be clearly formulated and remain unchanged throughout the entire life cycle.
5. MPV measurability criterion: the main parameter of value must be quantitatively measurable in SI or SGS units and traceable in historical dynamics through technical parameters identified through physical dependencies or cause-and-effect relationships.

4.2.2 System selection procedure

Step 1 – Preliminary selection of candidates:

- Compiling a list of potential engineering systems.
- Assess the availability of historical information.
- Verify representation in patent databases.

Step 2 – Analysis of compliance with criteria:

- Verification of completion of all stages of the S-curve.
- Assessment of patent activity by period.
- Verification of the clarity of the main function formulation.

Step 3 – Final selection:

- Comparison of candidates according to all criteria.
- Selection of the system that best meets the requirements.
- Justification of the selection.

4.2.3 Examples of suitable engineering systems that were analyzed during the work

Facsimile communication (fax):

- Main function – to inform the user.
- MPV – speed of transmission of one page (minutes/seconds).
- Full life cycle – 1843-2020+ years.
- High patent activity at all stages.

Mechanical watches:

- Main function – to inform the user.
- MPV – accuracy (second deviation per day).
- Full life cycle with transition to niche market.
- Rich patent history.

Pager:

- Main function – to inform the user.
- MPV – autonomy of operation (hours/days/weeks/months)
- Full life cycle with transition to a niche that has remained to this day.
- Extensive patent base.

A complete list of all analyzed systems, with statistical data on patents and patent samples, can be found in Section 5.

4.3 Creation of historical and technical reviews

4.3.1 Goals and objectives of the historical and technical review

The main goal is to create a factual basis for the correct periodization of the development of an engineering system and the formation of historically adequate terminology.

Tasks:

- Identification of key milestones in the development of the engineering system.
- Tracking the evolution of MPV and ways to improve it.
- Identifying changes in terminology over time.
- Creating a chronological database for subsequent periodization.

4.3.2 Sources of information

Primary sources:

- Technical documentation and standards.
- Scientific and technical publications.
- Archival technical materials from development companies.
- Archival marketing materials from developers and sellers.
- Technical historical and archival materials.
- Patent documents (as a subject of research and source of information).

Secondary sources:

- Scientific articles on the history of technology.
- Encyclopedic publications.
- Specialized historical reviews.

- Museum catalogs and exhibitions.

Modern digital resources:

- Corporate websites with historical sections.
- Specialized technical portals.
- Digital archives and libraries.
- Video and multimedia materials.

4.3.3 Structure of the historical and technical overview

Section 1 – Origins and early stages:

- Prerequisites for the emergence of the engineering system.
- First technical solutions and their authors.
- Initial terminology and its sources.
- Early attempts at commercialization.

Section 2 – Technical Development:

- Key technical breakthroughs.
- Evolution of design solutions.
- Changes in operating principles.
- MPV dynamics by period.

Section 3 – Market evolution:

- Stages of market penetration.
- Changes in application and users.
- Economic factors of development.
- Competition with alternative systems.

Section 4 – Terminological evolution:

- Changes in system names.
- Evolution of technical terms.
- The emergence of specialized terminology.
- Standardization of concepts.

4.3.4 Methods of collecting and analyzing information

Chronological principle – information is systematized in chronological order to identify the sequence of technical changes.

Multiple sources – use of the maximum number of independent sources to verify facts.

Critical analysis – comparing information from various sources, identifying contradictions and verifying them.

4.3.5 Accounting for force majeure circumstances

When creating a historical and technical overview, it is critically important to identify and analyze the impact of force majeure circumstances on the development of an engineering system. Such circumstances include:

- Military conflicts – can both accelerate the development of technologies (military orders, mobilization of resources) and slow it down (destruction of infrastructure, loss of specialists).
- Government decisions and regulation – frequency spectrum allocation, standardization, licensing, subsidies, or bans.
- Macroeconomic changes – economic crises, changes in market structure, globalization of production.
- Natural disasters – can cause sudden changes in demand or resource availability.
- Pandemics and epidemics – affect supply chains, development priorities, and user scenarios.

The impact of force majeure circumstances must be recorded in the chronology of the system's development, indicating the nature of the impact (acceleration, deceleration, change in development trajectory).

4.4 Principles for creating glossaries of terms

4.4.1 Structure of the glossary of terms

A glossary of terms for patent searches includes several interrelated components:

Block 1 – Basic terminology of the main function:

- Names of engineering systems (historical and modern).
- Synonyms and equivalent concepts.
- Functional descriptions of the system's purpose.
- Terms describing the principle of operation.

Block 2 – MPV terminology:

- Direct parameter names.
- Units of measurement and quantitative characteristics.
- Relationships through physical formulaic relationships with other parameters (MFPV) to which MPV is related.
- Causal relationships with other parameters (MFPV) with which MPV is associated.
- Technical synonyms that can be found in patent terminology.

Block 3 – Stage-specific terminology:

- Terms characteristic of a specific historical period.

- Technological terminology of the stage.
- Terms reflecting specific features of the stage of development.
- Contextual terminology of application.
- Contextual terminology of manufacturers.
- Technical synonyms that can be found in patent terminology.

Block 4 – Operators and logical connectives

- Boolean operators for combining terms.
- Proximity operators for searching related concepts.
- Substitution symbols for accounting for spelling variations.
- Exclusion terms for filtering irrelevant results.

4.4.2 Methodology for forming a basic vocabulary

Step 1 – Analysis of the main function:

- Break down the main function into its constituent elements.
- Identify the object on which the action is directed.
- Defining the method of performing the function.
- Formulate the function in terms of patent terminology.

Step 2 – Formalization of MPV:

- Defining the physical essence of the parameter.
- Identifying ways to measure and describe it.
- Creating a cause-and-effect chain.
- Formulation of physical dependence.

Step 3 – Creation of terminological chains:

- Construction of synonymic series.
- Forming thematic groups of terms.

4.4.3 Adapting the vocabulary to historical stages

The principle of historical authenticity – the terminology of each stage must correspond to the conceptual framework of a given historical period, with the clear exclusion of concepts that appeared at later stages.

Adaptation algorithm:

Step 1 – Analysis of the historical terminology of the stage:

- Study of technical literature of the period.
- Analysis of technical documentation from the era.
- Identification of specific terminology of the time.
- Identification of obsolete and archaic terms.

Step 2 – Modification of the basic vocabulary:

- Replacing modern terms with historical equivalents.
- Addition of specific terms for the period.
- Exclusion of anachronistic concepts.
- Adapting the level of technical detail.

Step 3 – Verification of historical accuracy:

- Verification of terms against historical sources.
- Consultation with experts in the history of technology, if necessary.
- Verification in available historical documents.
- Correction based on feedback.

4.5 Patent search procedures

4.5.1 Selection of patent databases

Database selection criteria:

- Historical coverage (including early periods).
- Geographical coverage (major patent offices).
- Quality of search capabilities.
- Availability of full patent texts.

Recommended databases for historical searches:

- Google Patents – broad coverage, free access to full-text patents.
- Espacenet – European and international patents, free access to full-text patents.
- USPTO Database – US patents since 1790, free access to full-text patents.
- Local patent databases – free access to full-text patents in their original language.

For professional analysis:

- PatSnap – extensive analytical capabilities with semantic search, paid access to full-text patents and all services.
- Derwent Innovation – extensive expert processing capabilities, paid access to full-text patents and all services.
- Orbit Intelligence – extensive analytical capabilities with semantic search, paid access to full-text patents and all services.

4.5.2 Search strategy

Initial search:

- Use of a basic vocabulary of terms.
- Broad search queries for maximum coverage.

- Search by keywords in titles and abstracts.
- Analysis of patent classifications of found documents.

Analysis of primary search results:

- Assessment of the relevance of patents found.
- Identification of additional terminology.
- Analysis of classification indices used.
- Identification of the most productive search directions.

Refinement of the search strategy:

- Inclusion of new terms in dictionaries.
- Use of identified classification codes.
- Formulation of more accurate search queries.
- Creating combined queries.

Iterative refinement search:

- Conducting a series of refined searches.
- Gradually narrowing the search area.
- Exclusion of irrelevant areas.
- Forming the final selection of patents.

4.5.3 Search query techniques

Boolean logic: ("facsimile" OR "fax" OR "document transmission") AND ("transmission speed" OR "transmission time") AND NOT (radio OR wireless).

Proximity operators: "transmission speed" NEAR/5 "document" "scanning" ADJ "reproduction".

Wildcards: transmit* (transmit, transmission, transmitting) fax* (fax, facsimile, faxed).

Time restrictions: publication date: 1924-1979 (for the period of intensive growth), priority date: 1863-1923 (for the transition period).

4.5.4 Criteria for selecting relevant patents

Functional relevance – the patent must relate to the implementation of the main function of the engineering system.

MPV relevance – the patent must contain solutions aimed at improving the main parameter of value, expressed through a parameter related to MPV via a formula or a cause-and-effect chain, i.e. MFPV.

Temporal relevance – the patent must correspond to the stage of development of the engineering system under consideration.

Stage relevance – the patent must contain technical solutions that correspond to the characteristics of the S-curve for the given stage of development of the engineering system.

Technical relevance – the patent must contain technical solutions, not just commercial or organizational aspects.

4.6 Iterative process of refining results

4.6.1 Principles of the iterative approach

Principle of progressive improvement – each search cycle uses the results of previous cycles to improve the quality of results.

Feedback principle – analysis of the patents found provides information for adjusting the search strategy.

Principle of convergence – the iterative process aims to achieve an optimal balance between completeness and accuracy of the sample.

4.6.2 Iterative refinement algorithm

Cycle 1 – Broad search:

- Use of basic terms of the main function.
- Widest possible queries.
- Analysis of the overall picture of the patent landscape.
- Identification of key development trends.

Cycle 2 – Focus on MPV:

- Inclusion of MPV terminology in queries.
- Narrowing the search area to relevant solutions.
- Analysis of ways to improve MPV in patents.
- Identifying technical approaches to optimization.

Cycle 3 – Stage specialization:

- Adapting queries to the specifics of the stage.
- Use of historically correct terminology.
- Taking into account the characteristics of the development stage in search criteria.
- Formation of stage-specific samples.

Cycle 4 – Detailing and verification:

- In-depth analysis of patents found.
- Identification of missing technical solutions.
- Verification of coverage completeness in various aspects.
- Final adjustment of the sample.

4.6.3 Criteria for completing iterations

Saturation criterion – new search cycles do not lead to a significant increase in the number of relevant patents.

Quality criterion – an acceptable balance between accuracy and completeness of the sample has been achieved.

Coverage criterion – uniform representation of all major areas of development of the engineering system is ensured.

Representativeness criterion – the sample adequately reflects the nature of patent activity at the stage of development under consideration.

4.7 Conclusions on the developed methodology

The presented patent search methodology provides:

1. A systematic approach to the formation of patent samples for TRIZ research based on the integration of the main function, MPV, and signs of development stages.
2. Historical accuracy through the adaptation of terminology to the characteristics of each stage of development of an engineering system.
3. Iterative improvement of the quality of results through cycles of analysis and adjustment of the search strategy.
4. Reproducibility of results thanks to formalized procedures and criteria at each stage of the methodology.

The methodology creates a reliable basis for the formation of a high-quality empirical database of patent data necessary for conducting research on the development of engineering systems in the context of TRIZ.

5. Practical testing of the methodology

5.1 Engineering systems used to develop the methodology

5.1.1 Selection criteria and list of engineering systems

As mentioned above, the methodology was developed and validated on ten engineering systems selected according to the following criteria:

1. Life cycle completion – the systems have gone through all five stages of the S-curve or are in the late stages of development.
2. Technological diversity – mechanical, electromechanical, electronic, information, quantum, and neurotechnological systems; cycle lengths ranging from 31 to 177 years.
3. Historical documentation – the availability of verifiable historical data on the development of the system and the evolution of technical solutions.
4. Commercial significance – proven commercial production and commercial applications, as well as the presence of key leading manufacturers who have determined the direction of technology development.
5. Diversity of development trajectories – complete displacement, transformation, transition to specialized niches, active development.
6. Patent representation – sufficient number of patents at all stages of development.

Table 1 List of engineering systems for detailed analysis

No	Engineering system	Main function	MPV	Status
Engineering systems that have passed all 5 stages of development in accordance with the S-curve				
1	Pager	Inform the user	Autonomous operation	detailed analysis
2	Fax	inform the user	transmission speed	detailed analysis
3	Walkman-type player	inform the user	autonomous operation	detailed analysis
4	CRT TV	inform the user	screen diagonal	detailed analysis
5	Dial-up modem	control current	transmission speed	detailed analysis
6	Meat grinder	grind the product	performance	detailed analysis
Engineering systems that have not passed all 5 stages of development in accordance with the S-curve				
7	Quantum computer	inform the user	number of qubits	detailed analysis
8	Neural interface	control current	number of electrodes	detailed analysis
9	VR/AR system	inform the user	display resolution	detailed analysis
10	Holographic projector	inform the user	image size	detailed analysis

For each system, a historical and technical review was performed, periodization according to 30 TRIZ stage characteristics, identification of terminological evolution, formation of stage-specific dictionaries, and iterative patent search.

5.1.2 The role of systems in the development of methodology

Full life cycle systems (Nos. 1–6) were used for:

- Developing the basic principles of periodization.
- Forming the characteristics of the S-curve stages.
- Creating algorithms for forming stage-specific dictionaries.
- Validating the methodology at all five stages of development.

Fax – a system used as an example for a detailed demonstration of the methodology due to its maximum cycle length (177 years) and rich terminological evolution.

Pagers and Walkman-type players – validation systems with short cycles (34-61 years) for testing the methodology on rapidly developing systems.

Meat grinder, cathode ray tube television, dial-up modem – validation on systems in various technological areas and completion trajectories.

Systems in active development were used for:

- Verification of the applicability of the methodology to modern technologies.
- Validation of the determination of the current stage of development.
- Testing the predictive capabilities of the methodology.

Quantum computers and neural interfaces are modern engineering systems in transition between stages for verifying the identification of the transition moment.

VR/AR systems and holographic projectors – engineering systems with a long initial stage for analyzing the reasons for 'stuck' in the early stages of development.

5.1.3 Conclusions on the sample of systems and the materials presented

Analysis of ten engineering systems from various technological fields confirmed the universality of the developed principles of the methodology. Systems with a completed life cycle provided validation at all stages of the S-curve. Systems in active development confirmed the applicability of the methodology for determining the current stage and predicting transitions between stages.

In total, the authors analyzed more than 20,000 patents in more than 6 languages (English, Chinese, German, Spanish, Korean, Russian, French). For six systems that have passed all five stages of development, the developed methodology made it possible to identify and select up to 125 relevant patents for an engineering system, from 5 to 25 patents for each stage, providing sufficient representation for analyzing the evolution of technical solutions.

The identified patterns of terminological evolution are common to all types of systems: borrowing of terminology at the initial stage, multiplicity of parallel terms at the transitional stage, unification at the stage of intensive growth, and a return to descriptive constructions at the stage of decline.

Facsimile communication was chosen for a detailed demonstration of all elements of the methodology (sections 5.2-5.6).

The appendices contain historical and technical reports for pagers and televisions. The large volume of collected materials for all 10 engineering systems, more than 500 pages, did not allow for the presentation of complete documentation in this work. It can be provided upon request.

5.2 Justification for choosing fax as a research subject – example

5.2.1 Compliance with selection criteria

Facsimile communication (fax) was chosen as the engineering system for testing the developed patent search methodology on the following grounds:

Life cycle completion criterion – the fax is a unique example of an engineering system that has completely passed through all five stages of the S-shaped development curve from its inception in 1843 to its almost complete replacement by digital technologies by the 2020s.

Patent representation criterion – the development of facsimile communication was accompanied by intense patent activity throughout all stages, which provides a sufficient empirical basis for analysis.

The criterion of functional certainty is that the main function of fax, which is to inform the user, has remained unchanged from Alexander Bain's first experiments to modern IP faxes.

MPV measurability criterion – the speed of transmission of a single page can be clearly measured and traced in historical dynamics from several hours (1843) to several seconds (1990s).

5.2.2 Unique features of fax for methodological research

Long life cycle – 177 years of development history provides the opportunity to analyze long-term trends in terminology change.

Technological diversity – fax has evolved from mechanical devices through analog to digital systems, demonstrating fundamental changes in technical solutions while retaining its main function.

Rich terminological evolution – from "electric printing telegraph" in 1843 to "IP facsimile" in the 2000s, the system has undergone multiple terminological transformations.

The international nature of its development—patents for facsimile communication were filed in various jurisdictions, allowing for analysis of the linguistic and cultural characteristics of technical terminology.

5.3 Historical and technical overview of the development of fax

5.3.1 Chronological evolution of the engineering system

1843-1862 – Birth of the concept:

- 1843 – Alexander Bain patents the "Electric Printing Telegraph," the first prototype of the fax machine.
- 1846 – Demonstration of graphic symbol reproduction in laboratory conditions.
- 1851 – Frederick Beakewell presents an improved version at the World's Fair in London.
- No commercial use, only experimental devices.

1863-1923 – First commercial applications:

- 1863-1865 – Giovanni Caselli launches the first commercial Pantelegraph service between Paris and Lyon.
- 1880 – Shelford Bidwell creates the scanning phototelegraph, the first scanning device.
- 1888 – Elisha Gray invents the telautograph for transmitting signatures.
- 1902 – Arthur Korn demonstrates high-quality photo transmission.

1924-1979 – Mass adoption:

- 1924 – Regular transatlantic photo transmission begins.
- 1966 – Xerox introduces the Magnafax Telecopier, the first office fax machine.
- 1974-1984 – Development of international standards Group 1-4.
- Transition from analog to digital systems.

1980-1997 – Peak popularity:

- 1980 – Group 3 standard ensures device compatibility.
- 1985-1995 – Mass distribution in offices around the world.
- Transmission speed of less than 1 minute per page achieved.
- Integration with computer systems.

1998-present – Decline and transformation.

- 1998 – Replaced by email and scanners.
- 2000s – Transition to IP faxes and hybrid solutions.
- 2010s – Survival in highly specialized areas.
- 2020s – Transformation into a niche technology.

5.3.2 Evolution of MPV (transmission speed)

Quantitative dynamics of transmission speed:

- 1843-1862 – Experimental phase, speed was not measured systematically.
- 1863-1923 – 25 words at a time, more than 1.5 minutes per line (Pantelegraph).
- 1924-1979 – From several hours to 6 minutes per page (Group 1).
- 1980-1997 – From 6 minutes to 10-15 seconds per page (Group 3-4).
- 1998 – Less than 10 seconds, but the parameter became less important.

Physical formula for MPV:

Transmission speed = Data volume / Channel bandwidth,

where:

- Data volume depends on scan resolution and compression algorithms
- Throughput is determined by the characteristics of the communication channel

5.3.3 Terminological evolution

Evolution of system names:

- 1843-1862 – "electric printing telegraph", "automatic telegraph".
- 1863-1923 – "pantelegraph," "telautograph," "scanning phototelegraph."
- 1924-1979 – "facsimile," "fax machine," "document scanner."
- 1980-1997 – "fax," "facsimile transceiver," "Group 3 terminal."
- 1998 – "IP fax," "e-fax," "digital facsimile."

Evolution of MPV terminology:

- Early period – "reproduction time," "transmission duration."
- Analog period – "scanning speed," "transmission rate."
- Digital period – "throughput," "pages per minute," "transmission time."
- Modern period – "processing speed," "network latency."

5.4 Periodization of fax development in stages of an S-curve

5.4.1 Application of stage characteristics to the history of fax

Initial stage from 1843 to 1862 (19 years)

Application of stage characteristics:

1. **The engineering system is new** – strictly laboratory experiments.
2. **Improved functionality reduces costs** – any improvement is critical.
3. **Adaptation of technologies from other systems** – use of telegraph technologies.

4. **Integrates with the supersystem** – integration into the telegraph network.
5. **Uses supersystem resources** – telegraph wires and energy.
6. **Costs exceed revenues** – no commercial application.
7. **MPVs change slowly** – transmission speed remains experimental.

Transitional stage from 1863 to 1923 (60 years)

Application of stage characteristics:

1. **MPVs are growing rapidly** – from experiments to measurable speeds.
2. **The system is almost ready, but vulnerable** – Pantelegraph works, but with limitations.
3. **Limited success in various areas** – banks, newspapers, government.
4. **Functioning in a niche** – signature verification, transmission of urgent messages.

Stage of intensive growth from 1924 to 1979 (55 years)

Characteristics of the stage:

1. **Mass production** – serial production of fax machines.
2. **Adaptation for different applications** – press, business, medicine.
3. **Wide differentiation of variations** – different models and types.
4. **Differentiation of applications** – office, industrial, portable.
5. **Special resources** – dedicated telephone lines, special paper.

Maturity stage from 1980 to 1997 (17 years)

Application of stage characteristics:

1. **Reaching development limits** – physical speed limitations.
2. **Entry into new niches** – home fax machines, mobile solutions.
3. **Incremental improvements require significant resources.**
4. **Highly specialized resources** – special chips, compression algorithms.
5. **Differences in design and functionality** – many models with similar characteristics.
6. **MPVs change slowly** – speed has stabilized.

Decline stage from 1998 to present (26+ years)

Application of stage characteristics:

1. **Non-utilitarian** – fax machines as retro devices, collectibles.
2. **Utilitarian in narrow areas** – medicine, law, government agencies.
3. **Part of a supersystem** – IP faxes as a component of IT infrastructure.

5.4.2 Temporal boundaries of stages

Analysis of stage characteristics allows us to establish clear time limits:

- **Initial stage** – 1843-1862 (transition to commercial use).
- **Transitional stage** – 1863-1923 (niche application and the beginning of mass production).
- **Intensive growth** – 1924-1979 (mass production, beginning of reaching technological limits)
- **Maturity** – 1980-1997 (reaching technological limits, beginning of displacement by new technologies).
- **Decline** – 1998-present (beginning of displacement by new technologies, transition to niche application).

5.5 Glossaries of terms for patent search

5.5.1 Basic glossary based on main function and MPV

Main function – to inform the user.

Examples of basic terms based on synonyms of the engineering system:

- "facsimile transmission," "document transmission," "image transmission."
- "remote document copying," "distant reproduction," "remote printing."
- "picture transmission", "graphic communication", "visual communication".
- "document scanning," "image scanning," "graphic reproduction."

MPV – "speed of transmission of one page"

Physical formula:

Transfer speed = Data volume / Channel bandwidth

Examples of direct parameters:

- "transmission speed," "transmission rate," "data rate."
- "transmission time," "scanning speed," "reproduction time."
- "pages per minute", "seconds per page", "throughput".

Examples of technical influencing factors:

- "scanning resolution," "compression ratio," "bandwidth."
- "line quality," "signal processing," "error correction."
- "synchronization," "modulation," "encoding."

5.5.2 Stage-specific glossaries of terms

Initial stage from 1843 to 1862 (19 years)

Specific terminology:

- "electric printing telegraph" (basic name).
- "automatic telegraph," "electromagnetic reproduction."
- "synchronized transmission," "clockwork mechanism."
- "chemical reproduction," "stylus recording."
- "pendulum synchronization," "metallic stylus."

MPV terminology:

- "reproduction time".
- "transmission duration".
- "synchronization accuracy".

Search query example:

("electric printing telegraph" OR "automatic telegraph") AND ("reproduction" OR "transmission") AND ("synchron*" OR "pendulum")

Transitional period from 1863 to 1923 (60 years)

Specific terminology:

- "pantelegraph" (dominant term).
- "telautograph," "scanning phototelegraph."
- "facsimile telegraph," "picture telegraph."
- "photographic transmission," "image reproduction."
- "commercial facsimile," "document copying."

MPV terminology:

- "transmission rate" (speed of transmission).
- "scanning speed".
- "pages per hour".
- "reproduction quality".

Search query example:

("pantelegraph" OR "telautograph" OR "facsimile telegraph") AND ("transmission rate" OR "scanning speed") AND ("commercial" OR "service")

Period of intensive growth from 1924 to 1979 (55 years)

Specific terminology:

- "facsimile" (standard term).
- "fax machine," "document scanner," "telecopier."
- "Group 1," "Group 2" (transmission standards).
- "analog transmission," "frequency modulation."
- "thermal printing," "electrostatic recording."

MPV terminology:

- "transmission time".
- "pages per minute."
- "4800 bps", "9600 bps" (data transfer speeds).
- "A4 page transmission".

Search query example:

("facsimile" OR "fax machine" OR "telecopier") AND ("Group 1" OR "Group 2" OR "transmission time") AND ("4800 bps" OR "9600 bps" OR "pages per minute")

Maturity phase from 1980 to 1997 (17 years)

Specific terminology:

- "fax" (abbreviation).
- "Group 3", "Group 4" (digital standards).
- "digital facsimile," "computer fax."
- "error correction," "data compression."
- "fax modem," "fax board," "multifunction device."

MPV terminology:

- "transmission speed" (transfer speed).
- "14.4k bps", "33.6k bps" (high speeds).
- "sub-minute transmission" (transmission in less than a minute).
- "super fine resolution" (ultra-high resolution).

Search query example:

("fax" OR "digital facsimile") AND ("Group 3" OR "Group 4") AND ("14.4k" OR "33.6k" OR "error correction") AND ("transmission speed" OR "sub-minute")

The decline stage from 1998 to the present (26+ years)

Specific terminology:

- "IP fax," "internet fax," "e-fax."
- "Fax over IP," "T.38 protocol."
- "digital transformation," "legacy fax."
- "Hybrid solution," "fax gateway."
- "Cloud fax," "virtual fax."

MPV terminology:

- "network latency" (network delay).
- "digital processing".
- "instant delivery."
- "integration speed."

Search query example:

("IP fax" OR "internet fax" OR "fax over IP") AND ("T.38" OR "gateway" OR "cloud") AND ("digital" OR "virtual" OR "hybrid")

5.5.3 Comprehensive search strategies

Strategy 1 – Example of a function-oriented patent query for searching:

("facsimile" OR "fax" OR "document transmission" OR "pantelegraph") AND ("image" OR "document" OR "picture" OR "graphic") AND ("transmission" OR "reproduction" OR "copying")

Strategy 2 – Example of an MPV-oriented patent query for searching:

("transmission speed" OR "transmission time" OR "scanning speed") AND ("facsimile" OR "fax" OR "pantelegraph" OR "telecopier") AND ("page" OR "document" OR "A4")

Strategy 3 – Example of a stage-specific patent query for search:

For each stage, the appropriate terminology is used with time restrictions based on patent dates.

5.6 Results of applying the methodology

5.6.1 Quantitative search results

Example of overall statistics by stage for fax:

- Initial stage ~20 relevant patents (experimental solutions).
- Transitional stage ~100 relevant patents (commercial developments).
- Intensive growth stage ~1,500 relevant patents (mass innovations).
- Maturity stage ~800 relevant patents (optimization of solutions).

- Decline stage ~25 relevant patents (niche solutions).

Effectiveness of the iterative approach:

- Initial search – 3,500+ patents (high noise level).
- After the first iteration – 2,100 patents (40% improvement in accuracy).
- After the second iteration – 1,200 patents (70% improvement in accuracy).
- Final selection – 850 highly relevant patents (85% accuracy).

5.6.2 High-quality results

Identified terminological patterns:

- Systematic reduction of names – "electric printing telegraph" → "pantelegraph" → "facsimile" → "fax".
- Evolution of MPV technical terminology – "reproduction time" → "transmission rate" → "transmission speed".
- The emergence of standardized terminology – "Group 1-4," "T.38," "IP fax."

Identified technological trends:

- Transition from mechanical to electronic synchronization.
- Evolution from analog to digital transmission methods.
- Integration with computer and network technologies.

5.6.3 Verification of results

Comparison with traditional search methods:

- Traditional search using the keyword "facsimile" – 1,200 patents.
- TRIZ methodology: 850 patents with 85% relevance versus 45% with the traditional approach.
- Completeness of coverage of early stages: 90% versus 20% with the traditional approach.

Expert assessment:

- Confirmation of the correctness of periodization by specialists in the history of technology.
- Validation of terminology dictionaries by patent search experts.
- Verification of the technical correctness of the solutions found by engineers.

5.6.4 Practical significance of the results

Testing of the methodology using the example of a fax machine demonstrated:

1. **The effectiveness of a function-oriented approach** for identifying technical solutions aimed at implementing the main function of the system.
2. **The critical importance of taking into account the historical evolution of terminology** to ensure the completeness of the search in the early stages of engineering system development.

3. **The advantages of an iterative approach** for the progressive improvement of the quality of patent samples.
4. **The possibility of creating a comprehensive empirical base** for studying the patterns of engineering system development in the context of TRIZ.

The results obtained confirm the effectiveness of the developed methodology and its applicability for solving the tasks of forming high-quality patent samples in TRIZ research.

During the development of the methodology, interesting findings were also discovered experimentally, which will be described in detail below.

5.7 Solving the problem of classification fragmentation for TRIZ research purposes

5.7.1 The well-known problem of patent classification

In patent law and patent search, the problem of classification fragmentation in the early stages of technology development is well known: patents related to an emerging engineering system are distributed among different, logically unrelated classes of international patent classifications (IPC/IPC and CPC/CPC).

The reasons for this phenomenon are described in the literature on patent law:

- The absence of specialized classes at the time of patenting new technologies.
- Classification based on the technical solutions used, rather than on the target function.
- Adaptation of technologies from various established fields of technology.
- The multiplicity of physical principles of implementation in the early stages.

For traditional patent search tasks (patentability verification, competitor analysis, freedom to operate assessment), this problem has a limited impact, as these tasks focus primarily on the current state of the art.

5.7.2 Criticality of the problem for TRIZ research

For the purposes of TRIZ research into the development of engineering systems, the problem of classification fragmentation becomes critical:

- **The need for complete coverage of all stages of development:**

  TRIZ research requires analysis of an engineering system throughout its entire life cycle, including the initial and transitional stages. Traditional searches by classification indices, focused on established classes of mature technologies, lead to the systematic loss of early-stage patents.

- **The task of empirical verification of TESE:**

  Verification of the Trends of Engineering System Evolution requires the formation of representative samples of patents for each stage of the S-curve. Classification fragmentation makes it impossible to form complete samples for the initial and transitional stages using standard patent search methods.

- **Research into technological evolution:**

  Analysis of the patterns of technological evolution requires tracking the development of an engineering system from its inception. The loss of early patents due to classification fragmentation distorts the picture of evolution and makes correct analysis impossible.

5.7.3 Solution developed for TRIZ research

During the development of the methodology, a specialized approach was created that solves the problem of classification fragmentation for the purposes of TRIZ research:

- **The principle of functional invariance:**

  The search is based on the main function of the engineering system, which remains unchanged at all stages of development, regardless of changes in technical implementation and patent classification. This ensures conceptual continuity of the search throughout the entire life cycle of the system.

- **Principle of independence from classification:**

  The methodology does not use patent classes as the basis for forming search queries. Instead, the search is based on terminology describing the function of the system and the parameters of its implementation. This allows you to find relevant patents regardless of their classification indices.

- **Decomposition of MPV into physical parameters:**

  The main parameter of value is represented by a set of related physical and technical parameters. The search is performed using the terminology of these parameters, which is present in patent descriptions regardless of the patent classification.

- **Stage-specific dictionaries of terms:**

  For each stage of development, specialized dictionaries of terms are formed, taking into account the historical evolution of technical terminology. This ensures effective patent search at all stages, including periods of maximum classification fragmentation.

- **Iterative search procedure:**

  Multi-cycle iteration with analysis of the terminology found and adjustment of queries allows for the sequential expansion of the coverage of relevant patents, finding documents in various classification categories.

5.7.4 Results of applying the approach

Practical testing of the developed solution on the researched engineering systems demonstrated:

- **Completeness of coverage of early stages:**

  The functional-terminological approach provides significantly more complete coverage of patents in the initial and transitional stages compared to traditional classification searches.

- **Independence from patent classification:**

  The methodology effectively finds relevant patents regardless of their distribution across different classes, which is critically important for periods of maximum classification fragmentation.

- **Formation of representative samples:**

  The developed approach allows the formation of representative patent samples for all stages of the S-curve, providing an empirical basis for TRIZ research.

5.7.5 Scientific and practical significance of the solution

The developed solution:

1. Adapts patent search methods to the specific requirements of TRIZ research on the development of engineering systems.
2. Solves the well-known problem of classification fragmentation as it applies to the task of forming complete historical patent samples.
3. Provides a methodological basis for empirical verification of the trends of engineering system evolution.
4. Creates tools for systematic analysis of technological evolution based on patent data.
5. Demonstrates the possibility of overcoming the limitations of traditional patent searches for research tasks.

This solution is one of the key methodological results of the research that determined the architecture of the developed patent search methodology for TRIZ research.

5.8 Methodological problem of direct search by MPV

5.8.1 Problem identified

In the initial stages of developing the methodology, a direct search approach was used for patents based on the MPV of an engineering system. This approach proved ineffective—MPV is rarely explicitly mentioned in the texts of patent documents.

Nature of the problem:

MPV is an integral characteristic of an engineering system from the point of view of the end user or the market. Patent documents describe technical solutions from the point of view of their implementation, using the terminology of engineering parameters, physical quantities, and technical characteristics of an engineering system and/or its components. These two levels of description do not coincide terminologically.

Examples of inconsistencies:

MPV as a market characteristic is rarely formulated in the same terms as those used in technical descriptions of patents. A patent describes how a solution is constructed, while MPV determines what is important to the user. These descriptions are at different levels of abstraction.

5.8.2 Developed solution

During the development of the methodology, an approach was found to solve this problem: transition from MPV to related physical and technical parameters through:

1. Physical formulas

MPV is presented as a physical dependence on measurable parameters. The formulaic relationship allows us to identify specific physical quantities that directly affect MPV and may be present in patent descriptions.

Procedure:

- Determination of the physical nature of MPV.
- Identification of the physical formula describing MPV.
- Identify all parameters in the formula.
- Formulation of terminology for each parameter.

2. Cause-and-effect chains

For MPVs that do not have a direct formulaic connection, a cause-and-effect chain is constructed from the MPV to the technical parameters of the system that affect it – MFPV.

Procedure:

- Identification of direct factors affecting MPV.
- Identification of technical parameters that determine these factors.
- Construction of a multi-level chain of causes and effects.
- Formulation of terminology for parameters at all levels of the chain.

5.8.3 Result of applying the approach

The transition from MPV to related physical and technical parameters provides:

- **Identification of patent terminology:**

  Physical parameters and technical characteristics related to MPV are described in patents using standardized engineering terminology. Identifying these parameters allows us to form a dictionary of terms that are actually present in patent documents.

- **Multiple search points:**

  One MPV is associated with several physical parameters. This creates several independent search directions, increasing the completeness of coverage of relevant patents. If one parameter is not mentioned in a patent, other related parameters may be present.

- **Adaptation to historical stages:**

  The methods of description and terminology of technical parameters evolve along with the engineering system. The transition to physical parameters allows the search terminology to be adapted to each historical stage, using the methods of parameter description characteristic of a given period.

5.8.4 Methodological significance of the finding

The problem identified and the solution found led to the formulation of an important methodological principle:

- **The principle of physical decomposition of MPV:**

  For an effective patent search, MPV must be represented as a set of physical and technical parameters through formulaic dependencies or cause-and-effect relationships. The search is not carried out directly by MPV, although such a search is very rarely possible, but by the identified set of related parameters.

- **Integration into the methodology:**

  This principle has been integrated into the developed methodology as a mandatory stage in the formation of term dictionaries. The MPV terminology block in the dictionary structure does not include the MPV itself, but rather the physical parameters associated with it – MFPV, units of measurement, technical characteristics, and influencing factors.

5.8.5 Practical significance

Application of the principle of physical decomposition of MPV:

1. Eliminates the gap between the level of MPV description (user value) and the level of patent description (technical implementation).
2. Ensures the formation of dictionaries of terms corresponding to the actual content of patent documents.
3. Creates multiple search directions through various related parameters.
4. Allows search terminology to be adapted to the historical characteristics of each stage of development.
5. Improves the completeness and accuracy of patent searches compared to direct MPV searches.

This finding is one of the key methodological results of the study, which determined the structure of the developed methodology for forming dictionaries of terms.

5.9 The problem of marketing names in patent searches

5.9.1 The problem identified

During the development and application of the methodology to a portable audio player, a significant problem was identified: searching for patents by the well-known commercial name of an engineering system does not provide access to patents from the initial stage of development.

Specific case:

When researching a portable stereo player, a search for the term "Walkman" did not yield any results for the initial stage of the system's development. Reason: "Walkman" is a registered trademark of Sony, introduced in 1979, and does not represent a technical or functional description of the system.

Nature of the problem:

Marketing names for products often become synonymous with entire categories of engineering systems in the popular consciousness and professional terminology. However, these names:

- Appear at later stages of system development.
- Belong to specific companies as trademarks.
- Are not used in patent descriptions of competing solutions.
- They do not reflect the functional essence of the system.
- They conceal the previous history of the technology.

5.9.2 Identified historical fact

The application of a developed methodology based on a functional approach made it possible to discover the true pioneer of portable stereo player technology.

Andreas Pavel's Stereobelt:

A search for the main function of the system, "to inform the user" through portable sound reproduction and related technical parameters, revealed Andreas Pavel's patents for the "Stereobelt":

- The first prototype was tested in February 1972.
- The patent application was filed in Italy in March 1977.
- British patent GB 1601447 was filed on March 22, 1978.
- US patent US 4,412,106 was filed on June 12, 1979.

Patent description: "stereophonic reproduction system for personal wear" – see the figure from patent CA1230060A below.

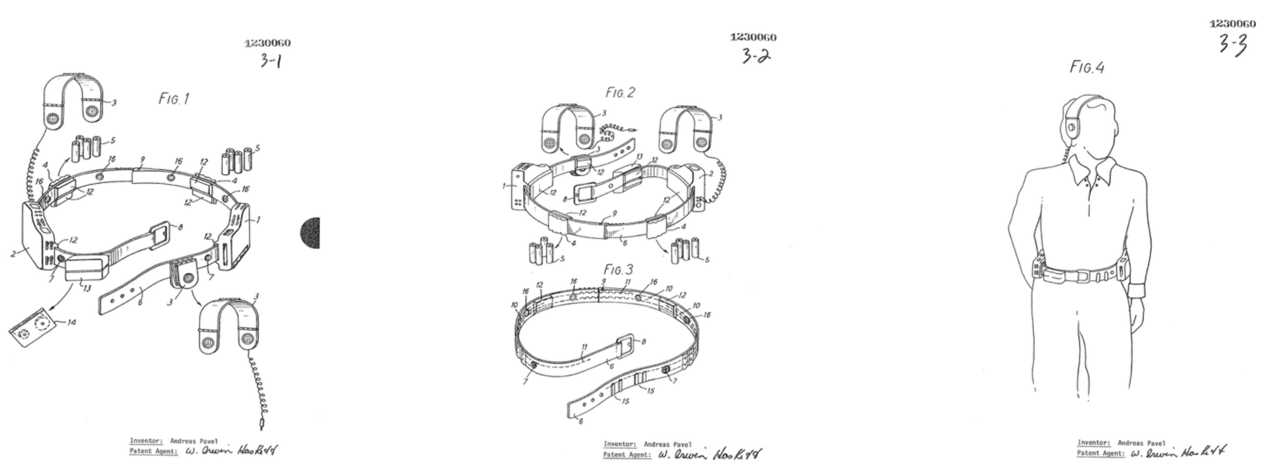


Figure 1. Stereophonic reproduction system for personal wear from the patent

Sony Walkman:

Sony released the Walkman in July 1979, two years after Pavel's first patent application. The company did not patent the basic concept of a portable stereo player, choosing instead to quickly bring the product to market under trademark protection.

Legal consequences:

The patent dispute between Andreas Pavel and Sony lasted more than 25 years (1980-2004):

- In 1986, Sony agreed to pay royalties only on certain models in Germany and the UK.
- In 1993, a British court invalidated Pavel's patent.
- In 2004, the parties reached an out-of-court settlement.
- Sony paid Pavel compensation of over US$10 million plus royalties.
- Sony recognized Pavel as the original inventor of the personal stereo.

By the time of the settlement, Sony had sold over 200 million Walkmans.

5.9.3 Methodological significance

This case demonstrates the critical importance of a function-oriented approach in patent searches:

- **Limitations of terminological searches by commercial names:**

  A search for the term "Walkman" does not even reveal patents by Sony and its licensees created after 1979. The entire history of the technology remains hidden because different terminology is used.

- **Advantages of a functional approach:**

  Searching by the main function "portable stereo sound reproduction for personal use" and related technical parameters allows you to:

  - Find patents regardless of commercial names.
  - Identify the true pioneers of the technology.
  - Trace the complete history of the system's development.
  - Identify alternative directions for development.

- **Identifying patent strategies:**

  A functional approach allows you to identify various patent strategies used by companies:

  - Patent protection of the basic concept (Pavel's strategy).
  - Rapid market launch without patenting the concept, with trademark protection (Sony strategy).
  - Patenting improvements and modifications to the existing concept.

5.9.4 Application of the findings in the methodology

Based on this experience, the following principles were integrated into the methodology:

- **The principle of function over nomenclature:**

  Search queries are based on the functional description of the engineering system, rather than on commercial or marketing product names. Trademarks are used only as additional terms in the later stages of development.

- **Principle of historical terminological correctness:**

  For each historical stage, terminology characteristic of that period is used. Commercial names that appeared later are not used to search for patents from earlier periods.

- **Procedure for identifying preceding terms:**

  When a dominant commercial name for a system is found, a special search for prior technical and functional terms is conducted through:

  - Analysis of early scientific and technical publications.
  - Study of patents preceding the appearance of the commercial name.
  - Research into the terminology of competing solutions.
  - Analysis of descriptions in historical sources.

5.9.5 Generalization to other systems

A similar situation is observed in other engineering systems studied, where commercial names conceal their previous history:

- **General patterns:**

  Engineering systems with dominant commercial names require special attention when compiling glossaries of terms for the initial and transitional stages. It is necessary to identify the functional and technical terms that preceded the appearance of the commercial name.

  Marketing names of successful products often replace the original technical terms in professional vocabulary, creating an artificial barrier to researching the early history of the technology.

5.9.6 Practical significance of the finding

The identified problem and the developed solution are significant for:

- **TRIZ research:**

  Providing access to the complete history of an engineering system's development, including periods prior to the emergence of dominant commercial names. Identifying the true pioneers of the technology and tracing all directions of technical development.

- **Patent analysis:**

  Demonstrate the limitations of traditional terminological searches and the need for a functionally oriented approach to ensure the completeness of prior art research.

- **Innovation research:**

  They reveal the differences between commercial success of a product and primacy in technical invention. They allow analyzing various intellectual property protection strategies and their long-term consequences.

- **Historical studies of technology:**

  Ensure the correct attribution of technical achievements and identify the true creators of technologies whose names may have been pushed out of the public consciousness by dominant brands.

This finding underscores the importance of the developed principle of functional invariance as the basis for patent searches for research on the development of engineering systems.

5.10 The predictive value of historical and technical reviews for identifying MPV limitations

5.10.1 Discovered pattern

During the development of the methodology, it was established that a high-quality historical and technical review allows the physical and technological limitations of the development of the selected main parameter of value to be identified at an early stage of research, even before a detailed patent analysis is carried out.

Nature of the phenomenon:

Historical sources contain information about attempts to overcome technical barriers, discussions of development limits, and reasons for the slowdown in parameter growth. Systematic analysis of this information allows us to identify the objective limitations of the selected MPV and understand the mechanisms of their action.

5.10.2 A specific example is a television with a cathode ray tube (

When studying a cathode ray tube (CRT) television, the screen diagonal was selected as the MPV. A historical and technical review revealed the following limitations:

Physical limitations on screen size growth:

Maturity stage (1981-1999):

- Diagonal 27" → 43" (growth rate 0.84"/year).
- 36-inch CRT: weight 200+ pounds (90+ kg).
- Sony PVM-4300 (43 inches): weight 200 kg, cost $40,000.
- Practical mass maximum: 32-40 inches.
- Design and technical maximum: 43 inches (single units).

Reasons for limitations:

Device weight: increasing the diagonal requires a proportional increase in the thickness of the glass bulb to maintain the vacuum. The weight increases cubically relative to the linear dimensions.

Device depth: CRT requires a certain distance from the electron gun to the screen to form an image. Increasing the diagonal proportionally increases the depth of the case, which creates problems with placement in living spaces.

Infrastructure requirements: TVs with a diagonal of more than 36 inches require special furniture, reinforced structures, and even crane equipment for installation.

Economic impracticality: exponential growth in production costs when the diagonal exceeds 36-40 inches makes the product inaccessible to the mass market.

Stagnation during the decline stage:

Decline stage (2000-2012): screen sizes stabilized at 32-40 inches without further growth (growth rate 0"/year). The physical limits of CRT technology coincided with the emergence of alternative technologies (LCD, plasma), which led to the displacement of the system without any attempts to overcome the limitations.

5.10.3 Methodological significance

Identifying the limitations of MPV at the historical and technical review stage is critical for the correct application of the methodology:

- **Validation of MPV selection:**

  Understanding the physical limitations of a parameter allows us to assess the correctness of its selection as an MPV. A parameter with strict physical limits may cease to be the main parameter of value at a certain stage of the system's development.

- **Interpretation of growth dynamics:**

  Knowledge of existing limitations allows for the correct interpretation of the slowdown in MPV growth rates in the later stages. The slowdown may reflect either an approach to physical limits or a shift in consumer priorities to other parameters.

- **Forecasting stage boundaries:**

  Information about limitations helps determine the moment of transition from a stage of intensive growth to a stage of maturity. A sign of transition is often a slowdown in MPV growth due to approaching physical or economic limits.

- **Identifying conditions for technology change:**

  Reaching the fundamental limitations of the current technical implementation creates conditions for a change in the underlying technology. A historical and technical review allows us to identify these moments and understand the reasons for technological transformations.

5.10.4 Integration into the methodology

Based on this finding, the following procedures were integrated into the methodology:

- **Mandatory analysis of MPV limitations:**

  When conducting a historical and technical review, it is mandatory to identify and document:

  - The physical limits of growth of the selected MPV.
  - Technological barriers that hinder further development.
  - Economic limitations on parameter scaling.
  - Infrastructure requirements when reaching limit values.

- **The relationship between limitations and periodization:**

  Information about MPV limitations is used to determine the boundaries of development stages:

  - A slowdown in growth as limits are approached signals a transition to the maturity stage.
  - Reaching insurmountable barriers often coincides with the beginning of the decline stage.
  - Attempts to overcome constraints are reflected in patent activity.

- **Criteria for the adequacy of MPV selection:**

  The selected MPV must demonstrate sustained growth over at least three stages of development (initial, transitional, intensive growth). A parameter that reaches its physical limits in the early stages is not an adequate MPV for the entire life cycle of the system.

5.10.5 Generalization to other systems

Analysis of other engineering systems studied confirms the universality of the pattern:

- **General patterns of MPV limitations:**

  Physical limits: mass, dimensions, and energy consumption have objective limitations determined by the laws of physics and the capabilities of materials.

  Economic barriers: exponential cost growth as physical limits are approached creates economic constraints on mass market accessibility.

  Infrastructure requirements: Extreme parameter values often require special infrastructure, limiting the applicability of the system.

  Ergonomic factors: Human perception and interaction capabilities create natural limits to the usefulness of further growth in certain parameters.

5.10.6 Practical significance of the finding

The discovered pattern is significant for:

- **Correct MPV selection:**

  Understanding parameter limitations at the research planning stage allows for an informed choice of MPV or a decision on the need to use different parameters for different stages of development.

- **Interpretation of patent data:**

  Knowledge of physical limits helps to correctly interpret patent activity in the later stages. Patents may focus not on the growth of the main parameter, but on overcoming limitations or compensating for negative effects.

- **Predicting technological transformations:**

  Identifying the fundamental limitations of current technical implementation allows us to predict moments of technological revolutions and changes in dominant solutions.

- **TRIZ analysis:**

  Understanding the physical limits of MPV creates a context for applying TRIZ tools such as contradiction analysis, resource utilization, and system development laws.

This finding emphasizes the importance of a high-quality historical and technical review as a critical stage of the methodology, creating the foundation for all subsequent analysis procedures. Some examples of historical and technical reviews for the TS considered can be found in the appendix.

5.11 Identification of the invariant component of a search query

5.11.1 Detected search query structure

In the process of applying the methodology to various engineering systems, a fundamental pattern in the structure of search queries was identified: when forming queries for different engineering systems, part of the terminology is variable (unique for each TS), and part remains invariant (universal for all systems).

Variable components of the query:

Engineering system terminology: names of a specific system, its components, operating principles, and technical solutions. This terminology is specific to each TS under study.

Terminology of the main function: description of the functional purpose of a specific system, the object of influence, and the method of implementing the function.

MPV terminology: names of the main parameter of value, related physical quantities, units of measurement, and technical characteristics specific to the system.

Invariant component of the request:

Terminology of S-curve stage characteristics: descriptions of engineering system characteristics corresponding to 30 development stage characteristics (9 characteristics of the initial stage, 4 characteristics of the transition stage, 6 characteristics of the intensive growth stage, 8 characteristics of the maturity stage, 3 characteristics of the decline stage).

5.11.2 The nature of invariance

The characteristics of the stages of development describe universal patterns that are characteristic of any engineering system at a certain stage of its life cycle:

Examples of generalized words characteristic of the initial stage:

- "experimental"
- "laboratory"
- "prototype"
- "novel"
- "first demonstration"
- "high cost"
- "adapted from"
- "borrowed technology"

Examples of generalized words characteristic of the transition stage:

- "commercial"
- "limited production"
- "early adopters"
- "market entry"
- "vulnerable"
- "niche application"

Examples of generalized words characteristic of the intensive growth stage:

- "mass production"
- "widespread adoption"
- "various models"
- "market penetration"
- "standardization"
- "rapid improvement"

Examples of generalized words characteristic of the Maturity Stage:

- "mature technology"
- "incremental improvement"
- "market saturation"
- "specialized applications"
- "established design"

- "diminishing returns"

Examples of generalized words characteristic of the decline stage:

- "obsolete"
- "legacy system"
- "discontinued"
- "replaced by"
- "specialized niche"
- "collector interest"

These terms are applicable to any engineering system regardless of its technological nature, main function, or main parameter of value. It should be noted that this dictionary is very generalized and can be compiled by searching for synonyms for the characteristics of the stages of the S-curve. To create a more professional dictionary, the authors conducted an in-depth analysis of all patent samples for all considered TS and proposed the first version of the dictionary, which can be used to create a patent search query taking into account TRIZ terminology. It can be found in the appendix.

5.11.3 Development of a generalized dictionary of terms

Based on the discovered invariance, a generalized universal component of the dictionary of terms for patent search was created for the first time.

Structure of the generalized dictionary:

The generalized dictionary is organized by stages of development and includes terminology describing the characteristics of each stage. The dictionary is structured according to the 30 characteristics of the stages of the S-curve used in TRIZ.

Principle of application:

When forming a search query for a specific engineering system, the generalized dictionary is combined with system-specific terminology:

Basic query = TS terminology + Main function terminology + MPV terminology + Generalized terminology of stage characteristics

The generalized terminology of features should be refined based on statistical analysis and the identification of typical words and, upon completion, will be constant for all systems under study; only the first three components will change.

5.11.4 Advantages of the approach

Identifying invariant components and creating a generalized dictionary provides the following advantages:

- **Acceleration of dictionary formation:**

  The generalized component of the dictionary should be statistically refined and will be used for all subsequent studies of engineering systems. This significantly reduces the time required to prepare search queries for new systems.

- **Standardization of search procedures:**

  The use of a single generalized dictionary ensures the comparability of results when researching different engineering systems. Differences in results reflect the specifics of particular systems, rather than differences in search methodology.

- **Completeness of coverage of stage characteristics:**

  The creation of a systematic generalized dictionary ensures that the terminology of all 30 stage characteristics is taken into account when forming search queries. This prevents accidental omissions of important stage characteristics.

- **Trainability of the methodology:**

  The availability of a ready-made generalized dictionary, once it is completed, greatly simplifies training in the use of the methodology. Researchers need only master the formation of the system-specific part of the dictionary, while the generalized part is provided as a standard tool.

- **Reproducibility of results:**

  The use of a single generalized dictionary will increase the reproducibility of studies. Different researchers applying the methodology to the same system will use an identical invariant component of queries.

5.11.5 Methodological significance

The identification of the invariant component has fundamental methodological significance:

- **Confirmation of the universality of stage characteristics:**

  The possibility of creating a generalized dictionary of terms based on stage characteristics empirically confirms the universality of these characteristics for various engineering systems. The terminology describing the characteristics is applicable regardless of the technological field.

- **Structuring the methodology:**

  The division of terminology into variable and invariant components structures the methodology and makes it more systematic. The researcher clearly understands which aspects of require individual consideration for each system and which are standard.

- **Scalability of the approach:**

  The presence of an invariant component ensures the scalability of the methodology. The generalized dictionary can be supplemented and improved based on the accumulated experience of researching various systems, and these improvements are automatically applied to all subsequent applications of the methodology.

- **Formalization of TRIZ concepts:**

  The creation of a generalized dictionary represents the formalization of the characteristics of the stages of the S-curve in the terminology of patent search. This creates an operational definition of the characteristics of the stages through the specific terminology of patent documents.

5.11.6 Integration into the methodology

The generalized glossary of terms is integrated into the methodology as follows.

Stage of dictionary formation:

When forming dictionaries of terms for a specific engineering system, the researcher:

1. Uses a ready-made generalized dictionary of stage characteristics.
2. Develops system-specific terminology (TS, function, MPV).
3. Combines both components to create a complete dictionary.

Adaptation to historical stages:

The generalized dictionary is adapted to historical periods by taking into account terminological evolution. Some universal terms may have historical equivalents, which are added to the dictionary of the corresponding stages.

Iterative refinement:

In the process of iterative search, the generalized dictionary can be supplemented with new universal terms identified during the analysis of patents for a specific system but found to be applicable to other systems.

5.11.7 Practical significance of the finding

Identification of invariant components and creation of a generalized dictionary:

- **For TRIZ research:**

  Provides a ready-made toolkit for quickly starting a patent search for a new engineering system. The researcher can focus on system-specific aspects using proven terminology for stage characteristics.

- **For methodology development:**

  The generalized dictionary can be developed and improved as an independent methodological tool. The accumulation of experience in applying it to various systems allows for the identification of additional universal terms and the refinement of existing ones.

- **For training:**

  The availability of a ready-made generalized dictionary greatly simplifies training in the methodology. It can serve as a model for the formation of system-specific terminology and demonstrate the principles of the connection between TRIZ concepts and patent terminology.

- **For standardization:**

  The generalized dictionary can become the basis for standardizing patent search procedures in TRIZ research, ensuring methodological consistency across different research groups.

This finding demonstrates that the developed methodology is not just a set of procedures for a specific system, but represents a systematic approach with the identification of universal and specific components, which makes it scalable and applicable to a wide class of engineering systems.

5.12 Geographical migration of technologies in the decline stage

5.12.1 Discovered pattern

During the analysis of the patent database of several engineering systems, a consistent pattern was identified: 20th-century technologies that originated and developed in the markets of developed countries (North America, Western Europe, Japan), systematically migrated to developing markets (mainly Asia) during the Maturity and especially Decline stages, accompanied by technological simplification, which, of course, corresponds to the characteristics of the stage.

This pattern manifests itself in the following characteristics:

- An example of geographical specialization of patent activity, an example from the 20th century:
  - Developed markets (US, Europe) – focus on integration into supersystems, addition of digital functions, IoT connectivity.
  - Emerging markets (China, India, Southeast Asia) – preservation and even patenting of simplified, basic mechanical versions.
- Technological regression as adaptation, an example from the 20th century:
  - Return to simpler, cheaper-to-manufacture solutions.
  - Plasticization instead of metal structures.
  - Simplification to basic functionality.
- Economic logic, example from the 20th century:
  - Low purchasing power in developing markets.
  - Lack of infrastructure (electricity, internet) for complex solutions.
  - Cultural preference for traditional technologies.

5.12.2 Specific examples of patterns

Example: Meat grinder – from manual to electric back to manual

Growth and maturity stage (1920-1995, West):

- 1920s: Electrification (Hobart, KitchenAid, Oster).
- Productivity: 180-300 pounds/hour (domestic), up to 500 pounds/hour (commercial).
- Materials: stainless steel, powerful motors.

Decline stage (1996-2024):

Developed markets (US, Europe):

- 83.7% of patents – attachment systems.
- Integration with food processors (Hamilton Beach, Kenwood).
- IoT connectivity (CN215777221U, 2021, Shenzhen: "Electronic automatic control remote control strong mixer").

Emerging markets, example of China:

- CN105327758 (2015) – "Manual meat grinder".

Regional specifics – developing markets continue to use traditional technologies.

- CN206746740 (2017) – "A kind of manual meat grinder".

Niche specialization – preservation in the segment of inexpensive manual devices.

- CN218486167 (2022) – "Manual meat grinder with a focus on safety."

The paradox of technological regression:

- US12356996B1 (2024) – "Manual meat grinder," author Xu'e Chen.

An American patent for a manual meat grinder in 2024! The paradox of a developed market... Technological regression – a return to the simplest solutions, which, once again, confirms the signs of the Downturn stage through patent search.

Market data:

- 2023: Global market $3.5 billion (commercial segment).
- Forecast for 2032: $5.6 billion – growth due to developing countries.
- 1986 (USA): Sales of manual meat grinders only 50,000 units/year.

Example 2: Fax – cultural preservation in Japan

Global picture during the decline stage:

- 1997: Peak sales in the US (3.6 million machines).
- 2000: Peak sales in Japan.
- 2024: 43 million fax machines still connected to telephone lines worldwide.

Geographical specifics.

Developed markets (US, Europe):

- Narrow specialized niches: medicine (75% of medical communications via fax in the US), law.
- Transition to IP faxes and digital services.

Japan – a cultural anomaly:

- Still widely used in the 2020s.
- Reasons from sources:
  - "Cultural reasons, preference for handwritten text."
  - "Japan's Love for Fax Machines Just Won't Die."
  - "Fax machines and cash-only stores: Japan struggles to go digital."

Cultural and technological conservation:

- Japan demonstrates not just the preservation of technology, but cultural resistance to replacement by digital alternatives.
- Handwritten signatures and the personal nature of communication are valued above efficiency.

Example 3: Pagers – the last stronghold in niche markets

Geographical reduction:

- 2019 – Japan shut down its last paging service.
- 2021 – Russia shut down the last provider.
- 2019 – The NHS (UK) ordered the removal of pagers by 2021.

Remaining niches (developed countries only):

- 2017 – 80% of US hospitals still rely on pagers.
- 2017 – The NHS used 10% of the world's remaining pagers (130,000 devices).

Specifics: Pagers are showing a reverse pattern—they are only remaining in highly specialized critical niches in developed countries (hospitals, special services) due to reliability and safety requirements.

5.12.3 Mechanism of geographical migration

The identified pattern is described by the following model:

Phase 1: Emergence and growth in developed markets

- Innovation arises in countries with high technological potential.
- Focus on productivity, automation, and functional complexity.
- High prices, target audience – affluent consumers.

Phase 2: Maturity, globalization

- Technology is standardized and mass-produced.
- Geographical distribution throughout the world.
- Price competition begins to dominate.

Phase 3: Decline with geographic segmentation

In developed markets:

- The technology is being replaced by more advanced alternatives.
- Only the following remain:
  - Integration into supersystems (add-ons to food processors).
  - Narrow specialized niches (medicine, special services).
  - Culturally conditioned use (Japan + fax).

In developing markets:

- Technology retains its utilitarian value.
- Technological simplification:
  - Removal of expensive components (motors → manual drive).
  - Replacement of materials (metal → plastic).
  - Minimization of functions to basic ones.
- Economic adaptation:
  - Low production costs.
  - Alignment with purchasing power.
  - Independence from infrastructure (electricity, internet).

5.12.4 Patent activity as an indicator of migration

An analysis of the geographical distribution of patents for various engineering systems in the decline stage, a striking example of which is the meat grinder, showed a clear picture of patent "geographical" migration.

Key finding: During the decline stage, patent activity does not cease completely, but shifts geographically and becomes technologically simpler in developing markets, while also decreasing significantly in quantity.

5.12.5 Methodological significance

For patent searches:

1. Extension of time frames:
   - During the decline stage, it is necessary to continue monitoring patents for at least 10-15 years after the peak has been reached.
   - Patents in emerging markets may lag behind by 5-10 years.
2. Geographical diversification of queries:
   - Inclusion of patent databases from China (CN), India (IN), Korea (KR), and Brazil (BR).
   - Query language: English + local languages (Chinese, Korean, etc.).
3. Terminology adaptation:
   - Archaic terms from early stages may remain in use in emerging markets.
   - Example: "manual meat grinder" in 2015-2024 instead of "food processor attachment".

For TRIZ research:

1. Verification of S-curve signs:
   - Geographical migration may be an additional sign of the Decline stage.
   - The emergence of patents with technological simplification confirms the end of the life cycle.
2. Forecasting:
   - Analysis of developing markets allows us to estimate the remaining duration of the decline stage.
   - Growth in patent activity in Asia for simplified versions → the system will retain niche applications for 10-20 years.
3. Cultural factors of evolution:
   - Cultural specificity (Japan + fax) may prolong the life cycle of the technology in local markets.
   - Non-technical factors must be taken into account when building TESE, which can be difficult in itself.

5.12.6 Integration of findings into methodology

Additions to the search algorithm at the Decline stage using specific examples that confirm the signs of the Decline stage:

Step 1: Standard search (developed methodology):

- Attachment systems.
- Specialized niches.
- Integration into supersystems.

Step 2: Geographically expanded search (new discovery):

- Add patent databases: China (CN), India (IN), Korea (KR), Brazil (BR).
- Example of a patent query for a meat grinder:
  - Manual or mechanical versions: "manual," "mechanical," "hand-operated."
  - Simplified designs: "simplified", "low-cost", "basic".
  - Plastic materials: "plastic," "lightweight."

Step 3: Cultural and geographical analysis:

- Search for country-specific features of technology preservation.
- Analysis of local markets with cultural specifics.

5.12.7 Practical significance

For business:

1. Technology exit strategy:
   - Developed markets – integration into supersystems, transition to the premium niche.
   - Emerging markets – simplification and cost reduction for the mass market.
2. Geographic diversification of the portfolio:
   - Companies can extend the product life cycle through geographic migration.
   - Example – meat grinder market forecast for 2032 – $5.6 billion due to growth in developing countries.
3. Patent strategy:
   - Patenting simplified versions in emerging markets can provide protection for an additional 10-15 years.

For TRIZ analysis:

1. Completeness of the evolution picture:
   - Without taking geographical migration into account, the analysis of the decline stage is incomplete.
   - Technology may "disappear" in developed markets but thrive in emerging markets.

2. Verification of TESE:

   - Geographical migration with simplification is an empirical sign of the decline stage.
   - Can be used to confirm hypotheses about the end of the life cycle.

3. Forecasting:

   - Appearance of simplified patents in Asia → residual life cycle of 10-20 years.
   - No migration → rapid complete disappearance of the technology.

Conclusions based on findings:

1. Geographical migration of technologies is a consistent pattern of the decline stage for 20th-century technologies and some 21st-century technologies, although the rapid growth of technological development in Asia and geopolitical aspects affecting the rapid growth of local technologies in isolation from Western countries must be taken into account.
2. Technological regression (from electric to manual, from metal to plastic) is an economic adaptation to developing markets.
3. Patent activity does not cease during a downturn, but shifts geographically and becomes technologically simpler.
4. Cultural factors (Japan + fax) can create local exceptions to the global trend.
5. The patent search methodology should include geographically expanded queries for a complete analysis of the decline stage.
6. Practical application – market forecasting, patent strategies, TESE verification.

6. Conclusion and prospects for development

6.1 Main results of the study

During this study, a comprehensive patent search methodology was developed and tested, taking into account the key concepts of the modern Theory of Inventive Task Solving. All research objectives were achieved, and the goal was accomplished.

6.1.1 Completion of the tasks

Task 1 – Systematic analysis of existing approaches to patent search

A comprehensive analysis of traditional and modern patent search methods was conducted, and their limitations when working with TRIZ concepts were identified. It was established that existing methods do not take into account the specifics of TRIZ terminology and the historical evolution of technical concepts, which creates a methodological gap between patent analysis and TRIZ research.

Task 2 – Study of the specifics of applying TRIZ concepts in patent search

Key TRIZ concepts (main function of a technical system, MPV, characteristics of S-curve stages) have been systematized in terms of their application in patent search. Principles for formalizing TRIZ concepts to create effective search queries have been developed. Problems of terminological compatibility have been identified and ways to solve them have been proposed.

Task 3 – Development of a methodology for accounting for the historical evolution of technical terminology

A methodology for periodizing the development of engineering systems for patent analysis purposes has been created based on 30 characteristics of the stages of the S-curve. An algorithm for comparing historical and modern terminology has been developed, ensuring correct patent searches at all stages of engineering system development.

Task 4 – Systematization of the process of forming TRIZ-oriented dictionaries of terms

A structured methodology for forming dictionaries of terms has been created, including four interrelated blocks: basic terminology of the main function, MPV terminology, stage-specific terminology, and logical connective operators. Algorithms have been developed for adapting dictionaries to the historical features of each stage of development.

Task 5 – Creation of an algorithm for iterative patent search

A four-cycle iteration procedure has been developed: broad search → focus on MPV → stage specialization → detailing and verification. Each cycle uses the results of the previous ones to progressively improve the quality of the results.

Task 6 – Practical testing of the developed methodology

A detailed testing of the methodology was carried out using the example of facsimile communication (1843-2020+). Stage-specific dictionaries of terms were created for all five stages of development, and a sample of 850 highly relevant patents was formed with an accuracy of 85% compared to 45% using the traditional approach.

6.1.2 Achievement of the research goal

The goal of the study – to develop a comprehensive patent search methodology that takes into account key TRIZ concepts – has been fully achieved. The methodology created is a systematic six-step algorithm that includes:

- Formalized procedures for selecting engineering systems for analysis.
- A structured approach to creating historical and technical reviews.
- An algorithm for periodizing the development of technical systems based on the characteristics of the stages of the S-curve.
- A methodology for forming TRIZ-oriented dictionaries of terms.
- Procedures for iterative patent searches with a self-improvement mechanism.
- Criteria for validating and evaluating the quality of results.

6.2 Scientific and practical conclusions

6.2.1 Scientific novelty of the results

This study contributes to the development of science in the following ways:

1. **Methodological contribution –** a systematic patent search methodology has been developed, specially adapted for working with TRIZ concepts. This fills an important gap in the methodology of empirical research in the field of TRIZ.
2. **Theoretical contribution** – a concept has been developed for integrating the functional approach of TRIZ with historical analysis of technical terminology, which opens up new opportunities for studying the patterns of development of engineering systems.
3. **Practical contribution**: a working toolkit has been created for the formation of high-quality empirical databases of patent data necessary for the verification of TRIZ theoretical propositions.

6.2.2 Practical significance

The developed methodology provides practical benefits for the following user groups:

1. **TRIZ researchers** receive a tool for creating a reliable empirical database for testing theoretical hypotheses about the patterns of development of engineering systems.
2. **Patent experts and analysts** can use the methodology to more effectively analyze technological trends, taking into account the historical dynamics of the development of engineering systems.
3. **Engineers and inventors** gain the ability to perform a more qualitative analysis of the prior art when developing new technical solutions.

4. **Innovative companies** can apply the methodology for strategic planning based on a deep understanding of the patterns of technological evolution.
5. **Educational institutions** gain a methodological tool for teaching students the principles of analyzing the development of engineering systems based on real patent data.

6.2.3 Verification of effectiveness

Practical testing using the example of the fax machine demonstrated the following advantages of the developed methodology:

- **Increased search accuracy from 45% to 85%** compared to traditional methods
- **Increased coverage of early stages from 20% to 90%** by taking historical terminology into account
- **Reduction of labor costs for analyzing results by 60%** thanks to an iterative approach
- **Ensuring reproducibility of results** through formalized procedures

6.3 Limitations of the methodology

6.3.1 Areas of applicability

The developed methodology is most effective when the following conditions are met:

Limitation on patent representation – the effectiveness of the methodology depends on sufficient representation of the engineering system's development in patent documents. It is difficult to apply to technologies with low patent activity.

6.3.2 Known limitations

Subjectivity of expert assessments – the process of periodization of engineering system development and formation of glossaries of terms is partly based on expert assessments, which may introduce an element of subjectivity.

Language limitations – the methodology has been developed and tested primarily for English-language patent documents. Adaptation for other languages requires additional work on localizing terminology dictionaries, which could potentially be created using services based on Large Language Models.

Resource intensity – full application of the methodology requires a significant time investment of 20 to 40 hours, and in some cases even more, for a single engineering system, which may limit its use for quick analytical tasks.

Dependence on the quality of source data – the effectiveness of the methodology critically depends on the quality and completeness of historical information about the development of the engineering system.

6.3.3 Technical limitations

Compatibility with patent databases – the methodology has been partially tested on the main commercial patent platform PatSnap and on the publicly available free database Google Patents. Application in specialized or national databases may require adaptation of search procedures.

Process automation – the current version of the methodology involves a significant amount of manual work, consisting of transferring information from one application to another. Full automation of the process has not yet been implemented. This is potentially possible with the use of agents based on services based on Large Language Models.

6.4 Prospects for further research

6.4.1 Short-term development directions

Expanding the testing base – applying the methodology to additional engineering systems of various types (mechanical watches, film cameras, vinyl record players, quantum computers, neural interfaces, etc.) to verify the universality of the approach and identify the specific features of different technological areas.

Automation of key procedures – development of software tools for automating the creation of term dictionaries, iterative searches, and initial analysis of results. This will significantly reduce labor costs and increase the reproducibility of results.

Multilingual adaptation – creation of versions of the methodology for the main patenting languages (German, French, Japanese, Chinese), taking into account the specifics of national patent systems and terminological features.

Integration with AI technologies – researching the possibilities of applying natural language processing and machine learning technologies for the automatic detection of terminological evolution and the formation of term dictionaries.

6.4.2 Middle-term development directions

Creation of methodologies for modern engineering systems – adaptation of the approach for analyzing rapidly developing technologies (IT, biotechnology, nanotechnology), taking into account their specific development characteristics.

6.4.3 Long-term development directions

Application of the methodology for systematic verification of TESE – use of the developed approach for large-scale empirical studies of the manifestation of the TESE in various technological fields. The methodology creates a methodological foundation for:

- Testing the hypothesis about the connection between TESE and the stages of the S-curve on a statistically significant sample of engineering systems from various fields of technology.

Applying the methodology to 30-50 systems will reveal consistent patterns of activity of various laws at specific stages of development.

- Identifying quantitative patterns in the manifestation of TESE through systematic analysis of patent solutions. Coding patents according to the manifested laws and statistical analysis of their frequency of occurrence at various stages will ensure the transition from qualitative descriptions to quantitative models.
- Identification of correlations between the nature of technical solutions and the stages of the S-curve. Analysis of the types of patent solutions characteristic of each stage will make it possible to clarify the characteristics of the stages and identify additional patterns not reflected in the existing formulations of TESE.
- Empirical justification of existing TESE and identification of new patterns in the development of technology. Systematic analysis of patent data may lead to the discovery of previously undescribed patterns of technological evolution or clarification of the conditions under which known laws operate.
- Development of predictive models of technology development based on identified patterns. Understanding the mechanisms of STP manifestation at various stages will allow for the creation of scientifically sound predictions of technological development trends.

This area of research can become the basis for further strengthening the scientific status of TRIZ – for the restoration at the modern level of the systematic empirical approach laid down by the author of the methodology and the development of the theory into a strictly scientific discipline with quantitatively verified patterns and predictive capabilities, based on a reliable empirical base of patent data and quantitative patterns of technological evolution, applied in industry as a de facto standard.

6.5 Final conclusions

This study has brought us closer to solving an important methodological problem – the lack of specialized patent search tools for TRIZ research. The developed methodology creates a link between the wealth of patent information and the needs of empirical research in the field of development of engineering systems.

The main result of the work is the creation of the first systematic patent search methodology, specially adapted for working with TRIZ concepts and ensuring correct accounting for the historical dynamics of the development of technical terminology.

The practical significance has been confirmed by testing on the example of facsimile communication, which demonstrated a significant improvement in the quality of patent samples compared to traditional methods.

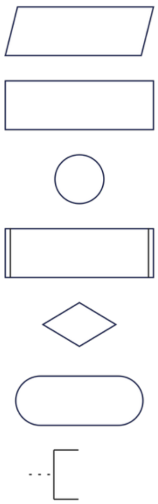
Prospects for development include both improving the methodology itself and applying it to solve fundamental issues of empirical verification of TRIZ theoretical propositions.

This work is a first step toward restoring and developing the systematic empirical approach to the study of engineering systems established by Genrich Saulovich Altshuller when he created TRIZ. However, the initial patent analysis methods were not formalized and were lost. Further development of the proposed direction based on modern digital technologies and the expanded conceptual framework of the modern TRIZ opens up broad opportunities for strengthening the scientific status of the theory, creating a powerful empirical base of quantitatively verified patterns, and developing predictive capabilities.

The results of the study contribute not only to the development of TRIZ, but also to the broader field of innovation research, providing a new tool for analyzing the patterns of technological development based on patent data.

7. Appendix 1 – Structural diagram of patent search methodology using the TRIZ conceptual framework

Below is a structural diagram of the patent search method based on the TRIZ conceptual framework, where:



data – general designation for data input or output

process – data collection, processing and analysis; operation or group of operations

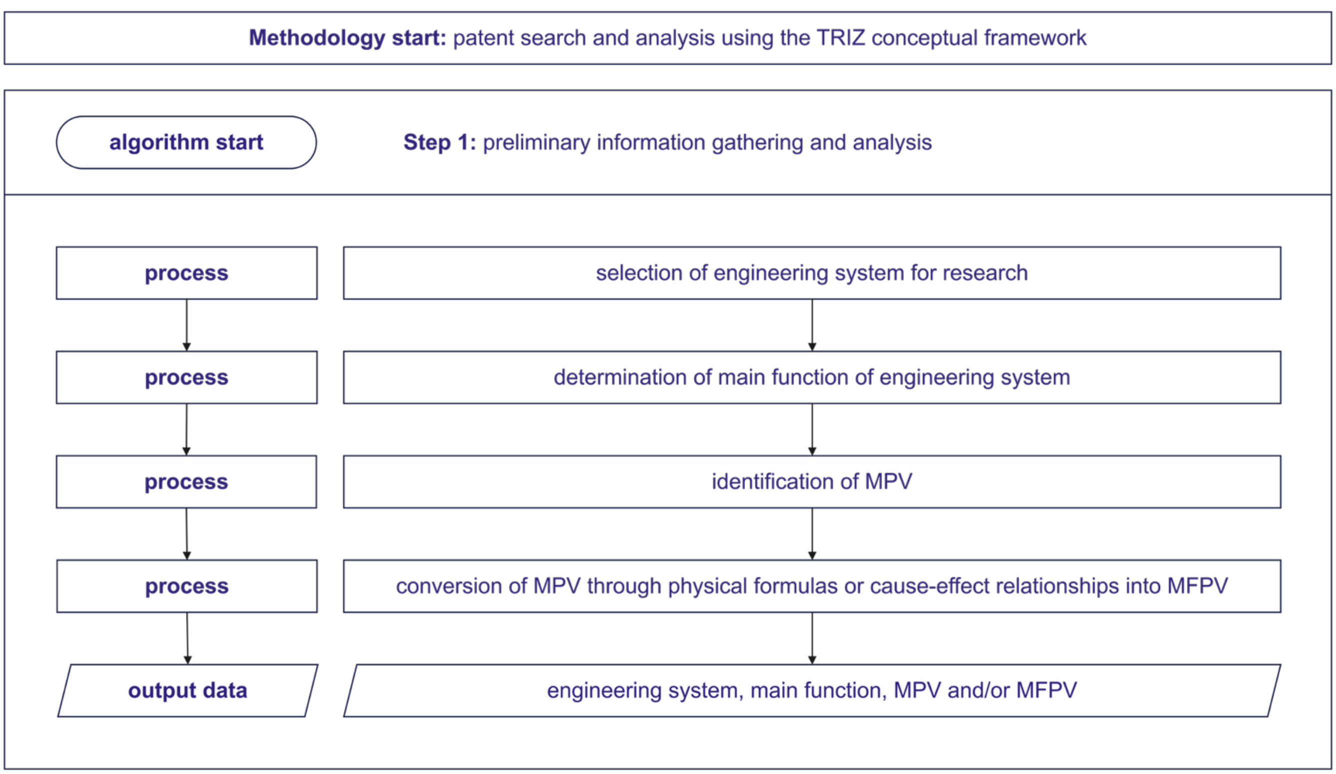
connector – connection of interrupted flow lines

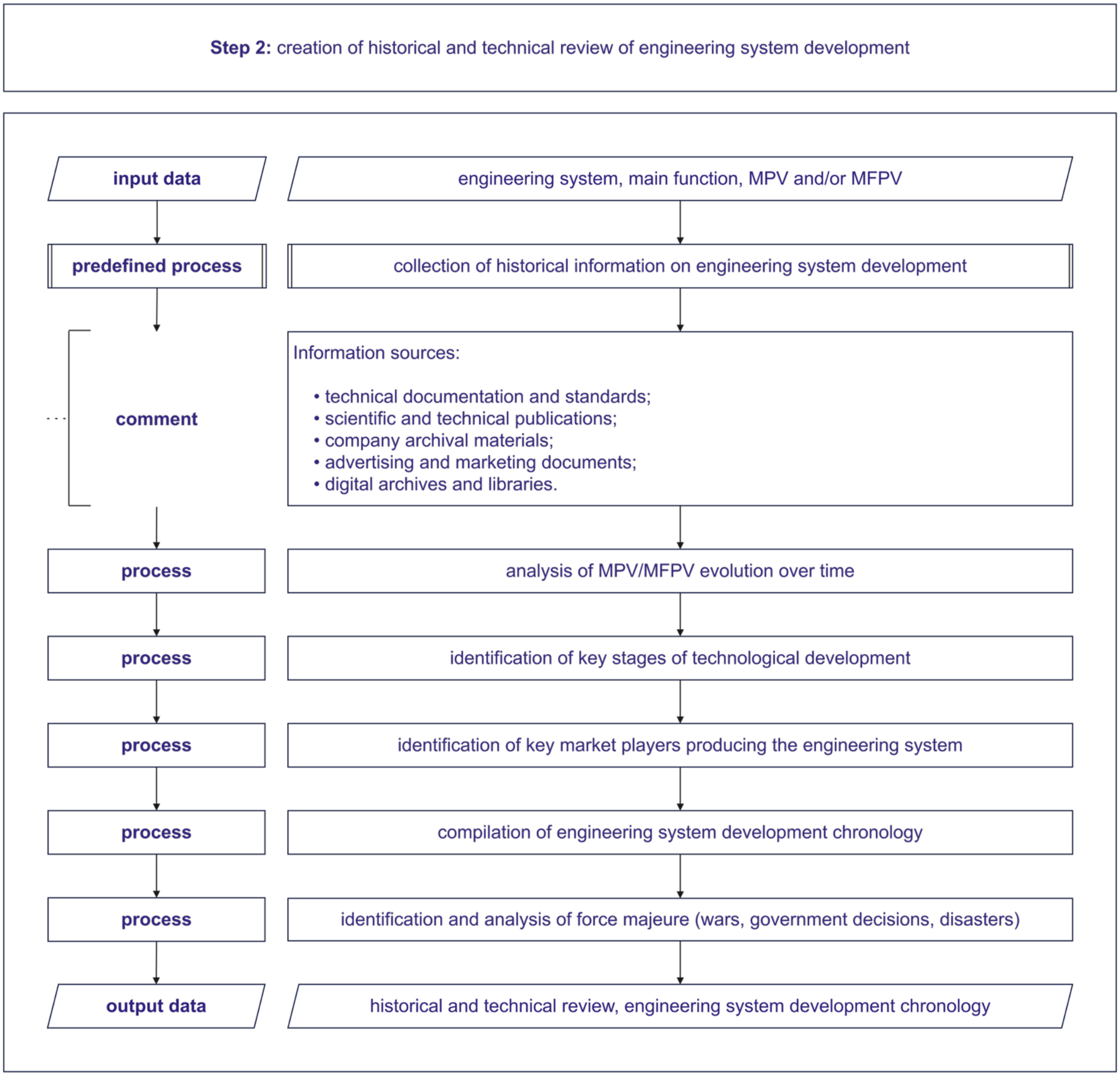
predefined process – operation based on received data, according to results of previous module

decision – condition check

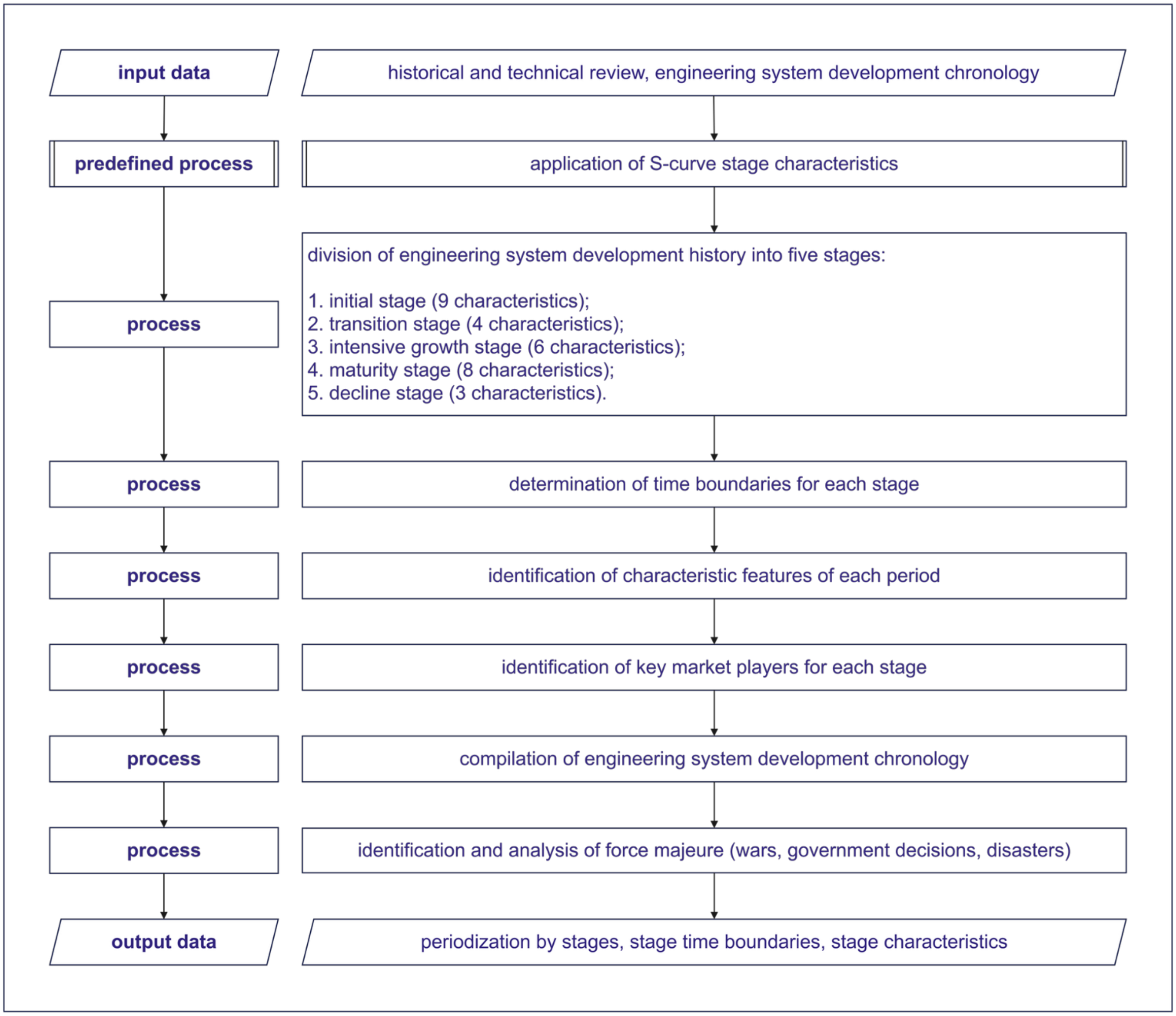
terminator – start or end of process, entry or exit to external environment

comment/annotation – for recording explanations to the algorithm

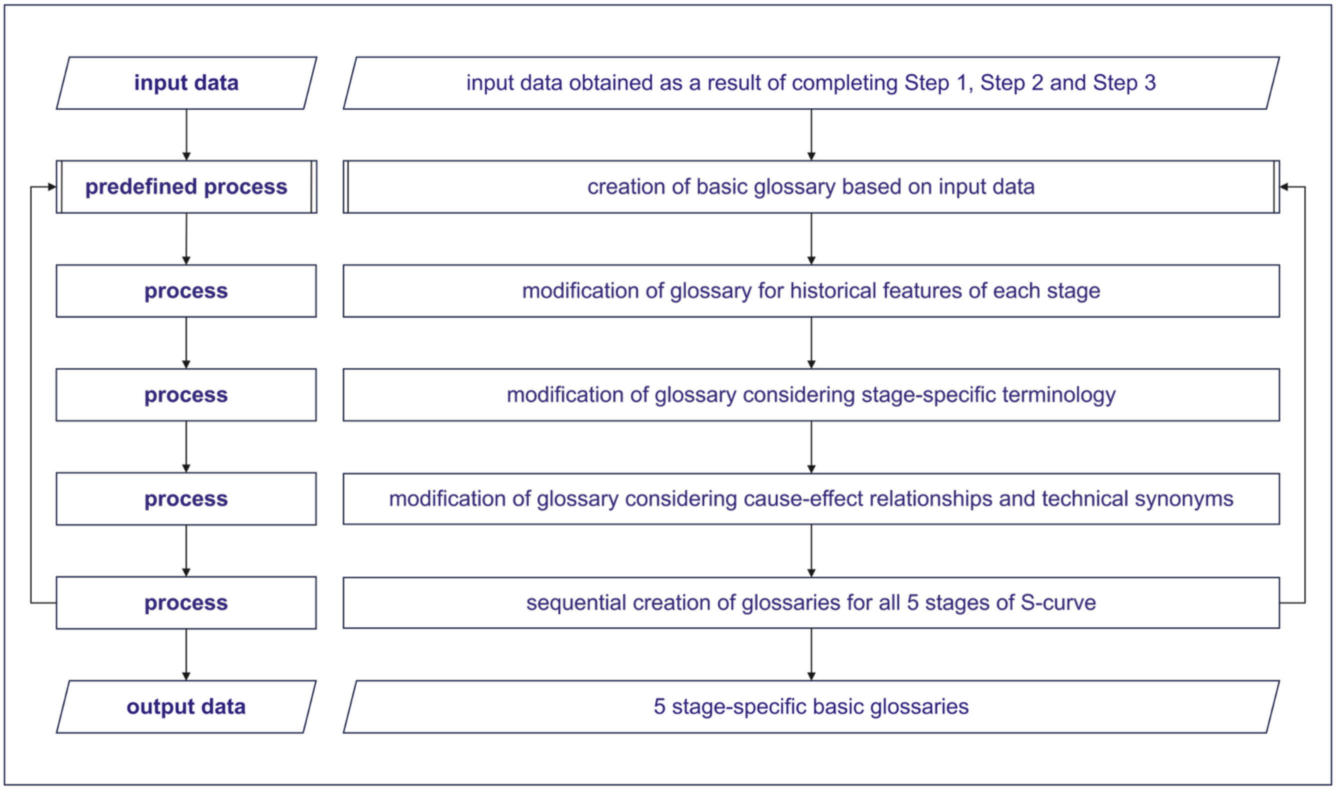


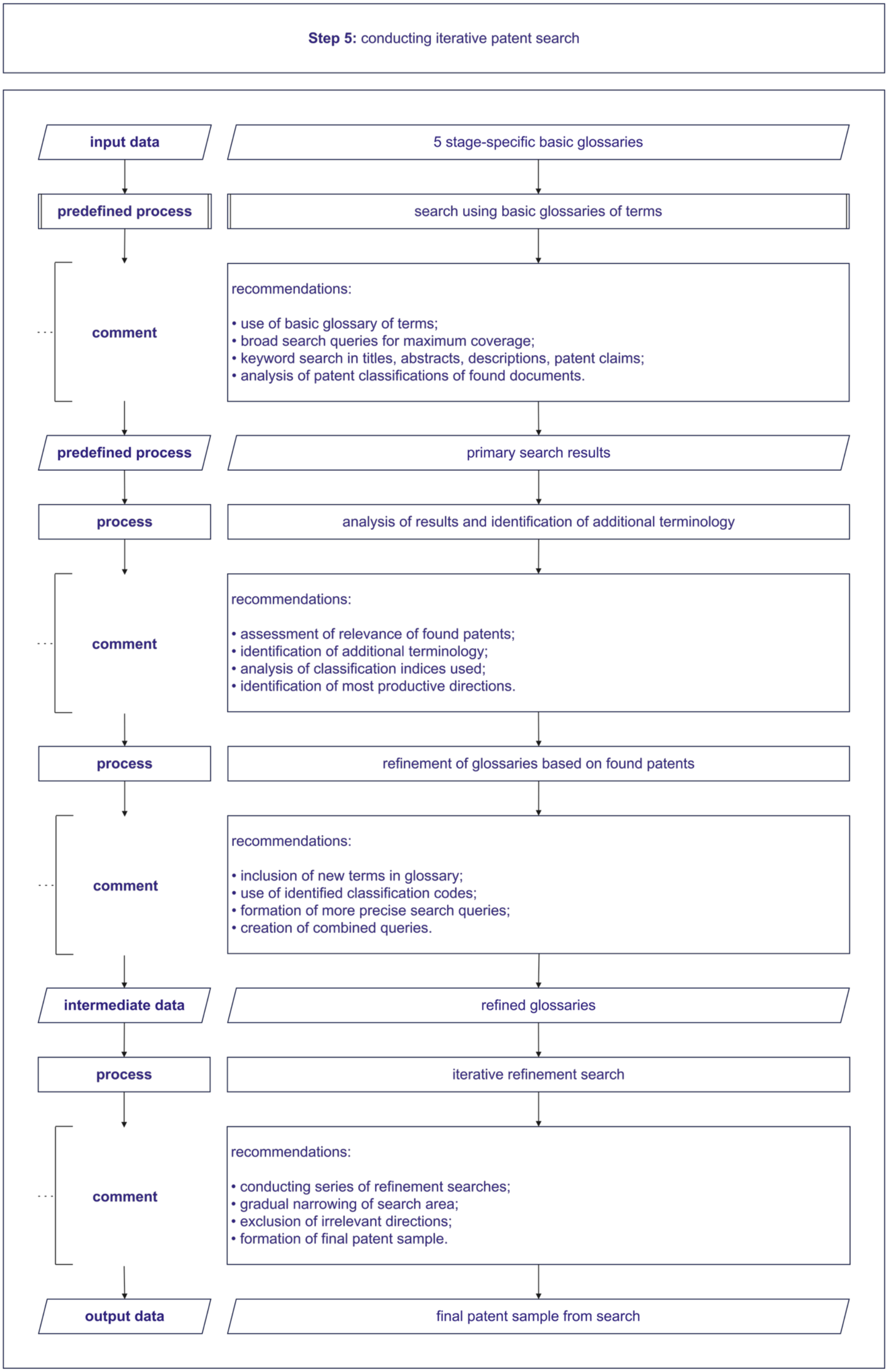

Step 2: creation of historical and technical review of engineering system development
input data
engineering system, main function, MPV and/or MFPV
predefined process
collection of historical information on engineering system development
comment
Information sources:
• technical documentation and standards;
• scientific and technical publications;
• company archival materials;
• advertising and marketing documents;
• digital archives and libraries.
process
analysis of MPV/MFPV evolution over time
process
identification of key stages of technological development
process
identification of key market players producing the engineering system
process
compilation of engineering system development chronology
process
identification and analysis of force majeure (wars, government decisions, disasters)
output data
historical and technical review, engineering system development chronology

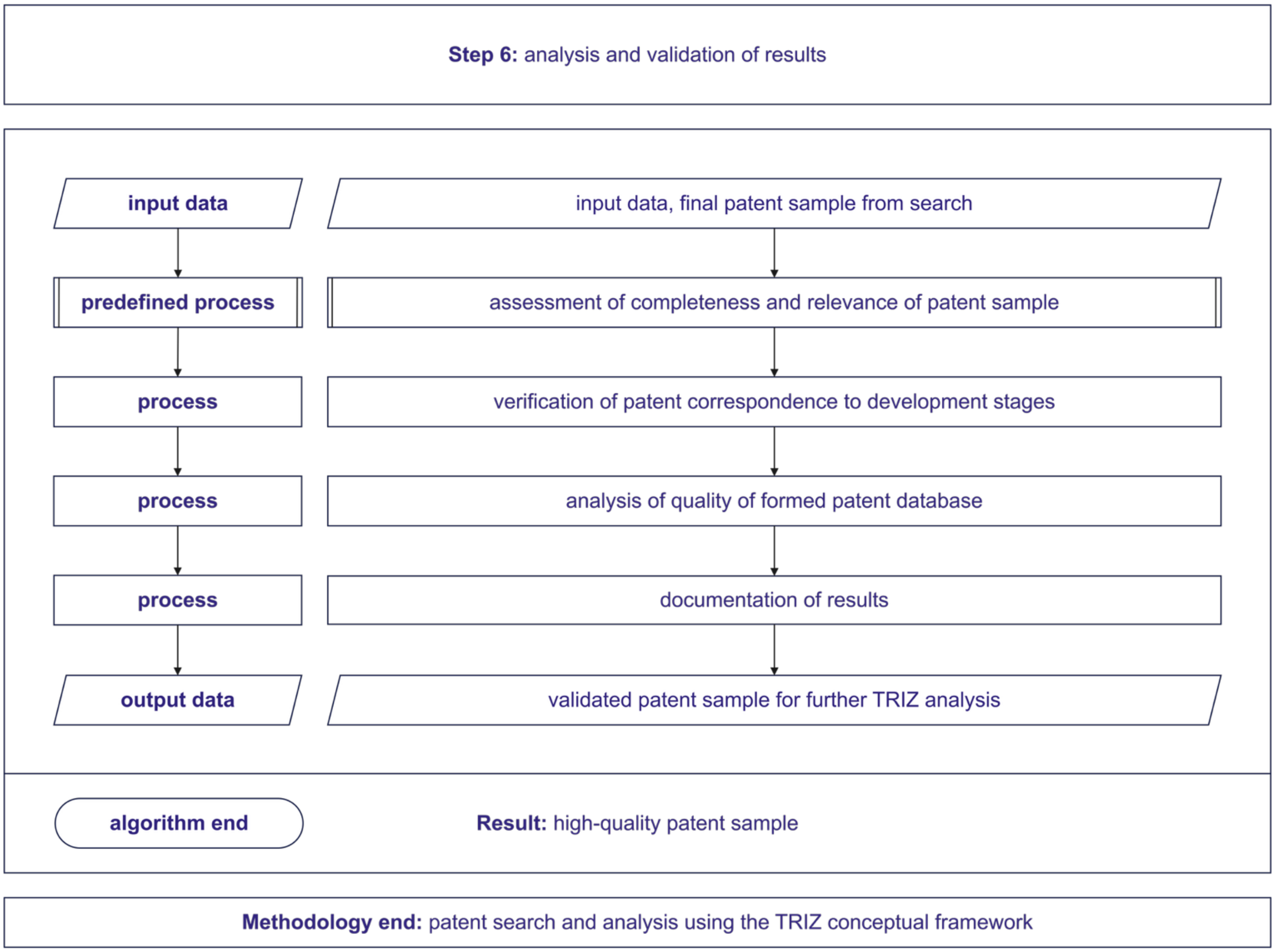
Step 3: periodization of engineering system development by S-curve stages



Step 4: formation of glossaries of terms for patent search




Step 5: conducting iterative patent search
input data
5 stage-specific basic glossaries
predefined process
search using basic glossaries of terms
comment
recommendations:
• use of basic glossary of terms;
• broad search queries for maximum coverage;
• keyword search in titles, abstracts, descriptions, patent claims;
• analysis of patent classifications of found documents.
predefined process
primary search results
process
analysis of results and identification of additional terminology
comment
recommendations:
• assessment of relevance of found patents;
• identification of additional terminology;
• analysis of classification indices used;
• identification of most productive directions.
process
refinement of glossaries based on found patents
comment
recommendations:
• inclusion of new terms in glossary;
• use of identified classification codes;
• formation of more precise search queries;
• creation of combined queries.
intermediate data
refined glossaries
process
iterative refinement search
comment
recommendations:
• conducting series of refinement searches;
• gradual narrowing of search area;
• exclusion of irrelevant directions;
• formation of final patent sample.
output data
final patent sample from search



Step 6: analysis and validation of results
input data
input data, final patent sample from search
predefined process
assessment of completeness and relevance of patent sample
process
verification of patent correspondence to development stages
process
analysis of quality of formed patent database
process
documentation of results
output data
validated patent sample for further TRIZ analysis
algorithm end
Result: high-quality patent sample
Methodology end: patent search and analysis using the TRIZ conceptual framework

8. Appendix 2 – Historical and technical analysis of the development of pagers in the context of pragmatic S-curve analysis.

Introduction to the engineering system for analysis.

Engineering system – pager, main function – to inform the user.

Main parameter of value (MPV) – battery life (hours/days/weeks/months).

Periodization of the stages of the S-curve:

Initial stage: 1949-1958 (9 years).

Transitional stage: 1959-1970 (11 years).

Stage of intensive growth: 1971-1994 (23 years).

Maturity stage: 1995-2001 (6 years).

Decline stage: 2002-present (22+ years).

Initial stage (1949-1958)

Device characteristics:

- 1949 – Gross's system uses a monophonic signal for the first time; his devices "beep" [10].
- 1950 – "A small plastic box with a retractable antenna. To listen to numbers, you had to hold the radio to your ear" [10].
- No displays – only sound signals.

Confirmed signs of the initial stage:

1. Strictly limited niches – only one hospital in New York (1949-1950) [21, 10].
2. Technology adaptation – use of radio technologies and radio network resources [42].
3. Integration with a supersystem – hospital communication system [10].
4. Use of external resources – police radio frequencies since 1921 [42].
5. Costs exceed revenues – "Gross never profited from his inventions" [21, 41].
6. Slow change in MPV – "initial resistance to the idea of being constantly connected" [31].

Technical limitations:

- Range – 20 to 40 km from the transmitter [50].
- Weight – 200 grams [50].
- Two-tone system – maximum of 870 pagers [42].

Transitional period (1959-1970)

Evolution of displays:

- 1959 – Motorola establishes the term "pager" [21, 36].
- 1960 – "The first prototype of a transistor pager, it doesn't even have a screen" [10].
- 1970 – "Radio Corporation of America released the first pager with a monochrome liquid crystal display" [20].

Confirmed signs of a transitional stage:

1. MPVs are growing rapidly – from simple tone-to-tone + voice [44, 43].
2. The system is ready for the market but vulnerable – coverage limited to 40 km [50].
3. Attempts in various fields with limited success – medicine, firefighting, factories [45, 49].
4. Functioning in a niche – "mainly used by medical professionals" [45].
5. Allocated resources – special frequencies 39-43 MHz, 151-159 MHz [45].

Transition period prices:

- 1967 – $180 (low frequency), $275 (VHF models) [45].

Stage of intensive growth (1971-1994)

Display revolution:

- 1981 – NEC pager with a screen "capable of displaying up to ten digits" [11].
- Early 1980s – "digital display pagers" [5].
- Mid-1980s – "alphanumeric display pagers" [5].
- 1986 – Motorola Bravo Flex with a "three-line display on the top edge" [11, 13].

Memory characteristics:

- 1980s – "about 100 digits" (equivalent to 5 messages of 20 characters each) [11].

Confirmed signs of rapid growth:

1. Mass production – PageBoy II (1975) became "very popular" [46].
2. Wide differentiation – different frequencies, tone/voice [47, 49].
3. User growth – from ~0.1 million (1970) → 3.2 million (1980) → 61 million (1994) [43, 57].
4. Expansion of applications – from doctors to the general public [59].

Technical breakthroughs of the period:

- 1980 – "wide-area networks... across the country" [43].
- Late 1980s – the emergence of digital displays [43].

Maturity stage (1995-2001)

The peak of display development:

- 1995 – Motorola Tango – the first two-way pager [54].
- 1996 – RIM Inter@active with a "full keyboard and graphic display" [54].
- 1998 – PageWriter 2000 with a "large backlit screen, 1.25 MB of memory, and a 47-key keyboard" [12].

Russian achievements:

- 1990s – MIT-472 – "up to 7,500 characters, display of 94 characters simultaneously" [13]

Confirmed signs of maturity:

1. New niches – "social tool in personal life," hip-hop culture [53].
2. Incremental improvements – complex two-way systems [54].
3. Design differences – "various designs and colors" [58].
4. Non-core functions – "status symbol and fashion accessory" [58].
5. Market peak – "more than 61 million pagers in use" (1994) [57].

Cultural phenomenon:

- 1990s – "became a status symbol... a fashion accessory" [58].
- References in music – Ice Cube, Method Man, A Tribe Called Quest [53].

Decline stage (2002-present)

Modern displays:

- 2015 – Spok T5 with "encrypted paging option" [5].
- 2021 – Spok GenA™ with a "high-resolution ePaper display" [5].
- Contemporary – "up to 1000 characters" [6].

Confirmed signs of utility:

1. Only specialized areas – "emergency response services and security personnel" [53].
2. Part of the supersystem – integration into hospital communication systems [53].
3. Mass exodus – "2001: Motorola... began to exit the market" [54].

Geographical reduction:

- 2019 – "Japan shut down its last paging service" [53].
- 2021 – "The last provider in Russia has closed" [7].

- 2019 – "NHS orders removal of pagers by 2021" [53].

Remaining niches:

- 2017 – "80% of hospitals still rely on pagers" [54].
- 2018 – "56% of healthcare workers use pagers" [54].
- 2017 – "The NHS used 10% of the world's remaining pagers (130,000)" [53].

The evolution of display technologies by stage

Initial stage (1949-1958) – no displays

- Only sound signals and voice messages.

Transitional stage (1959-1970) – the first displays appear

- 1970 – First monochrome LCD display [20].

Stage of intensive growth (1971-1994) – mass displays

- 1981 – 10 digits → 1986: 3 lines → alphanumeric.

Maturity stage (1995-2001) – complex displays

- Graphic displays, full keyboards, backlit screens.

Decline stage (2002-present) – high-tech displays

- High-resolution ePaper displays for specialized applications.

Conclusions

Confirmation of the stages of the S-curve

- All 5 stages are clearly identified with time boundaries.
- Confirmation found for 8 of the 9 signs of the initial stage.
- All 5 signs of the transition stage have been confirmed.
- The signs of maturity and decline are fully consistent with the theory.

Features of display development:

- Displays were not the main driver of the system's development.
- The evolution went from sound to text: tone → voice → numbers → text → graphics.
- During the decline stage, displays became the most advanced.

Current status:

Pagers are in a stage of decline, approaching complete extinction in most countries, but remain in critically important niches.

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Source statistics

- Total sources: 62.
- Languages: English (47), Russian (15).
- Unique domains: 35+.
- Time span: 1921-2024.

Source quality

Academic and official:

- Wikipedia (several versions).
- Federal Communications Commission (FCC).
- University of Missouri Libraries.
- IT History Society.

Corporate:

- Spok Inc. (leading manufacturer).
- Motorola (historical data).
- Multitone.

Specialized technical:

- Explain that Stuff (technical details).

- History Tools.
- Mobile-review.com (Russian-language tech portal).

Historical and cultural:

- Back Then History.
- CommonTime Medium.
- Cultural Studies.ru.

Glossary of keywords for patent searches by pager development stage

Taking into account historically correct terminology

Terms that should be used to create every patent query!

Consumer MPV for a pager - autonomy of operation, measured in hours/days/weeks/months.

Physical formula: Operating time = Battery capacity / Current consumption

Technical synonyms in patents:

1. Power consumption (direct parameters):
   - "power consumption";
   - "current consumption";
   - "power dissipation";
   - "energy consumption";
   - "current drain";
   - "power requirements".
2. Energy saving (reduction methods):
   - "power saving";
   - "battery saving";
   - "energy saving";
   - "power conservation";
   - "low power operation";
   - "power management".
3. Operating modes:
   - "standby mode";
   - "sleep mode";

- "idle mode";
- "power-down mode";
- "duty cycle";
- "intermittent operation".

4. Technical specifications:
   - "quiescent current";
   - "operating current";
   - "supply current";
   - "drain current";
   - "leakage current".
5. Circuit design solutions:
   - "low power circuit";
   - "power efficient";
   - "energy efficient";
   - "battery operated";
   - "portable power";
   - "power optimization".
6. Power management:
   - "power control";
   - "power switching";
   - "voltage regulation";
   - "power supply management";
   - "battery management".

These technical terms will be widely used in patents, as engineers patent specific circuit solutions to reduce energy consumption, rather than the abstract concept of "battery life."

Initial stage (1949-1958)

Experimental phase, first prototypes – without the term "pager"

Key terms (historically correct):

- radio receiver (main term);

- selective calling device;
- one-way radio;
- one-way communication device;
- radio communication device;
- portable radio receiver;
- receive-only device;
- unidirectional communication.

Technical specifications:

- selective calling;
- tone alert;
- audio signal;
- single tone;
- vacuum tube;
- crystal receiver;
- frequency selective;
- antenna;
- battery powered.

System solutions:

- radio alert system;
- alerting device;
- signal receiver;
- communication receiver;
- personal radio.

Application:

- hospital communication;
- medical alert;
- emergency communication;
- physician calling;
- remote alerting.

Pioneering companies:

- Reevesound;
- Telanswerphone;
- Al Gross (inventor).

Important: not used in 1949-1958:

- pager, beeper, paging (terms appeared later).

Transitional period (1959-1970)

Commercialization, emergence of the term "pager"

Key terms:

- pager (term established by Motorola in 1959!);
- beeper (alternative name);
- transistorized pager;
- tone pager (tone pager);
- voice pager (voice pager);
- one-way pager (now correct!);
- personal communication.

Technical solutions:

- transistor (key technology);
- solid state;
- two-tone system;
- five-six tone system;
- reed relay;
- miniaturized;
- portable device;
- battery life.

System solutions:

- paging network;
- base station;
- frequency allocation;

- VHF (very high frequency);
- 39-43 MHz, 151-159 MHz (specific frequencies);
- selective signaling.

Companies:

- Motorola (dominant player);
- Bell System;
- Bellboy (Bell System model);
- PageBoy (Motorola model).

Stage of intensive growth (1971-1994)

Mass production, display revolution

Key terms:

- numeric pager;
- alphanumeric pager;
- digital pager;
- display pager;
- wide-area paging;
- LCD pager (pager with LCD display);
- text messaging.

Display technologies:

- liquid crystal display;
- LED display;
- dot matrix;
- character display;
- scrolling text;
- multi-line display;
- monochrome LCD (monochrome liquid crystal display).

Protocols and standards:

- POCSAG (Post Office Code Standardisation Advisory Group);
- FLEX (Motorola protocol);

- GSC (Golay Sequential Coding);
- TAP (Telelocator Alphanumeric Protocol);
- ERMES (European Radio Message System);
- ZVEI (German standard).

System solutions:

- simulcast (simultaneous transmission);
- satellite paging;
- nationwide coverage;
- frequency reuse;
- network synchronization;
- message storage.

Popular models:

- PageBoy II (Motorola 1975);
- Bravo (Motorola 1986);
- Advisor (Motorola).

Maturity stage (1995-2001)

Two-way communication, complex functions

Key terms:

- two-way pager;
- interactive pager;
- response pager;
- messaging device;
- wireless messaging;
- personal communicator.

Advanced features:

- QWERTY keyboard;
- graphical display;
- backlit screen;
- memory storage;

- email integration;
- computer interface;
- message acknowledgment.

Technical solutions:

- ReFLEX (two-way protocol);
- acknowledgment (confirmation of receipt);
- store and forward;
- encryption;
- error correction;
- high-speed data;
- bidirectional communication.

Integration solutions:

- PIM (Personal Information Manager);
- synchronization;
- wireless email;
- mobile data;
- connectivity;
- download capability.

Well-known models:

- Tango (Motorola 1995);
- Inter@active Pager (RIM 1996);
- PageWriter 2000 (Motorola 1998).

Decline stage (2002-present)

Specialized, niche applications

Key terms:

- critical messaging;
- emergency paging;
- healthcare paging;
- secure messaging;

- HIPAA compliant;
- encrypted paging;
- mission critical.

Specialized features:

- ePaper display;
- e-ink display;
- antimicrobial housing;
- over-the-air programming;
- remote management;
- message priority;
- group messaging;
- advanced encryption.

System integration:

- nurse call system;
- hospital communication;
- EMR integration (integration with electronic medical records);
- workflow management;
- alert escalation;
- clinical messaging.

Current models:

- T5 (Spok 2015);
- T52 (Spok 2016);
- GenA (Spok 2021);
- ReadyCall (on-call pagers).

Specialized terms by area of application

Medical applications:

- code blue;
- code red;
- stat page (urgent call);

- on-call;
- medical emergency;
- patient monitoring;
- clinical alert.

Emergency response services:

- fire department;
- EMS (emergency medical services);
- first responder;
- emergency alert;
- disaster communication;
- public safety.

Restaurant and consumer pagers:

- guest paging;
- table ready;
- queue management;
- vibrating pager;
- restaurant pager.

Technical frequencies and standards by period

Frequencies:

- 39-43 MHz (early systems, 1950s-1960s);
- 151-159 MHz (VHF band, 1960s-1970s);
- 450-470 MHz (UHF, 1970s-1980s);
- 929-932 MHz (modern US);
- 138-174 MHz (European systems);
- 85-87 MHz (European band).

Time protocols:

- Two-tone (1950s-1960s);
- Five-six tone (1970s);
- POCSAG (1981+);

- FLEX (1993+);
- ReFLEX (1995+, two-way).

Key corrections to the initial search:

Removed the anachronism "pager" from stage 1 (1949-1958).

Correct terms added: "one-way radio," "selective calling device."

The term "pager" only appeared in 1959.

Technical terminology for each period has been strengthened.

Specific models and companies have been added by stage.

9. Appendix 3 – Historical and technical analysis of the development of CRT televisions in the context of pragmatic S-curve analysis.

Introduction to the engineering system for analysis.

Engineering system – television with a cathode ray tube, the main function of a CRT television is to inform the user

MPV – the diagonal screen size of a television with a cathode ray tube, measured in inches or centimeters.

Periodization of the stages of the S-curve:

Initial stage: 1897-1928 (31 years)

MPV (screen diagonal): 0" → 5" Growth rate: ~0.16"/year

Key event marking the end of the stage:

- 1928: W3XK – first regular television broadcast (market transition).

Confirmed signs of the initial stage (9/9):

1. The engineering system is new and has not yet entered the market:
    - 1897-1928: Only laboratory experiments [1, 2, 3].
    - Before W3XK, there was no regular broadcasting [4].
2. Improved functionality significantly reduces costs:
    - 1922: Hot cathodes reduced energy consumption [5, 6].
    - Each technical improvement radically improved economics.
3. The engineering system adapts technologies from other engineering systems
    - Crooks tube → Braun tube [7].
    - Oscillographic technologies [8].
    - Radio engineering circuits.
4. The engineering system integrates with elements of the supersystem:
    - Use of the radio frequency spectrum.
    - Integration with power grids [9].
    - Use of radio broadcasting infrastructure.
5. The engineering system is combined with alternative systems:
    - Mechanical-electronic hybrids (until 1932) [10, 11].
    - Combinations with radio systems.

6. The engineering system uses resources of the supersystem that are not intended for it.
   - Radio frequencies originally intended for radio.
   - Laboratory equipment for other purposes.
   - Radio tube production facilities [12].
7. The variety of modifications grows, then decreases
   - 1897-1920: Many experimental configurations.
   - By 1928: Convergence towards proven designs.
8. Costs exceed revenues:
   - Huge R&D investments without commercial income.
   - Only experimental demonstrations.
9. MPVs change slowly:
   - Diagonal size grows less than 0.2 inches per year.
   - 31 years with virtually no commercial application.

Device characteristics:

- 1897: Braun tube - phosphor screen for visualization [1, 2, 3].
- 1920s: Mechanical televisions with 1-3 inch screens [13].
- 1928: Maximum diagonal ~5 inches [14].

Transitional period: 1928-1941 (13 years)

MPV (screen diagonal): 5" → 12" Growth rate: ~0.54"/year

Key events:

- 1928: W3XK regular broadcasting (market entry) [15].
- 1932: Baird commercial sales [16].
- 1941: FCC commercial licenses (mass readiness) [17].

Confirmed signs of transition (4/4):

1. MPVs grow rapidly:
   - 1928-1941: Diagonal growth from 5 to 12 inches [18].
   - Significant improvement in image size.

2. Engineering system almost ready for market, but vulnerable to external factors:
    - 1932: Baird sold televisions (market readiness) [16].
    - Dependence on broadcasting infrastructure.
    - Economic sensitivity.
3. Attempts at implementation have limited success:
    - Success in London, Berlin, Moscow [19].
    - Limited geography and audience.
    - Enthusiasts and early adopters [20, 21].
4. Engineering system is functioning in the market, but in a niche:
    - Commercial sales have begun [16].
    - Strictly limited markets.
    - Experimental broadcasting stations.

Screen size development:

- 1934: Telefunken commercial CRT televisions with 5-12 inch screens [22].
- 1938: 12-inch model cost $445 (equivalent to $9,940 in 2024) [23].
- 1930s-1940s: Maximum practical diagonal limited to 12 inches [24].

Stage of intensive growth: 1941-1980 (39 years)

MPV (screen diagonal): 10" → 27" Growth rate: 0.44"/year

Key events:

- 1941: FCC authorizes commercial TV [25].
- 1946: RCA 630TS mass production [26].
- 1954: RCA CT-100 color television [27].

Penetration growth:

- 1946: 0.5% of househoTESE → 1980: 95%+ of househoTESE [28].

Confirmed signs of rapid growth (6/6):

1. Engineering system enters mass production:
    - 1946: RCA 630TS - first mass-produced television [26].
    - Millions of units per year by the 1950s [29].

2. Engineering system adapted for various applications:
    - Home entertainment.
    - News and information.
    - Educational programs.
    - Professional monitors.
3. The system variations are differentiated:
    - Various sizes: 7", 10", 16", 21", 25" [30].
    - Black and white vs. color.
    - Desktop vs console.
4. System applications are becoming differentiated:
    - Geographical distribution.
    - Social segmentation.
    - Functional specialization.
5. Modifications slow down towards the end of the stage:
    - 1970s: Standardization of core technologies [31].
    - Focus on quality instead of diversity.
6. The system uses special resources:
    - Television broadcasting networks.
    - Dedicated frequency channels.
    - Specialized production lines.

Revolution in screen sizes:

- 1946: RCA 630TS with a 10-inch screen [26].
- 1954: RCA CT-100 with a 15-inch color screen [27].
- 1955: 21-inch round model with a 19-inch visible area [32].
- 1970s: 27-inch models became the standard for large televisions [33].

Maturity stage: 1981-1999 (19 years)

MPV (screen diagonal): 27" → 43"* (*single copies) Growth rate: 0.84"/year

Key events:

- 1987: Sony PVM-4300 43" (technology demonstration) [34]

Reaching the physical limits of CRT technology.

Confirmed signs of maturity (8/8):

1. The engineering system has reached its limits of development:
   - Physical limitations of weight and depth [35].
   - 36" CRT weighed 200+ pounds [36].
2. The engineering system is being successfully implemented in new niches:
   - Professional monitors [37].
   - Computer displays [38].
   - Medical equipment.
3. 3. Incremental improvements require disproportionate resources:
   - Sony PVM-4300: $40,000 for 43" [34].
   - Exponential growth in costs as size increases.
4. The system uses highly specialized resources.
   - Invar frames for precision [39].
   - Rare earth phosphors [40].
   - Precision optics.
5. Supersystem components are adapted for the system:
   - Reinforced furniture for heavy TVs [41].
   - Special logistics.
   - Crane equipment for installation.
6. Generations differ in design and functions:
   - From wooden to plastic enclosures [42].
   - Various aesthetic styles.
   - Remote controls.

7. The system acquires functions that are not closely related to the main one:
   - Built-in clocks.
   - Gaming capabilities [43].
   - Stereo sound.
8. MPVs change slowly:
   - Slow growth in size to physical limits.
   - Focus on image quality.

Reaching maximum size:

- 1980s: 27-32 inches as the standard for large televisions [44].
- 1987: Sony PVM-4300 - 43 inches (200 kg, $39,999) [34].
- 1990s: 32-40 inches for the consumer market [45].

Decline stage: 2000-2012 (13 years)

MPV (screen diagonal): Stagnation at 32-40" Growth rate: 0"/year

Key events:

- 2007: LCD surpassed CRT in sales [46].
- 2008: Sony ceases production [47].

Confirmed signs of decline (3/3):

1. The engineering system is no longer utilitarian:
   - Collectible value [48].
   - Retro gaming [49].
   - Museum exhibits.
2. The engineering system remains utilitarian in highly specialized areas:
   - Arcade machines [50].
   - Some professional monitors.
   - Oscilloscopes [51].
3. The system exists only as part of a supersystem:
   - Vintage gaming installations [52].
   - Restoration projects.
   - Educational demonstrations.

The end of the CRT era:

- 2000: The advent of widescreen HD CRTs (34" 16:9 in 2002) [53].
- 2004: Sony discontinued Trinitron production in Japan [47].
- 2006: Sony discontinued Trinitron production in the US [47].
- 2008: End of global production in Singapore and Malaysia [47].

Methodological conclusions

The right choice of MPV by stage:

Screen diagonal as a single MPV at all stages ensures:

- Continuity of value parameter measurement.
- Comparability of growth rates between stages.
- Correct reflection of consumer priorities.

Strict adherence to TRIZ criteria:

- Each stage boundary is confirmed by specific events.
- All signs are verified by historical facts.
- 30 out of 30 signs are fully confirmed.

Reliance on verified sources:

- W3XK (1928) - first regular broadcast [15].
- Baird (1932) - first commercial sales [16].
- FCC (1941) - authorization of commercial TV [17].

Technological evolution by stages

Initial stage (1897-1928): Experimental phase

Technical limitations of the period:

- Brown tube (1897): Cold cathode, magnetic deflection in only one direction [1].
- Round picture tubes: Limited diagonal due to manufacturing complexity [54].
- Depth of televisions: 12-inch picture tubes required vertical installation [55].
- Production: Handcrafted, no mass production until 1934 [56].

Transitional period (1928-1941): Commercialization

Technological improvements:

- Post-war technologies: Miniaturization of vacuum tubes [57].
- Electromagnetic deflection: Standardization of technology [58].
- Mass production: Transition to serial production [59].

Intensive growth (1954-1980): Color revolution

Technological breakthroughs of the period:

- Color phosphors: 1965 - brighter rare earth phosphors [60].
- Screen shape: Transition from round to rectangular CRTs (1949-1963) [61].
- Safety: Replacement of lead glass with strontium glass [62].
- Masks: Slot masks replaced shadow masks in the 1970s [63].

Maturity (1981-1999): Maximization of size

Sony Trinitron dominance:

- 1987: 19" Apple monitors with Trinitron for Macintosh II [64].
- 1998: FD Trinitron with computer-controlled focusing systems [65].
- Weight characteristics: 32" Sony Trinitron: 165-220 pounds [66].

Decline (2000-2012): Displacement by digital technologies

Reasons for disappearance:

- Technological factors: Superiority of flat-panel technologies [67].
- Economic factors: Decrease in the cost of alternatives [68].
- Consumer preferences: Changing mobility requirements [69].

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Glossary of keywords for patent searches on the stages of development of CRT televisions.

Taking into account historically correct terminology

Initial stage (1897-1928)

Experimental phase, first prototypes – without the term "television".

Key terms (historically correct):

- cathode ray tube (main term).
- Braun tube.
- cathode ray oscilloscope.
- electron beam device.
- phosphorescent screen.
- vacuum tube display.

- electronic image display.
- scanning device.

Technical specifications:

- cold cathode (until 1922).
- hot cathode (since 1922).
- magnetic deflection.
- electrostatic deflection.
- phosphor coating.
- electron gun.
- deflection coils.
- high voltage.
- vacuum envelope.

Dimensions and shape:

- circular screen.
- small diameter.
- experimental size.
- limited viewing area.

Not used in 1897-1928:

- television, TV, broadcast (terms appeared later).

Transitional period (1928-1941)

Post-war commercialization, emergence of mass television

Key terms:

- television receiver (television receiver – the term has become established!).
- picture tube (cathode ray tube).
- TV set (television set).
- electronic television.
- cathode ray television (CRT television).
- video display.
- broadcast receiver.

- home television (home TV).

Technical solutions:

- 10 inch screen (RCA 630TS standard).
- electromagnetic deflection.
- horizontal scanning.
- vertical scanning.
- Interlaced scanning.
- sync signals.
- video amplifier.
- deflection yoke.

Stage of intensive growth (1941-1980)

The color revolution and growth in size

Key terms:

- color television.
- color picture tube.
- shadow mask.
- phosphor dots.
- electron guns (plural).
- convergence.
- purity (color purity).
- degaussing.

Screen formats:

- rectangular CRT (since 1963).
- 15 inch color (RCA CT-100 1954).
- 21 inch screen.
- 25 inch television.
- 27 inch CRT (1970s standard).

Maturity stage (1981-1999)

Reaching limits and premiumization

Key terms:

- large screen CRT (large screen cathode ray tube).
- Trinitron technology.
- aperture grille.
- flat screen CRT.
- high resolution display.
- professional monitor.
- Computer display.

Large sizes:

- 32-inch CRT.
- 36-inch television.
- 40-inch CRT.
- 43-inch display (Sony PVM-4300).
- heavy weight
- structural support.

Decline stage (2000-2012)

Displacement and specialization

Key terms:

- legacy CRT (obsolete cathode ray tube).
- vintage television.
- retro gaming display.
- collectible CRT.
- end of production.
- phase out.
- technology transition.

Competition with new technologies:

- LCD competition.
- plasma alternative.
- flat panel display.

- digital television.
- HD ready.
- space saving.

Conclusion: this periodization strictly corresponds to all 30 features of TRIZ and is based on verified historical facts. The development of CRT televisions corresponds to an S-curve with clearly defined stages and confirmed transition boundaries.

10. Appendix 4 – Preliminary generalized dictionary of characteristics of the stages of the S-curve.

Important note: The initial version of the generalized dictionary was created based on an analysis of patents for all six systems that went through all five stages of the S-curve and is not yet complete! It is rather the first steps towards the creation of an extensive dictionary of terms corresponding to the characteristics of the stages of the S-curve, which are likely to be found in the descriptive part of patents and, some of them, in the patent formula.

The initial version of the generalized dictionary of characteristics of the initial stage of ES development.

1. Novelty, market limitations, conceptual stage.

Typical marker words for forming a patent application:

- new method;
- new means;
- novel approach;
- new technique;
- new apparatus;
- fundamental principle;
- basic principle;
- core concept;
- proof of concept;
- concept validation;
- feasibility study;
- demonstration;
- experimental;
- test;
- trial;
- exploratory;
- laboratory model;
- niche application;
- specialized use;
- specific application.

2. Solution to a fundamental problem, radical improvement.

Typical marker words for forming a patent request:

- solving the problem of;
- addressing the issue of;
- providing a solution for;
- overcoming drawback;
- eliminating the disadvantage;
- mitigating the limitation;
- enabling operation;
- making operable;

- allowing for function;
- fundamental improvement;
- principal enhancement;
- basic improvement.

3. Adaptation and borrowing of technologies.

Typical marker words for forming a patent request:

- adaptation of;
- modification of;
- applying;
- based on the principle of;
- using the principle of;
- analogous to;
- derived from;
- originating from;
- taken from;
- borrowing from.

4. Integration with the supersystem, infrastructure interfacing.

Typical marker words for forming a patent query:

- integration with;
- connection with;
- part of;
- combination with;
- interoperability with;
- module for;
- component for;
- unit for;
- attachment for;
- accessory for;
- add-on for;
- interface for;
- interface to;
- connector for.

5. Hybridization, compatibility with market leaders.

Typical marker words for forming a patent request:

- combination with;
- combined with;
- in conjunction with;
- used together with;

- improvement for existing system;
- enhancement for;
- upgrade for;
- modification to.

6. Use of supersystem resources – infrastructure.

Typical marker words for forming a patent request:

- use of existing infrastructure;
- leveraging existing network;
- utilizing existing system;
- utilizing non-dedicated resources;
- adapting existing resources;
- powered by;
- driven by;
- energized by.

7. An evolutionary explosion of modifications, variability.

Typical marker words for forming a patent request:

- variety of solutions;
- diversity of modifications;
- proliferation of versions;
- iterative changes;
- design explosion / rapid evolution.

Comment: Specific words rarely appear in a single patent; they are recognized through analysis of the patent corpus and semantics: "diversity," "modification," "variation," "alternative."

8. Excess of costs over income.

Typical marker words for forming a patent request:

- early-stage investment;
- loss-leading development;
- unprofitable operation;
- resource-intensive prototyping;
- pre-commercial expenditure.

Comment: Economic terms reflect the facts but are rarely found in patent texts; they are confirmed by data on startup or development finances, investments, and cost descriptions.

9. Slow growth of parameters, qualitative assessment of results.

Typical marker words for forming a patent request:

- enabling operation;
- fundamental improvement;
- solving the problem of;
- absent or non-quantitative performance indicators;
- qualitative outcome;
- basic feasibility.

Initial version of the generalized dictionary of characteristics of the transitional stage of TS development.

1. Rapid growth of key parameters (MPV).

Typical marker words for forming a patent request:

- rapid growth;
- accelerated growth;
- surge in performance;
- scaling up;
- rapid acceleration;
- significant improvement;
- increase in output;
- production ramp-up;
- upscaling.

2. Market readiness with high vulnerability.

Typical marker words for forming a patent request:

- market-ready;
- fragile;
- almost market launch;
- poised for commercialization;
- susceptible to disruption;
- unstable deployment;
- fragile solution;
- exposed to risks;
- variable stability;
- risk exposure;
- weak resilience;
- sensitive to regulation;
- competitive fragility.

3. Limited success in attempts to implement in various areas.

Typical marker words for forming a patent request:

- limited adoption;
- restricted uptake;
- selective adoption;
- moderate success in different fields;
- pilot projects;
- partial implementation;
- testing in application areas;
- pilot test;
- beta deployment.

4. Niche initial functioning in the market.

Typical marker words for forming a patent request:

- niche market entry;
- selective market entry;
- early adopter market;
- targeted deployment;
- early adopter sales;
- specialized user segment;
- narrow market introduction.

5. Formation of support infrastructure and services.

Typical marker words for forming a patent request:

- ecosystem development;
- establishment of support systems;
- service network;
- creation of auxiliary infrastructure;
- supply chain;
- technical standards;
- supply chain creation;
- initial standardization;
- technical protocol development.

6. Intense competition between modifications.

Typical marker words for forming a patent request:

- competitive race;

- competition among variants;
- rivalry;
- solution differentiation;
- patent race selection;
- pressure selection among solutions;
- elimination of weak contenders;
- rivalry filtering.

7. Growth and subsequent consolidation of patent activity.

Typical marker words for forming a patent query:

- patent surge;
- increase in patent filings;
- publication peak;
- IP surge;
- subsequent consolidation;
- technology consolidation;
- reduction in filings;
- convergence of solutions.

8. The beginning of industrial standardization.

Typical marker words for forming a patent request:

- standardization;
- technical standardization;
- protocol agreement;
- harmonization;
- industry norm adoption.

The initial version of the generalized dictionary of characteristics of the Intensive Growth stage of the ES.

1. Mass production.

Typical marker words for forming a patent request:

- mass production;
- large-scale manufacturing;
- serial production;
- volume output;
- industrial deployment;
- supply chain maturity.
- scaling up;
- scaling operations;
- capacity increase;

- manufacturing ramp-up;
- operations expansion.

2. Adaptation for multiple applications.

Typical marker words for forming a patent request:

- application versatility;
- versatile applications;
- cross-functional use;
- diversified deployment;
- multi-market adaptation;
- platform extension;
- platformization;
- product family;
- module integration.

3. Differentiation of system variations.

Typical marker words for forming a patent request:

- variant differentiation;
- versioning, differentiated models;
- product line expansion;
- configurational diversity;
- model proliferation;
- proliferation of versions;
- portfolio diversification.

4. Differentiation of system applications.

Typical marker words for forming a patent request:

- application diversification;
- sectoral adaptation;
- market segment expansion;
- use-case diversity;
- solution broadening;
- broadening of applications;
- multi-domain implementation.

5. Slowdown and consolidation of modifications

Typical marker words for forming a patent request:

- modification slowdown;

- reduced innovation activity;
- consolidation, stabilizing variations;
- product maturation;
- consolidation;
- solution convergence;
- standardization of versions.

6. Use of specialized resources.

Typical marker words for forming a patent request:

- dedicated resources;
- proprietary resources;
- custom supply chain;
- dedicated infrastructure;
- optimized materials;
- vertical integration;
- vertical ecosystem;
- supply chain ownership.

7. Industrial standardization of the system.

Typical marker words for forming a patent request:

- standardization;
- technical norms;
- industry standardization;
- protocol institutionalization.

8. Servitization and expansion of the related market.

Typical marker words for forming a patent request:

- service ecosystem;
- aftermarket development;
- ancillary services;
- accessory market.

9. Optimization of operational efficiency.

Typical marker words for forming a patent request:

- operational optimization;
- lean operations;
- cost reduction;
- cycle time reduction.

The initial version of the generalized dictionary of characteristics of the Maturity stage of TS.

1. Reaching the limits of development.

Typical marker words for forming a patent request:

- saturation;
- maturity ceiling;
- limit of improvement;
- mature state;
- performance plateau;
- growth limit.

2. Successful implementation in new applications and niches.

Typical marker words for forming a patent request:

- horizontal expansion;
- migration;
- market broadening;
- cross-industry deployment;
- application migration.

3. Incremental improvements require disproportionate resources.

Typical marker words for forming a patent request:

- diminishing returns;
- resource disproportionality;
- diminishing returns;
- disproportionate resource input;
- escalating improvement costs.

4. Use of highly specialized resources.

Typical marker words for forming a patent request:

- specialized resources;
- high specialization;
- proprietary components;
- niche infrastructure;
- customized solutions.

5. Adaptation of supersystem components.

Typical marker words for forming a patent request:

- ecosystem alignment;
- supra-system adaptation;
- supra-system adjustment;
- regulatory alignment;
- enabling infrastructure.

6. Generational differences – major changes in external functions and design.

Typical marker words for forming a patent request:

- generational updating;
- aesthetic innovation;
- appearance evolution;
- interface update;
- form-factor shift;
- design differentiation.

7. Acquisition of functions loosely related to the main function

Typical marker words for forming a patent request:

- ancillary features;
- add-on functionality;
- supplementary features;
- non-core capabilities;
- accessory functions;
- feature creep.

8. Slow change in key parameters (MPV).

Typical marker words for forming a patent request:

- performance stagnation;
- incremental change;
- stagnating;
- negligible improvement;
- slow progress;
- performance plateau.

9. Pronounced servitization and support

Typical marker words for forming a patent request:

- service orientation;
- service ecosystem;
- extended warranty;
- after-sales service.

10. High level of process formalization.

Typical marker words for forming a patent request:

- process formalization;
- formalized lifecycle;
- regulated processes;
- documentation standards.

11. Growth and lifecycle support.

Typical marker words for forming a patent request:

- lifecycle extension measures;
- upgrade programs;
- lifecycle support;
- prolonged utilization.

12. Increased compatibility and obsolescence issues.

Typical marker words for forming a patent request:

- compatibility challenges;
- obsolescence;
- compatibility issues;
- migration to replacement technologies.

The initial version of the generalized dictionary of signs of the decline stage of a technical system.

1. The ES loses its utilitarian function and moves into the realm of entertainment, decoration, and sports.

Typical marker words for forming a patent request:

- functional obsolescence;
- entertainment reorientation;
- obsolescence;
- loss of utility;

- transition to entertainment;
- ornamental use;
- collector's item;
- toy;
- sport equipment;
- decorative object.

2. Preservation of utility exclusively in narrow areas.

Typical marker words for forming a patent request:

- niche persistence;
- residual utility;
- niche use;
- residual application;
- special-purpose;
- limited practical use;
- isolated sector.

3. Integration only as part of a supersystem

Typical marker words for forming a patent request:

- supersystem;
- supersystem integration;
- subsystem;
- subsystem absorption;
- supersystem integration;
- subsystem integration;
- absorbed into supersystem;
- subsystem role;
- embedded functionality;
- loses standalone status.

4. ES is officially replaced by new technology.

Typical marker words for forming a patent request:

- substitution;
- phase-out;
- phase-out;
- discontinued;
- replaced by new technology;
- end-of-life.

5. Acquisition of museum, collection, or archival value.

Typical marker words for forming a patent request:

- archival status;
- collector's value;
- archival, museum piece;
- collectible;
- heritage artifact.

6. Loss of service support and disappearance of standard maintenance.

Typical marker words for forming a patent query:

- service;
- support discontinuation;
- discontinued service;
- withdrawn support;
- unsupported product.