Research of Development of Foreign Railway Companies Using Patent and Bibliometric Analysis

Maxim M. ZHELEZNOV **Oleg I. KARASEV** **Egor A. SHITOV** **Yulia A. SHITOVA**

Zheleznov, Maxim M., National Research Moscow State University of Civil Engineering, Moscow, Russia.
Karasev, Oleg I., Lomonosov Moscow State University, Moscow, Russia.
Shitov, Egor A., Lomonosov Moscow State University, Moscow, Russia.
Shitova, Yulia A., Lomonosov Moscow State University, Moscow, Russia*.

ABSTRACT

The modern stage of economic development is intricately linked with accelerated pace of advancement in technology and hence introduces into basic corporate agenda the need to regularly benchmark best competitive practices. Considering highly competitive environment usual tools and metrics do not allow to reveal promising directions of innovative development, whose implementation will help in building new competitive advantages with similar companies.

To reveal early signs, revealing emerging directions of innovative development, promising technology and decisions, global practices implement tools and instruments of patent and bibliometric search, allowing to assess current corporate practices in the field of both fundamental and applied research.

The article presents the results of a research on activity of leading world railway companies in the field of technological and scientific research, and of priority directions of innovative development, obtained using tools of patent and bibliometric analysis. The research also described the dynamics and the structure of publications and patent applications in the railway sector, the differences in the structure of cooperative links of leading railway companies regarding publication and research activity.

The article also studied structuring of patent and publication activity of some companies, showing priority directions of technological and scientific efforts.

Keywords: technological development, transport, structure, dynamics, publication activity, patent activity, cooperation links.

*Information about the authors:
Zheleznov, Maxim M. – D.Sc. (Eng), associate professor, professor of the department on information systems, technologies and automation in construction of National Research Moscow State University of Civil Engineering, Moscow, Russia, M.Zheleznov@mail.ru.
Karasev, Oleg I. – Ph.D. (Economics), director of the center of scientific-technological forecasting of economic faculty of Lomonosov Moscow State University, Moscow, Russia, oikarasev@econ.msu.ru.
Shitov, Egor A. – Master in Management, leading specialist of the Center for big data storage and analysis of Lomonosov Moscow State University, Moscow, Russia, egor.shitov29@gmail.com.
Shitova, Yulia A. – Master in Management, leading specialist of the Center for big data storage and analysis of Lomonosov Moscow State University, Moscow, Russia, julyaa.titova@gmail.com.

The level of technological development of railway companies is among key factors determining effectiveness of operating activities. Given reduction of technological and innovation cycle time and accelerated decision-making processes, the quality of organization of scientific and technological development is a critical factor in terms of maintaining the company's leading positions and its competitiveness.

A basic element of technological development is a system of cross-cutting scientific and technological priorities that determines the vector of a company's long-term vision in terms of development and implementation of advanced developments and solutions. Subject to an increase in the technology transfer rate from the development stage to time of implementation, the companies are forced to regularly conduct a comprehensive analysis of the areas of research and development that are in demand. This practice is common among leading railway companies and allows them to stay in line with technological and innovative trends that have a significant impact on development of the entire railway industry.

In order to identify significant areas of technological development, various tools can be used, including *bibliometric and patent analysis*, which allow, among other things, to identify emerging directions that are potentially critical for development of the entire industry, called «early signals». For instance, analysis of patent information can help to conduct multidimensional analysis of the groups of promising technologies, innovative products, and services, following many criteria, including legal ones [1]. Key objectives of patent and bibliometric analysis comprise:

• determination of the scope, dynamics and directions of scientific and technological development of both the industry as a whole and individual companies;

• determination of leaders in the field of basic and applied research;

• identification of organizational and cooperative ties of industry companies with research organizations, universities and other commercial partners;

• identification of individual authors, employees and scientists making a significant contribution to development of the industry in certain areas of scientific and technological development;

• identification of «early signals» and potentially significant technological developments [2].
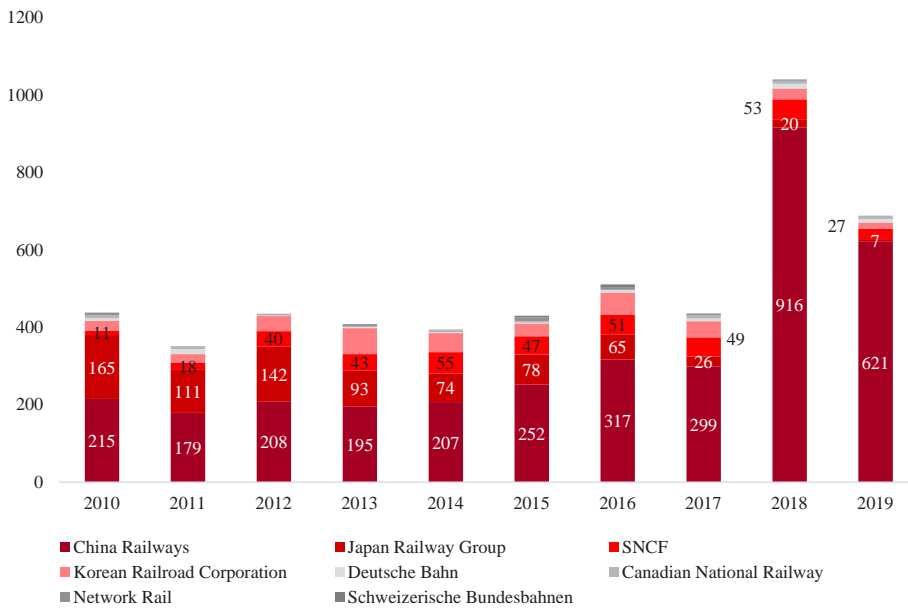
According to the concept of technology readiness levels (hereinafter – TRL), fundamental and applied research corresponds to the early stages of technology development: TRL1–TRL3 [3]. An analysis of scientific and technological activities of companies in the context of these TRL allows revealing implicit technological trends. The advantage of bibliometric and patent analysis is the ability to study implicit directions of scientific and technological development that are not reflected in open sources and published documents of corporate strategic planning [2].

Companies with a wide portfolio of publications and patents traditionally have their own developed scientific and technical unit. One of the indicators of activity and effectiveness
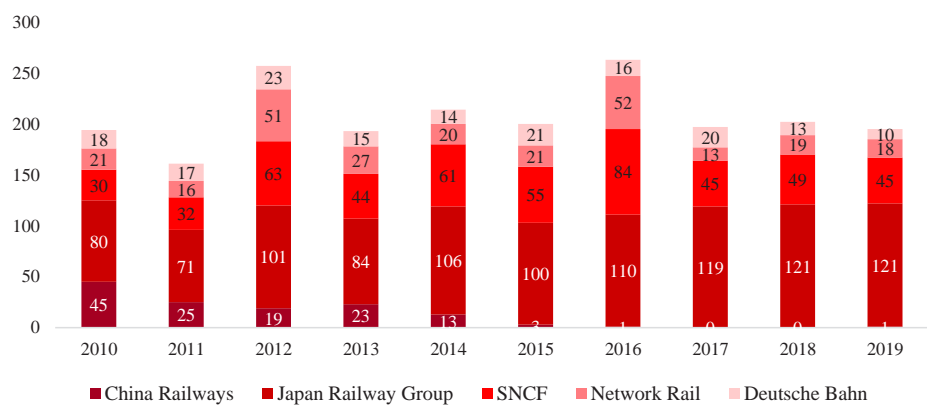
Pic. 1. Dynamics of publication activity of leading foreign railway companies in the period 2010–2019, publications per year. Source: Bibliographic and abstract database Scopus. [Electronic resource]: https://www.scopus.com/home.uri. Last accessed 25.02.2020.

Zheleznov, Maxim M., Karasev, Oleg I., Shitov, Egor A., Shitova, Yu. A. Research of Development of Foreign Railway Companies Using Patent and Bibliometric Analysis

Pic. 2. Dynamics of patent activity of leading foreign railway companies in the period 2010–2019, patents per year. Source: World Intellectual Property Organization PatentScope search system for international and national patent funds. [Electronic resource]:
https://patentscope.wipo.int/search/ru/search.jsf. Last accessed 29.07.2019.

of its functioning is the dynamics of publication and patent activity. The leaders of the railway industry in the field of publication activity are representatives of the Asia-Pacific region: China Railways (China), Korail (South Korea) and JR Group (Japan) (Pic. 1). French railway company SNCF is also characterized by high publication activity during 2010–2019.

The publication activity of most railway companies is characterized by stable positive dynamics, which are extrapolated as a whole to the situation in the railway industry. A significant predominance of Asian railway companies is also observed in the field of protection of the results of intellectual activity (patent activity).

An analysis of patent activity can be used to identify key indicators of technological change [5]. An analysis of patent activity allows one to identify various scientific and technological achievements, as well as existing and emerging areas of technological development of companies.

During the period 2010–2019 railway companies with a high level of patent activity comprised JR Group (Japan), SNCF (France) and Korail (South Korea) (Pic. 2).
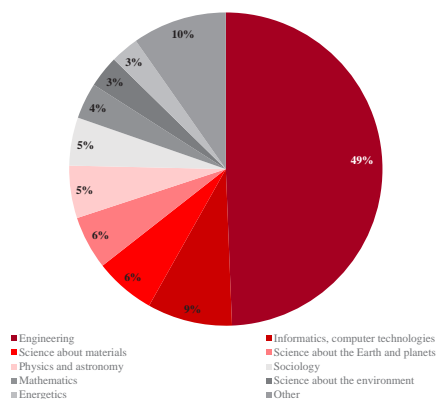
Patent analysis allows to build an understanding of R&D activity of companies in the aspect of technological areas and

solutions that are not directly visible to an external observer [5]. The bibliometric and patent analysis allows identifying relevant technological trends, and also provides an opportunity to suggest the future vector of development of critical technologies and solutions in the industry.

Consideration and analysis of the structure of publications and patents based on the principles of classification allows identifying individual areas that are of particular interest to companies. Pic. 3 shows the structure of publication activity of a number of leading railway companies in the context of research areas for the period 2010–2019.

The most demanded topic of publications of leading foreign railway companies is engineering, which is generally characteristic of the industry under analysis. Also in the structure of publications researches related to computer science and computer technology, material science, earth and planet science, physics and astronomy are widespread.

After a closer examination of the structure of publication activity of the French railway company SNCF, it can be concluded that there is a high degree of compliance of its scientific

• WORLD OF TRANSPORT AND TRANSPORTATION, Vol. 18, Iss. 1, pp. 22–36 (2020)

Zheleznov, Maxim M., Karasev, Oleg I., Shitov, Egor A., Shitova, Yu. A. Research of Development of Foreign Railway Companies Using Patent and Bibliometric Analysis

Pic. 3. Structure of publications of a number of leading foreign railway companies since 2010, %.
Source: Bibliographic and abstract database Scopus. [Electronic resource]:
https://www.scopus.com/home.uri. Last accessed 15.12.2019.
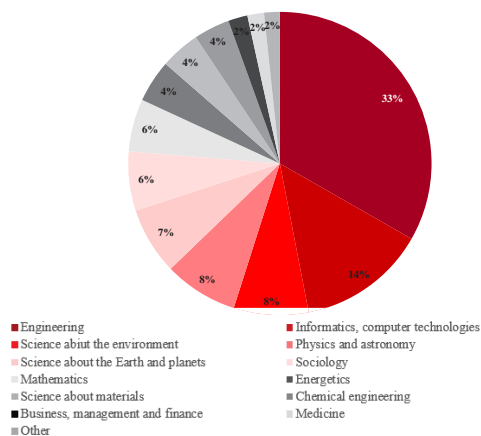
Pic. 4. Structure of publication activity of the company SNCF since 2010, %. Source: bibliographic and abstract
database Scopus. [Electronic resource]: https://www.scopus.com/home.uri. Last accessed 18.12.2019.

and technological priorities with industry-wide specifics (Pic. 4).

Most SNCF publications correlate with research in engineering, computer science and computer technology, environmental science, and physics and astronomy. These subject areas form about 66 % of all publications of the French railway company.

The most cited SNCF articles in recent years, most frequently have refered to studies investigating materials and soil (Table 1).

The most sought-after thematic areas of registered patents related to the railway industry are largely correlated with publications of leading railway companies. A similar fact suggests a relatively stable relationship between basic and applied research in the railway industry. In particular, this fact is

confirmed by the growing tendency to adopt initiatives aimed at full support of technological developments at all stages of the life cycle. An equally important factor explaining this conclusion is the traditional specifics of the railway industry and the relatively narrowly focused topics of scientific and technological development, primarily related to rolling stock, maintenance of infrastructure facilities and the railway track [6].

The most popular thematic areas of registered patents of a number of leading railway companies are (see Pic. 5):

• organization and control of traffic on railways, railway safety equipment;

• track superstructure; means and devices for laying and repair of railway tracks of all types.

● **WORLD OF TRANSPORT AND TRANSPORTATION, Vol. 18, Iss. 1, pp. 22–36 (2020)**

Zheleznov, Maxim M., Karasev, Oleg I., Shitov, Egor A., Shitova, Yu. A. Research of Development of Foreign
Railway Companies Using Patent and Bibliometric Analysis

The most cited articles of SNCF for the period 2016−2019

No.	Article's title	Field	Publication year	Number of citations
1	Potential of vehicle-to-grid ancillary services considering the uncertainties in plug-in electric vehicle availability and service/localization limitations in distribution grids	Electric cars/ Chargers (batteries)/ Smart chargers	2016	31
2	Statistical evaluation of fatigue strength of double shear riveted connections and crack growth rates of materials from old bridges	Fatigue of materials/ Models/ S-N curves	2017	27
3	Effects of inclusion contents on resilient modulus and damping ratio of unsaturated track-bed materials	Railways/Soils	2017	22
4	Effects of water and fines contents on the resilient modulus of the interlayer soil of railway substructure	Railways/Soils	2016	19
5	Investigation on the mechanical behavior of track-bed materials at various contents of coarse grains	Construction and construction materials	2018	6

Source: Bibliographic and abstract database Scopus. [Electronic resource]: https://www.scopus.com/home.uri. Last accessed 25.02.2020.
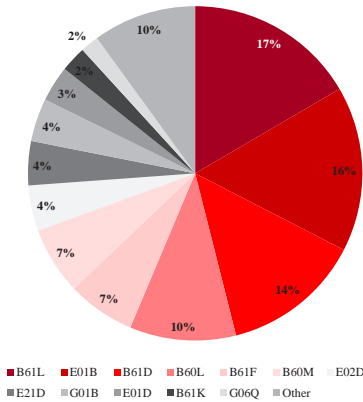
Pic. 5. Structure of registered patents of a number of leading foreign railway companies since 2010, %. Source: Official website of the patent database of the World Intellectual Property Organization. PatentScope. [Electronic resource]: https://patentscope.wipo.int/search/ru/search.jsf. Last accessed 27.07.2019.

The interpretation of the thematic areas of patents of the railway industry presented in Pic. 5 is given in Table 2.

Pic. 6 is a linear graph of patent activity of the German railway company Deutsche Bahn, which allows for identification of interdisciplinary patent relationships.

The vertices of the graph correspond to the thematic areas of patents presented in Table 3. The edges of the graph are interdisciplinary patent communications. Near the vertices of the graph, the strength of the thematic field is given, expressed through the number of company patents related to it.

According to the presented picture, the main areas of patenting are: transport infrastructure, instruments for measuring and testing, cargo management. Active patenting takes place at the junction of the given subject areas, as well as at the junction of directions related to communications and land vehicles (railway transport).

In general, in the railway industry over the entire period of publication activity of companies, there is a trend of cooperation with universities, national and international research centers and laboratories, such cooperation is especially noticeable in the publications of SNCF and Japan Railway Group (Pic. 7). More than 60 % of publications and research carried out by leading railway companies are issued jointly with educational and research organizations. The SNCF, for instance, when publishing joint fundamental articles and conducting research cooperates in 87% cases with academia, universities, research centres and laboratories,

● **WORLD OF TRANSPORT AND TRANSPORTATION, Vol. 18, Iss. 1, pp. 22–36 (2020)**

Zheleznov, Maxim M., Karasev, Oleg I., Shitov, Egor A., Shitova, Yu. A. Research of Development of Foreign Railway Companies Using Patent and Bibliometric Analysis

Table 2

International Patent Classification (IPC) of the most addressed patents in the railway industry

IPC	Decryption
B61L	Guiding railway traffic; ensuring the safety of railway traffic
B61D	Body details or kinds of railway vehicles
B61F	Rail vehicle suspensions, e.g. underframes, bogies or arrangements of wheel axles; Rail vehicles for use on tracks of different width; Preventing derailing of rail vehicles; Wheel guards, obstruction removers or the like for rail vehicles
B61K	Other auxiliary equipment for railways
E01B	Permanent way; Permanent-way tools; Machines for making railways of all kinds
B60L	Propulsion of electrically-propelled vehicles; Supplying electric power for auxiliary equipment of electrically-propelled vehicles; Electrodynamic brake systems for vehicles in general; Magnetic suspension or levitation for vehicles; Monitoring operating variables of electrically-propelled vehicles; Electric safety devices for electrically-propelled vehicles
B60M	Power supply lines, or devices along rails, for electrically-propelled vehicles
E02D	Foundations; Excavations; Embankments; Underground or underwater structures
E21D	Shafts; tunnels; Galleries; Large underground chambers
G01B	Measuring length, thickness or similar linear dimensions; Measuring angles; Measuring areas; Measuring irregularities of surfaces or contours
E01D	Bridges
G06Q	Data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; Systems or methods specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes, not otherwise provided
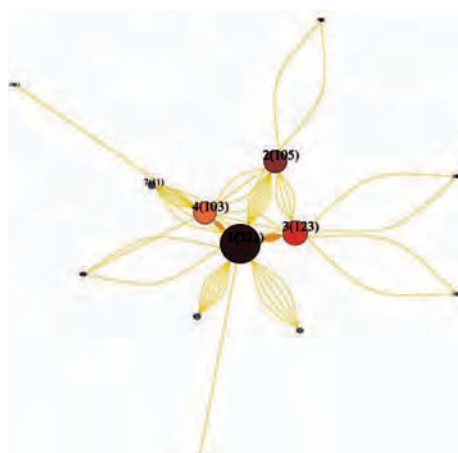
Pic. 6. Directions of patent activity of Deutsche Bahn for the period 1991–2018. Source: Official website of the patent database of the World Intellectual Property Organization. PatentScope. [Electronic resource]: https://patentscope.wipo.int/search/ru/search.jsf. Last accessed 27.07.2019.
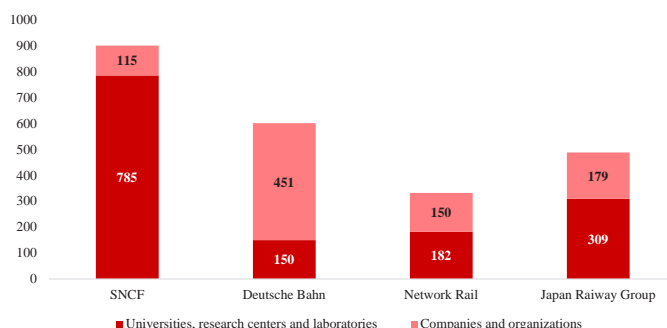
Pic. 7. Structure of cooperation relationship and joint publications in the context of companies, publications for direction. Source: Bibliographic and abstract database Scopus. [Electronic resource]: https://www.scopus.com/home.uri. Last accessed 02.08.2019.

Table 3

Decryption of thematic areas of patents to Pic. 6

Vertex	Meaning
1	Railway tracks
2	Design of roads, railway tracks and bridges
3	Measurement and testing
4	Vehicles in general
5	Signaling
6	Ground non-rail vehicles
7	Transportation, packaging and storage of fragile materials
8	Lifting and pulling mechanisms
9	Hand and portable power tools and manipulators
10	Construction
11	Heating, ventilation and their regulation
12	Aviation and astronautics
13	Locks, keys, window or door accessories, safes

Source: Official website of the patent database of the World Intellectual Property Organization. PatentScope. [Electronic resource]: https://patentscope.wipo.int/search/ru/search.jsf. Last accessed 27.07.2019.

while Deutsche Bahn conducts 75 % of joint research together with market actors, different commercial companies, and organisations.

Due to the accelerated pace of technological development, railway companies are forced to regularly update the trends and dynamics of innovative activity of leading peer companies, as well as leaders of related industries in order to identify priority vectors of scientific and technological development and an approximate assessment of their own competencies and prospects.

The tools and methods of bibliometric and patent research used in the analysis of publication and patent activity allow obtaining up-to-date data illustrating the level of innovative development in the industry, tracking development trends, identifying early signals of know-how and identifying priority thematic areas of research. Such an analysis is especially important in the task of identifying areas of new knowledge and determining strategies for scientific and technological development, which is constantly facing organizations of any level in the current stage of scientific and technological development.

REFERENCES

1. Ena, O., Popov, N. Methodology of development of patent landscapes of the FIPS project office [*Metodologiya razrabotki patentnykh landshaftov proektnogo ofisa FIPS*]. Stankoinstrument, 2019, Iss. 1, pp. 28–35.

2. Gibson, E., Daim, T., Garces, E., Dabic, M. Technology Foresight: A Bibliometric Analysis to Identify Leading and Emerging Methods. Foresight and STI Governance, 2018, Vol. 12, Iss. 1, pp. 6-24. DOI: 10.17323/2500-2597.208.1.6.24.

3. Technology transfer. Guidelines for assessing maturity of technologies [*Transfer tekhnologii. Metodicheskie ukazaniya po otsenke urovnya zrelosti tekhnologii*]. National Standard of the Russian Federation. GOST R 58048-2017. Date of introduction: 2018-06-01.

4. Grigoryan, M. Patent analysis: strategic justification, application, advantages and limitations [*Patentniy analiz: strategicheskoe obosnovanie, primenenie, preimushchestva i ogranicheniya*]. *Scientific and methodical electronic journal Concept*, 2015, Vol. 30, pp. 341–345.

5. Grishina, S. Patent analysis as a tool for strategic diagnostics [*Patentniy analiz kak instrument strategicheskoi diagnostiki*]. Scientific and Technical Sheets of St. Petersburg State Polytechnic University. *Economic sciences*, 2008, pp. 113–115

6. Zheleznov, M. M. Formation of priority areas of scientific research by the example of the parent organization of JSC Russian Railways in the field of development, creation, testing and implementation of equipment and technologies in railway transport (OJSC VNIIZhT) [*Formirovanie prioritetnykh napravlenii nauchnykh issledovanii na primere golovnoi organizatsii OAO «RZD» v sfere razrabotki, sozdaniya, ispytanii i vnedreniya tekhniki i tekhnologii na zheleznodorozhnom transporte (OAO VNIIZhT)*]. *Bulletin of the Joint Scientific Council of JSC Russian Railways*, 2013, Iss. 6, pp. 2–12.

● WORLD OF TRANSPORT AND TRANSPORTATION, Vol. 18, Iss. 1, pp. 22–36 (2020)

Zheleznov, Maxim M., Karasev, Oleg I., Shitov, Egor A., Shitova, Yu. A. Research of Development of Foreign Railway Companies Using Patent and Bibliometric Analysis