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Research Article

# Patents Analysis of Iranian Steel Industry Using Soft Systems Methodology

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## ABSTRACT

This research analyzed the situation of Iranian steel industry in case of patent, based on the soft systems methodology (SSM). The patent analysis in different fields during the years 2003 to 2024 shows significant fluctuations of the number of patents. "Technology" and "chemistry" have higher number of patents than the other fields. Studies and expert opinions showed that "technology" patents should be considered endogenous to industries, the results of experience and wised thinking, which mainly comes from within the industry and by artisans. However, in order for the practical knowledge gained to be transformed into technology, it is necessary to develop a system. But in the field of "chemistry", patents are related to the growth of universities in the field. Therefore, the growth of patents in this field is in line with the growth of universities and will continue. However, the practical use of these patents is dependent on the growth of investment in the steel industry. It is necessary and recommended to develop a system that can bring the inventions to practice. These two systems must be integrated to manage the entire innovation process of Iranian Steel, and in order to bring the patents into practice. We have provided this integrated system. The integrated system includes activities such as: Analysis of the current investment plans, designing a system for attracting foreign investors, Planning for the integration of technology and research within the country, establishing a technology documentation office, establishing a technology acquisition/preparation office, Establishing a technology documentation/standardization office.

## 1. Introduction

The steel industry plays a direct role in the country's economic growth and gross domestic product [1]. One of the fundamental aspects of the steel industry is the extent of technology use across the production chain. Moreover, in this industry the adoption of advanced and up-to-date technologies is vital [2]. Iran's steel industry, with rich mineral reserves and a skilled workforce, has significant potential capacities. However, numerous challenges such as technological backwardness and the need to update equipment threaten this industry's competitiveness. Investment in research and development, market analysis, and collaboration with competitors can help upgrade the industry and place it on a path of sustainable growth [3]. Attention to intense competition in the steel industry and the impact of novel technologies on productivity,

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quality, and production costs makes identifying future technology development pathways one of the industry's core challenges. In this study, the main question is: by analyzing registered patents in the steel industry, how can emerging technology trends be identified and the industry's future trajectories be forecasted? By examining registered patents, innovation patterns can be extracted and potential opportunities for investment in research and development can be identified. In this regard, a soft systems methodology has been used. This method enables a comprehensive analysis of the complex technological environment and helps identify the key factors influencing technology development in the steel industry. The primary aim of the research is to determine the future direction of steel technology, and the subsidiary objectives are to identify technologies in decline and to classify the patents.

## 1.1. Problem Statement

The Iranian steel industry, despite possessing relative advantages such as rich iron ore reserves and a skilled workforce, faces profound structural and technological challenges that jeopardize its sustained growth and competitiveness in global markets. The obsolescence of technology in Iran, the urgent need for modernization and upgrading of infrastructure, and the increasing pressure of international competition are among the most significant obstacles confronting this vital industry. Achieving sustainable development and solidifying its position in the global arena necessitates targeted investment in research and development, precise analysis of market trends, and constructive engagement with various stakeholders. In this context, patent analysis serves as a powerful tool for monitoring innovation trajectories and identifying technological opportunities, thus playing a pivotal role. However, existing reviews indicate a scarcity of comprehensive studies on patent analysis in the Iranian steel industry, particularly those employing novel systemic approaches such as Soft Systems Methodology (SSM). This research gap underscores the imperative for a more in-depth study. The objective of this research is to extract innovation patterns and delineate future technological landscapes within the Iranian steel industry through patent analysis. The findings of this study can form a basis for formulating technology development strategies and macro-level policies aimed at enhancing and ensuring the sustainability of this industry amidst global transformations. This approach empowers decision-makers to select optimal pathways for investment and sustainable development of the Iranian steel industry, armed with a more comprehensive understanding of technological dynamics.

## 1.2. Research Background

The steel industry faces multiple challenges, including increased global competition, pressure to improve productivity, the need to reduce costs, and environmental requirements. Recently, two fundamental trends have significantly affected the steel industry: the transition to a low-carbon economy and the digitalization of production processes [4]. One of the main challenges of knowledge management systems is the effective discovery and exploitation of content stored in knowledge bases. A patent is an invention in a specific technological field. Studies have shown that a substantial portion of the information presented in patents is relatively new [5]. Patent analysis in the literature on the steel industry is found in a limited number of studies, some of which are presented below. Wang et al. conducted research on the research and development strategies of iron and steel companies based on semantic topic analysis of inventions [6]. Empirical studies were carried out regarding R&D orientation, R&D quality, and strategies for preserving achievements from macro and micro perspectives. The results showed that in terms of R&D topic layout strategy, most companies, after quickly completing their layout, adopted a strategy of sustained preservation. Regarding the R&D focus strategy, most companies concentrated on specific R&D areas and employed strategic management. For the R&D quality control strategy, some companies chose a strategy of extending the duration of granting invention patents and developed high-quality patents with long lifespans. These research findings provide a reference value for Chinese companies in adjusting their R&D strategies and for the government in formulating supportive policies. Mao et al. examined the technological status and trends in the treatment of industrial wastewater through patent analysis [7]. The results showed that from 1973 to 2020, the number of patents related to this industry continuously increased. Analysis of core technologies indicated that methods, devices, materials, and related industries were hot topics. In the technology of activated sludge treatment for industrial wastewater, there has been a trend from treatment using single technologies toward treatment using combined technologies. Savchenko et al. examined innovation development trends in the Russian iron and steel industry based on a patent analysis of the largest national metallurgy companies [8]. This article uses the patent method to forecast technology based on patent research. The results of the patent document analysis are presented for major metallurgical companies (Severstal, Magnitogorsk Iron & Steel Works (MMK), Novolipetsk Steel (NLMK), Metalloinvest Management Company, the EVRAZ group, and Mechel). The use of patent analysis in strategic management decision-making is recommended as a basis for developing innovation-driven business in the transition to a digital economy. Yoo and Park developmental pathways in electric steel technology were examined using patent information [9]. The results showed that, based on the characteristics of electric steel patents and the development pathways shown in the main-path network, future R&D directions are as follows: in the magnetic domain refinement subbranch, further R&D will likely focus on solving the problem of increased iron losses in materials with a high degree of grain alignment. According to patent HPP 1372 (US6444050), materials with large grain diameters have greater spacing between grain boundaries and generate weaker magnetic energy. This implies a reduction in the magnetic domain refinement region and an increase in magnetic domain size, which consequently increases iron losses.

It is shown from the literature that there are materials related to patent analysis, but quite a few in regard to steel industry. Moreover, despite some material about steel's innovation in Iran [11], we could not find substantial material about Iranian steel's patent analysis either based on soft systems methodology or other approaches. So, it worth trying it.

## 2. Materials and Methods

There are different approaches to patent analysis, like applying expert systems, text mining techniques, and using statistical analysis. In this study, we use statistical analysis based on Soft Systems Methodology (SSM) to analyze the statistical status of inventions (fig. 1.). This methodology consists of 7 stages, which are described in the part 3 of this paper. In the stages 1 and 2, the Iranian steel invention's situation is reviewed and analyzed. In the stage 3, systems related to the steel inventions are defined based on the different worldviews of subject-matter experts. The experts from the steel's academic sector and industry, who are in charge with steel subject matters for a long time. In the stage 4, models related to those systems are constructed, and in the stage 5, a comparison is made between the problem situation and the models, to find out "What features are different and why?". In the stage 6, the results of the comparisons lead to the presentation and analysis of suggestions for improving and changing the invention's system. In the stage 7, the proposed suggestions are documented for implementation [10].

The following describes the stages pursued.

## 3. Results and Discussions

This section presents the stages of the Soft Systems Methodology used to analyze the inventions.

### 3.1. Stages 1 and 2 - Clarification and Analysis of the Problem Situation

In this paper, data related to inventions were extracted from the database of the Iranian Intellectual Property Registration Organization and analyzed. Keywords included technical terms in steel technologies, such as "stainless steel," "steel nanotechnology," "steel wastewater treatment," and other modern technologies. Inventions relating to a 20-year period were collected. Each patent was examined carefully to ensure that the registered inventions were complete and valid. Incomplete or invalid patents (inventions whose registration date was older than 20 years or whose documentation and records were deficient) were removed. The selected inventions were then examined more closely. Analytical methods, such as statistical analysis and trend analysis, were used to analyze the data. Data were reported as mean and standard deviation and analyzed using SPSS software. Then, the analyses and resulting charts were provided to the experts so that, using interviews with them,

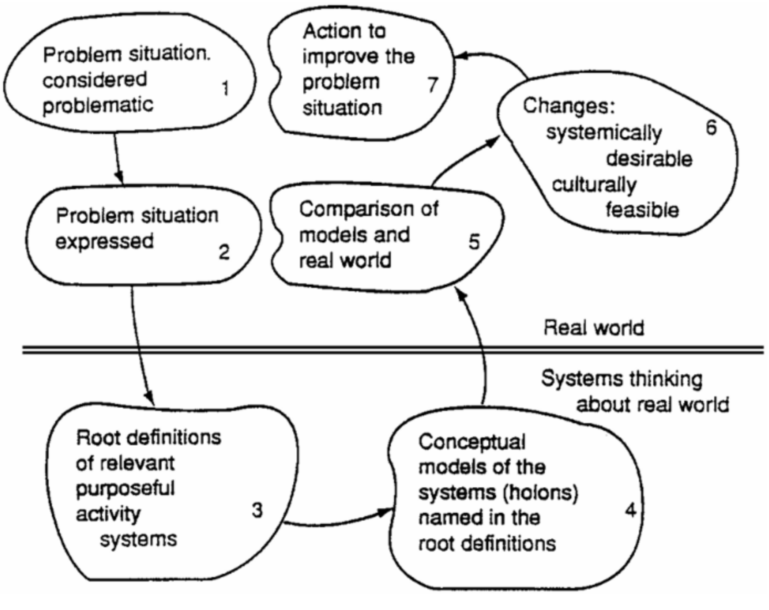


Fig. 1. Schematic structure of SSM.

specialists, and elites of the steel industry and following the Soft Systems Methodology (SSM), final conclusions could be reached [10]. Table 1. shows descriptive characteristics of various inventions, including recycling, bolted connections, steel, technology, automotive, construction, molding, steel boiler, chemical field, steel sheet, smelting, wire rod, and miscellaneous. For each of these fields, the maximum, minimum, standard deviation, and mean values are provided. For example, between 1 and 12 patents have been submitted annually related to "steel" in the last 20 years (fig. 2). Some fields, such as technology and the chemical field, exhibit greater dispersion and higher means compared to other fields. High standard deviation values indicate large variation in the number of inventions, while low standard deviation points to greater homogeneity.

Below, and for the sake of brevity, only the more important areas such as "technology", "chemistry" ,"steel", and "construction" are reviewed in general terms.

### 3.1.1. Steel Inventions

Fig. 2. shows the chart of the number of inventions in the "steel" domain over different time intervals from 2003 to 2024. In total, 59 inventions were registered in the steel domain during these time intervals, with large fluctuations. In the last years, a sharp decline in the number of registered inventions is observed, which may be related to various factors such as changes in policies, the market, or technology.

Table 1. Descriptive characteristics of the number of patents filed over 20 years in Iran in different steel-related fields.

| Patent | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|
| Recycling | 3.75 | 0.92 | 2 | 6 |
| bolted connections | 3 | 3.38 | 2 | 5 |
| Steel | 5.9 | 8.59 | 1 | 12 |
| Technology | 14.9 | 1.72 | 2 | 34 |
| Automotive | 2.21 | 2.02 | 1 | 6 |
| Construction | 6.9 | 0.57 | 5 | 12 |
| Molding | 1.33 | 0.57 | 1 | 2 |
| steel boiler | 1.33 | 5.31 | 1 | 2 |
| chemical field | 9.22 | 4.89 | 4 | 20 |
| steel sheet | 5.77 | 1.82 | 2 | 15 |
| Smelting | 2 | 5.05 | 1 | 6 |
| wire rod | 4.66 | 1.82 | 1 | 11 |
| Miscellaneous | 3.9 | 1.91 | 1 | 7 |

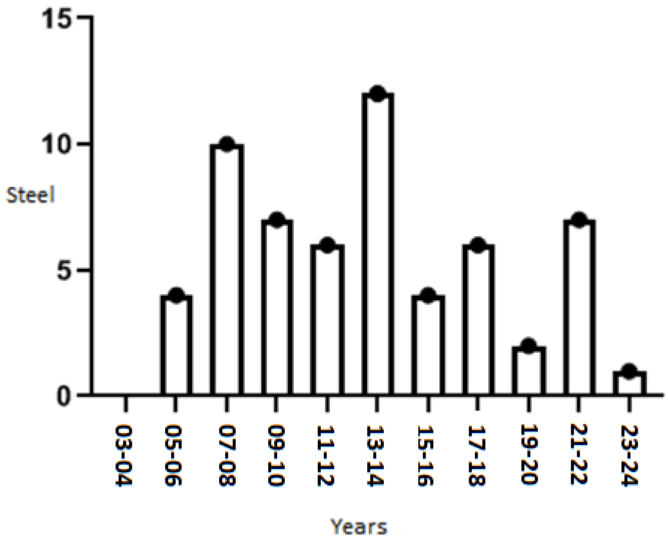


Fig. 2. Chart of the status of steel inventions over the years.

Some plausible reasons for these fluctuations are: the steel market is heavily dependent on various industries such as construction, automotive, and machinery. Increases or decreases in demand from these industries can directly affect the level of research and development and consequently the number of inventions registered in the steel domain. Government support policies for the steel industry can play an important role in the number of inventions. For example, the country's comprehensive scientific roadmap (published in 2009) mandates the Iranian government to "achieve the first position in science and technology in the Southwest Asian region by 2025". Moreover, between 2009 and 2015, a series of upstream documents and laws, including the Fifth Development Plan Law (2011–2015), the Law on Supporting Knowledge-Based Companies (2010), and the Faculty Promotion Regulations, established a specific legal and executive framework for increasing science production, publishing scientific articles, registering patents, and commercializing research in universities. These documents formally mandated universities to improve scientific and technological indicators. New innovations and technological advances can provide incentives to register new inventions. Overall, the fluctuation trend in the field of steel inventions indicates the influence of multiple factors, including market changes, government policies, technological advances, and economic conditions. Based on interviews with experts, the fluctuations in the number of inventions in the steel domain can be related to a combination of economic, political, and technical factors.

### 3.1.2. Technology Inventions

Fig. 3. shows the chart of the number of inventions in the "technology" field across different time intervals from 2003 to 2024. In total, 149 inventions in the technology field were registered during these time periods. Factors such as changes in market demand, industrial needs, global competition, and government support policies likely played roles in these fluctuations and the relative stability. A sharp increase in inventions during a particular period may have been due to an urgent need for new innovations, while the relative stability in subsequent periods could indicate a focus on optimizing and exploiting existing technologies. Overall, these trends indicate that the technology sector is rapidly changing and evolving, but after a peak period it entered a phase of relative stability. This pattern may result from various factors such as innovation cycles, changes in market needs, and the influence of policies and economic conditions. A study showed that scientific capability alone is not sufficient for the growth and development of technology, and the development of intellectual property infrastructures in this area is essential [12]. Safari and Eldaghi [13] reported that the most important parameters affecting technology production are market metrics. According to the interviews, inventions in the "technology" field reflect significant impacts from various industry trends and policies. In 2007–2008, according to experts, the need for new innovations and competitive pressure in the market caused a considerable increase in patent registrations. Also, according to some interviewees, after this peak period, inventions in this field decreased in subsequent years, which may have resulted from optimizing existing technologies and changes in government policies and economic priorities. In later years, inventions reached relative stability because more attention was focused on exploiting existing technologies and efforts were more directed toward completing and optimizing them. This trend indicates that after periods of major innovations, the focus shifts toward consolidating and improving technologies and responding to market needs across different industry levels.

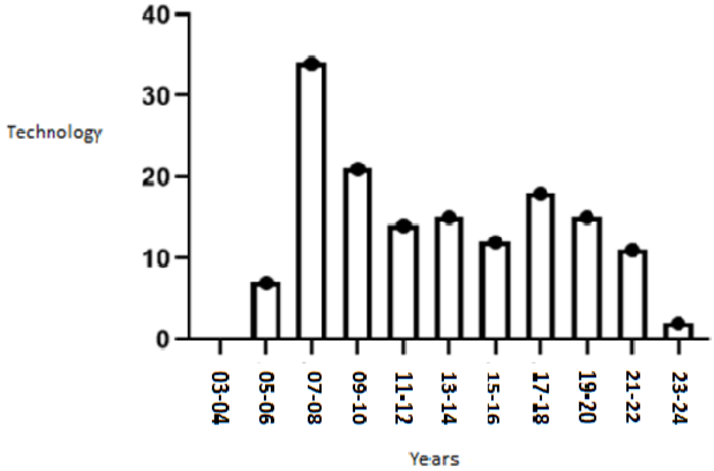


Fig. 3. Status diagram of technology patents over the years.

### 3.1.3. Construction Inventions

Fig. 4. shows the diagram of the number of patents in the "construction" field in different time periods from 2003-2024.

During periods of economic prosperity, construction activities increase, which leads to the growth of patent registration in this field. Access to financial resources and public and private investments in the construction sector can create greater incentives for innovation. Technological innovations, such as new building materials, sustainable technologies, or modern construction methods, can lead to an increase in the number of patents. For example, the rapid growth in the number of patents in the years 2021-2022 may be due to the entry of new technologies. The development and expansion of smart infrastructure, the demand for smart and sustainable buildings, changes in building regulations and national standards, stricter laws on sustainable energy and building safety, changes in demographics and societal needs, such as increased demand for housing or commercial spaces, climate change and the need for more resilient buildings against natural disasters, can lead to new innovations and inventions in the construction sector. On the other hand, factors such as changes in the market, the occurrence of political or social crises, or sanctions, may lead to a decrease in activities and, consequently, a decrease in the number of patents in some years. For example, the lack of patent registration in the years 2023-2024 may be due to economic changes or lack of support for the building industry during that period. Overall, the trend of patents in the construction sector indicates a relative stability with limited fluctuations. However, these fluctuations can reflect various conditions and changes in the economic, social, and technological environment. Based on interviews, the trend of patents in the "construction" field over the years indicates continuous activity and relative stability. The interviews also indicated that economic and social factors can have a significant impact on the number of patents in the construction sector.

### 3.1.4. Chemistry Inventions

Fig. 5. shows the graph of the number of inventions in the field of "Chemistry" in different time intervals from the years 2003-2024.

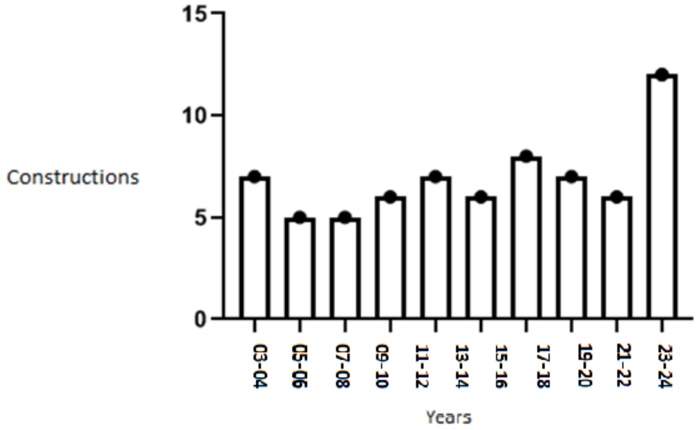


Fig. 4. Status diagram of construction patents over the years.

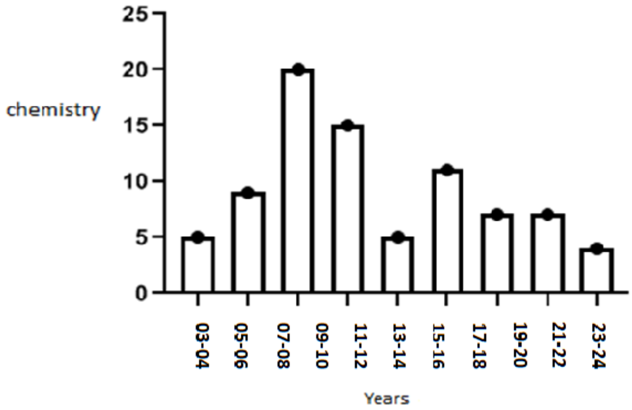


Fig .5. Graph of the status of chemistry inventions during different years.

The reasons for fluctuations and changes in this field can be attributed to the following factors: industrial needs and changes in research orientations can affect the number of inventions. Patents registered in the field of steel chemistry grew during the period 2007-2010 due to the following reasons:

1) Developmental leap of the steel industry: During this period:

- Iran's steel capacity and production increased steadily.
- Most steel companies, such as Mobarakeh Steel Co., had plans to expand and increase capacity.

2) Policy of self-sufficiency and technology localization: In the late 1980s, due to the intensification of international restrictions, strategic industries, including steel, were forced to:

- Domesticate the technical knowledge of producing special steels
- Domesticate additives and ferroalloys
- Redesign metallurgical processes

Such external pressure usually leads to an increase in domestic innovations and patenting

3) Patenting incentives in universities: In those years:

- Patenting was a special privilege for the promotion of faculty members
- Universities established more active intellectual property offices
- Financial support for domestic patent registration increased
- Therefore, part of the growth in patenting was due to the incentive policies of the higher education system.

4) Focus on special and strategic steels: During this period, the demand for:

- Wear-resistant steels in mines, Steels used in the oil and gas industries, and Micro alloy steels with elements Nb, V, Ti, increased.

Since these areas are directly related to the chemical composition of steel, the chemical sector accounted for the largest share of innovation.

The decline in chemical sector inventions in Iran's steel sector after 2011 should be analyzed in the context of economic, institutional, and structural changes in the innovation system in Iran. This decline might be the result of several variables at the same time:

1) Intensification of industrial and financial sanctions (2011–2013): After 2011, financial and industrial sanctions against Iran were significantly intensified. Its consequences for industrial innovation:

- Limited access to laboratory equipment and advanced materials
- Difficulty in sourcing ferroalloys and specific microalloying elements
- Reduced international technological cooperation
- More difficult registration and prosecution of foreign patents

As a result, the focus of the steel industry shifted from "petrifiable innovation" to "continuing production and survival".

2) Declining real investment in industrial R&D large companies such as: Isfahan Mobarakeh Steel Company and Khuzestan Steel during this period, most of their resources were spent on: Stabilizing production, Managing costs, Expanding physical capacity, rather than developing new patentable chemical technologies. In heavy industries, when economic pressure hits, the first vulnerable sector is usually research and development.

3) Weak commercialization and return on investment: A large proportion of patents filed before 2011 did not reach widespread commercialization.

When the economic return on patenting is low:

- Companies have less incentive to file new patents
- Focus shifts to internal operational solutions (without formal registration)

### 3.1.5. Correlation Between Variables

Table 2. shows the correlation between the number of different inventions. The numbers in parentheses indicate the significance level of the correlations, which represents the probability that these correlations were not obtained randomly. Strong correlations (above 0.9) are present, and most correlations in this table are above 0.9, indicating a very strong relationship between the variables. For example, the correlation between the number of recycling inventions and screw connections is 0.974, and the correlation between the number of technology and steel inventions is 0.986. These high correlations indicate that inventions in these areas have grown simultaneously or have been similarly influenced by factors such as economic conditions or industrial policies. Weak or non-significant correlations are (less than 0.7). In some cases, correlations are weaker or even non-significant. For example, the correlation between wire and miscellaneous is 0.717, which is relatively weaker than other correlations. This may indicate a weaker relationship between these areas or differences in their growth trends. The numbers in parentheses indicate the level of statistical significance. A low significance level (e.g., less than 0.05) indicates that the observed correlation is likely real and not due to chance. For example, a correlation between smelting and steel sheeting with a significance value of 0.002 indicates that this relationship is highly significant. On the other hand, values higher than 0.05 indicate a lack of correlation significance, meaning that the relationship may be purely coincidental. Based on the correlation table, the relationship between different variables can be examined, and it can be determined which variables have strong or weak relationships with each other. Here, the most important relationships between variables are examined: Recycling has a very strong relationship with screw connection variables (0.974), steel (0.977), technology (0.977), and the field of chemistry (0.968). This indicates

that inventions in the field of recycling have developed simultaneously and similarly with these fields. Screw connection has a strong relationship with steel (0.977), technology (0.957), recycling (0.974), and construction (0.983). This suggests that inventions in these areas have likely developed jointly or in parallel. Steel has a strong relationship with technology (0.986) and screw connection (0.977). This strong relationship between steel and technology demonstrates the importance of technological innovations in the development of steel inventions. Technology has strong relationships with steel (0.986), recycling (0.977), screw connection (0.957), and the field of chemistry (0.955). This indicates that technology has acted as a key driver of innovation in these areas. Building with bolted connections (0.983) and recycling (0.958) have strong correlations. This suggests that innovations related to buildings have often been associated with bolted connection techniques and recycling. The field of chemistry has a strong correlation with technology (0.955) and steel (0.953). This indicates that chemical innovations have often contributed to the development of technology and the steel industry. Some variables, such as wire and miscellaneous, have weaker or non-significant correlations with other variables. For example, wire does not have a strong relationship with any of the other variables, which may indicate that innovation in these areas has been independent of other areas. The melting variable also has weak but significant relationships with some variables, but these relationships are not as strong as in other areas. Based on the correlations presented, it can be concluded that many areas of innovation, such as technology, steel, and recycling, are strongly interconnected, and development in one of these areas likely drives growth in others. On the other hand, some areas, such as wire and miscellaneous, have less connection with other areas, which may be due to the specific or specialized nature of these areas. Many areas of invention, such as recycling, steel, technology, and bolted connections, have advanced simultaneously and similarly. This high correlation indicates that progress in one of these areas is usually accompanied by progress in other areas. Technology has acted as a key factor in the development of inventions in various fields, especially steel, recycling, and bolted connections. This analysis shows that technological innovations and synchronicity in the advancements of inventions in different fields are significantly related to each other, and these relationships can help to better understand the trends and patterns of invention development.

In analyzing the data, by examining the statistics, we conclude that inventions have a steady trend, and the year (2007-2008) is an exception, perhaps due to the pressure from the government at the time to show Iran's improving scientific status. This in itself implies that there is no integrated system for research and innovation. Among the inventions, technology, chemistry, and construction are in a better position. Technology should be considered as emerging from within industries and resulting from experience combined with thought, and thought combined with experience, mainly originating from within the industry and by industrialists. This shows that with the maturation of the steel industries, inventions also increase, and it seems that the future path of steel technology will be through this route. In other words, it is predicted that the future of steel technology is tied to the maturation of current industries and government investment. If the government's economic situation improves, inventions will also increase. However, in order for the practical knowledge gained in industries to be transformed into technology and benefit the country, the necessity of having an integrated system is evident.

Regarding chemistry, unlike the field of technology, chemical inventions are related to the growth of academic centers in the field of chemistry. This field is currently growing at a rapid pace, and Iran has a high scientific capability in this field. Therefore, the growth of inventions in this area is synchronized with the growth of universities. It is predicted that this trend will continue, but the practical use of these types of inventions depends on the growth of investment in the steel industry. Therefore, it is predicted that inventions in this area will increase at the same rate, but their practical application will remain weak and limited, as in the past. In other words, in this area, the growth of inventions will continue at a constant rate, but their application will be low. The existence of a system that can bring inventions in this field to fruition with the investment of existing Iranian industries, or even from abroad, and bring foreign currency to the country is necessary and recommended.

The numbers in parentheses indicate the level of statistical significance – source of research findings. In the field of construction, inventions are due to the growth of investment in construction. And this growth is owed to a sick economy. It is not that inventions are for the needs of construction, and this area is influenced by the construction market. It is predicted that inventions in this area will mostly be limited to construction steel and specific applications of steel in construction and will not show significant growth. Especially since the periods of recession and boom in construction vary and fluctuate a lot. Therefore, examining this area will not be as beneficial and effective in the process of steel inventions as the other two areas.

## 3.2. Stage 3: Defining Root Definitions of Related Systems

In this stage, systems related to patent analysis are defined based on different perspectives. More specifically, the essence of the "patent analysis system" is determined and defined from various viewpoints. One of the systems that can be defined in relation to patent analysis is:

Table 2. The correlation between the number of different inventions.

| Inventions | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| recycling (1) | 0.907 (0.033) | 0.955 (0.011) | 0.958 (0.010) | 1.000 (0.015) | 0.951 (0.013) | 0.977 (0.000) | - | 0.977 (0.023) | 0.961 (0.039) | 0.978 (0.023) | - | 0.969 (0.010) |
| bolted connections(2) | - | 0.976 (0.033) | 0.968 (0.011) | 0.949 (0.010) | 0.985 (0.010) | 0.970 (0.157) | 0.945 (0.212) | 0.972 (0.000) | 0.957 (0.000) | 0.914 (0.011) | 0.720 (0.280) | 0.974 (0.000) |
| steel (3) | - | - | 0.986 (0.000) | 0.953 (0.000) | 0.979 (0.000) | 0.945 (0.212) | 0.956 (0.189) | 0.988 (0.000) | 0.937 (0.000) | 0.940 (0.002) | 0.781 (0.219) | 0.977 (0.000) |
| technology (4) | | | - | 0.987 (0.000) | 0.986 (0.000) | 0.986 (0.000) | 0.986 (0.000) | 0.986 (0.000) | 0.986 (0.000) | 0.986 (0.000) | 0.817 (0.183) | 0.977 (0.000) |
| automotive (5) | | | | - | 0.930 (0.000) | 0.953 (0.000) | 0.844 (0.156) | 0.984 (0.000) | 0.953 (0.000) | 0.953 (0.000) | 0.953 (0.000) | 0.938 (0.000) |
| construction(6) | | | | | - | 0.929 (0.171) | 0.942 (0.058) | 0.971 (0.000) | 0.947 (0.000) | 0.919 (0.001) | 0.693 (0.307) | 0.983 (000/0) |
| molding (7) | | | | | | - | 0.977 (000/0) | 0.954 (0.046) | 0.922 (0.078) | 0.977 (0.000) | 0.977 (0.000) | 0.894 (0.106) |
| steel boiler (8) | | | | | | | - | 0.922 (0.078) | 0.867 (0.133) | 0.998 (0.044) | 0.922 (0.078) | 0.956 (0.044) |
| chemical field (9) | | | | | | | | - | 0.955 (0.000) | 0.953 (0.000) | 0.831 (0.169) | 0.968 (000/0) |
| steel sheet (10) | | | | | | | | | - | 0.863 (0.012) | 0.791 (0.419) | 0.936 (0.000) |
| smelting (11) | | | | | | | | | | - | 0.769 (0.231) | 0.907 (0.002) |
| wire rod (12) | | | | | | | | | | | - | 0.717 (0.238) |
| miscellaneous ( 13) | | | | | | | | | | | | - |

### 3.2.1. First System Definition (Root Definition-RD1)

A system for converting patents into technology, with the aim of localizing technology, through patent analysis.

This definition sets the goal as "localizing technology" and names the system's mission as "converting patents into technology". Furthermore, this definition introduces "patent analysis" as the means of carrying out the mission. Such a system has the following characteristics.

### 3.2.2. CATWOE Analysis for this System

C (Customers): Steel companies, research centers, industrial policymakers, technology investors (Government). A (Actors): Patent analysts, steel engineers, universities, incubators, standardization bodies, innovation funds. T (Transformation): Converting inventions into technologies. W (Worldview): Analyzing inventions to transform them into technology can be done with the aim of localizing technology. Analyses have shown that we mainly have strengths in two areas: chemistry and technology. Inventions, in order to be transformed into technology, require a system and a systematic process to make this transformation possible. O (Ownership): Ministry of Industry, Mine and Trade (MIMT), industrial associations, steel companies, innovation funds. E (Environment): We mainly have strengths in two areas: chemistry and technology, technology sanctions, environmental changes, developments in the global steel market, government support policies, successes of innovation funds, national industrial budgets and plans. Now, we could use the CATWOE analysis to improve RD1.

### 3.2.3. Definition of the Second System: RD2

A system for "transforming inventions into technology," with the aim of "producing indigenous technology," through "government intervention and policymaking, investment by steel companies, and academic research primarily in the two fields of chemistry and technology," and taking into account sanctions, the research strength of universities, environmental changes, global steel market developments, budgets, and national industrial plans.

### 3.3. Stage 4: Building Conceptual Models

In this stage, an operational conceptual model is developed and drawn based on each of the RDs. This model represents the minimum number of activities that needed to be exist for the system, so that it able to fulfill its mission and achieve its goal. Here, a model is presented for RD2. This model includes six key activities that are defined as a coherent process for localizing and developing technology in the steel industry. In steps 1 and 2 of the SSM analysis, it was determined that this process should be shaped by investments from domestic or foreign companies.

These activities include:
1. Attracting domestic investors from domestic state-owned and private steel companies,
2. Attracting foreign investors,
3. Conceptual technology planning,
4. Detailed technology planning,
5. Technology preparation,
6. Technology development

The above components in more detail are:
1. Attracting domestic investors from state-owned steel companies Identifying steel companies with the capacity to invest in technology Creating motivation for investment by providing economic and technological analyses Designing financial and credit incentives for domestic companies Arranging memoranda of understanding between industry and research centers.
2. Attracting foreign investors Identifying international investors and multinational steel companies Analyzing the political and economic risks of attracting foreign investment Arranging technology transfer and joint venture agreements Reviewing government support laws and policies for attracting foreign investment.
3. Conceptual technology planning Analyzing patents and global innovation trends in the steel industry Identifying technological gaps in the domestic steel industry Defining industrial needs and technology localization requirements Developing conceptual scenarios for technology development.
4. Detailed technology planning Determining the technical and engineering specifications of the desired technology Designing production processes and required standards Reviewing operational challenges and environmental considerations Forecasting research and development (R&D) costs.
5. Technology Acquisition Selecting the appropriate method for acquiring technology (internal development, technology purchase, partnership with foreign companies) Negotiating technology transfer and reverse engineering agreements Procuring necessary equipment, raw materials, and technical knowledge Establishing experimental infrastructure for technology testing.
6. Technology Development Documenting processes and technical knowledge Standardizing and optimizing technology for mass production Training personnel to operate the new technology Integrating the technology with the steel industry supply chain.

Conceptual Model Overview (Relationships between the activities)
1. Domestic and foreign investment (Stages 1 and 2) are prerequisites for technology development.
2. After securing investment, conceptual and detailed technology planning (Stages 3 and 4) takes place.
3. Subsequently, technology is acquired through internal development, purchase, or technology transfer (Stage 5).
4. Finally, the technology is developed, documented, and implemented (Stage 6).

This model is depicted in Fig. 6. Also, the process flowchart of the model is depicted in Fig. 7.

### 3.3. Step 5: Comparison

In this step, we compare the current situation with the RD2 model. This comparison is done using the method suggested in the book "System" [10], which involves creating a Table of the activities present in the model and asking questions about them (Table 3.).

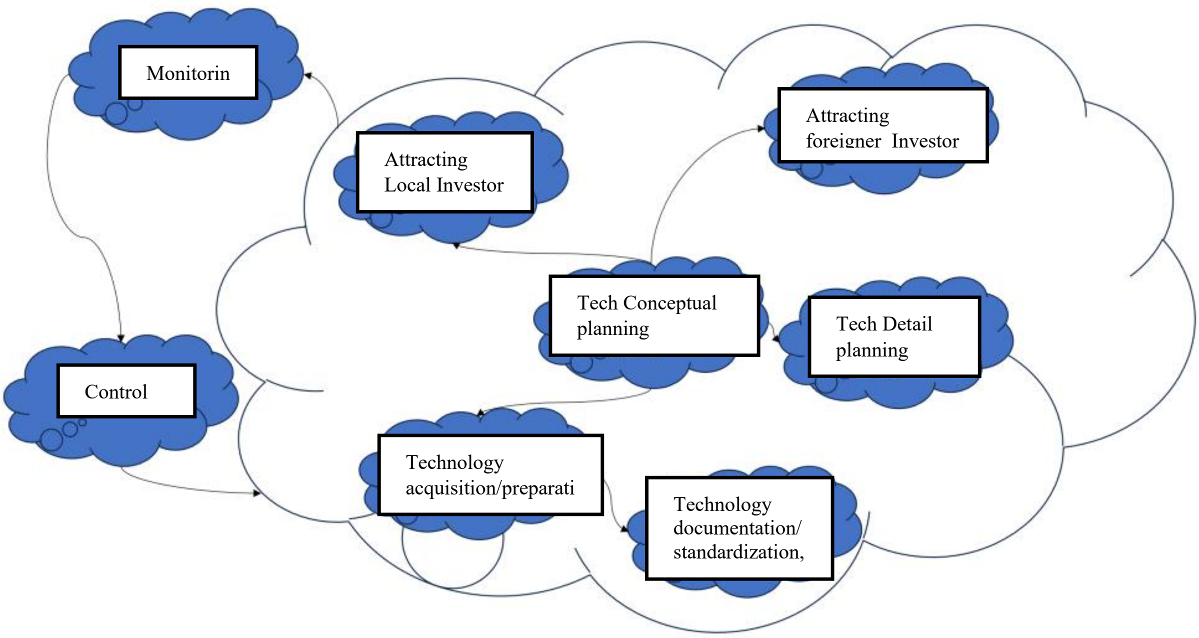


Fig. 6. RD2 Conceptual Model.

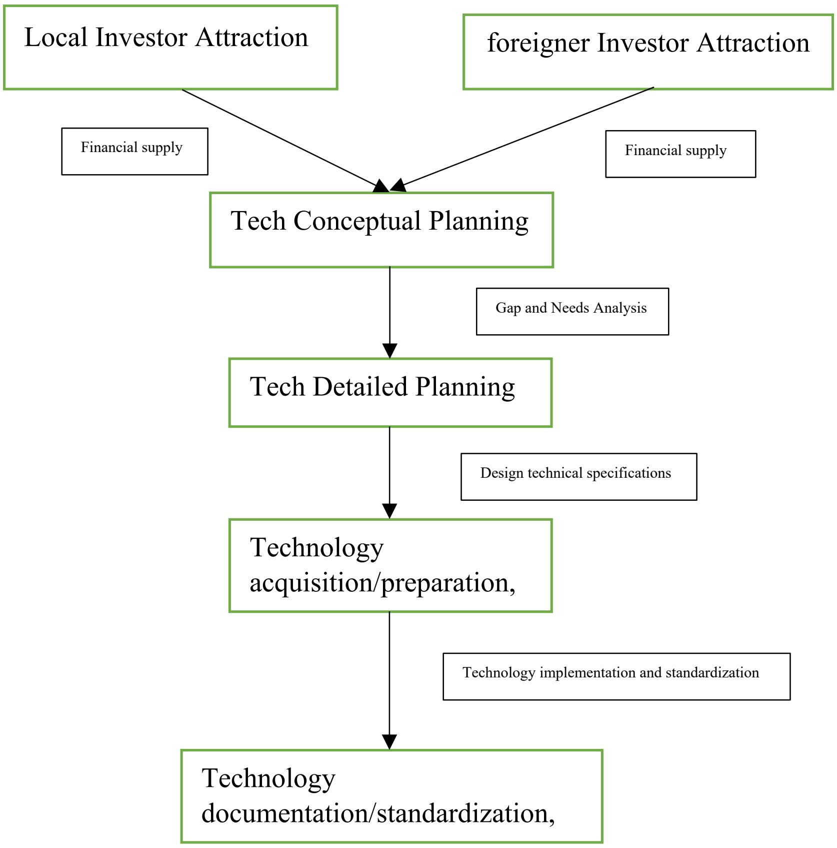


Fig. 7. The model's flowchart.

Table 3. Comparison of the current situation and the RD2 model.

| Activity | Is it existing in the real world's situation? | Present mechanism? | Criteria? | Proposed changes | Comments |
|---|---|---|---|---|---|
| Attracting Local Investors from Iron and Steel Companies | Yes | Through investment funds | Number of projects | Analysis of the current investment plans | Experts have identified the fields of chemistry and technology for attracting investors. |
| Attracting Foreign Investors | No | | | Designing a system and process for attracting foreign investors—taking into account that the country's strength lies in the field of chemistry and its research. Attraction efforts should be aligned in this direction. | This may require the formulation of new laws or the country's accession to international conventions. This possibility should be investigated. |
| Conceptual Technology Planning | Yes | The Ministry of Industry, Mine, and Trade and steel companies, through universities and research centers. | Technology Readiness Levels (TRL) standard. | Planning for the integration of technology and research within the country. | This system exists but requires re-engineering to become fully integrated. |

Table 3. Continued.

| | | | | | |
|---|---|---|---|---|---|
| Detailed Technology Planning | Yes | Steel companies plan the details of the technology. | Technology application based on the judgment of industry experts. | We need to establish a technology documentation office with the participation of universities and companies. | The integration mentioned in the previous line should also be considered here. |
| Detailed Technology Planning | Yes | Steel companies plan the details of the technology. | Technology application based on the judgment of industry experts. | We need to establish a technology documentation office with the participation of universities and companies. | The integration mentioned in the previous line should also be considered here. |
| Technology Acquisition/Preparation | Yes | Steel companies acquire/prepare the technology. | Technology application based on the judgment of industry experts. | We need to establish a technology acquisition/preparation office with the participation of universities and companies. | The integration mentioned in the previous line should also be considered here. |
| Technology Documentation/Standardization | Yes | Steel companies document/standardize the technology. | Technology application based on the judgment of industry experts. | We need to establish a technology documentation/standardization office with the participation of universities and companies. | The integration mentioned in the previous line should also be considered here. |
| | | | | The documented technology must be presented clearly and should be standardized. | |

## 3.4. Step 6: Propose Desired and Feasible Changes

From the proposed changes' column of Table 3., we present and describe suggestions.

1. Investor Attraction Plans: Investor attraction plans have existed before. However, they do not seem to have been very effective. Considering that experts have identified the fields of chemistry and technology as areas for attracting investors, it seems that attracting investors in these two areas should be a priority. Nevertheless, it is suggested that the strengths and weaknesses of existing investor attraction plans be examined. That is, a national-level pathology should be conducted.
2. Planning a System and Process for Attracting Foreign Investors: According to the reviews and opinions of experts, the country's strength lies in the field of chemistry and its research. Therefore, attraction should be in this direction. Currently, there are many obstacles to attracting foreign investors. A thorough review and investigation should be conducted, and measures should be taken to remove investment barriers. In this way, it may be necessary to develop laws or for the country to join international conventions. This should be investigated.
3. Planning to integrate technology and research in the country: A conceptual technology planning system exists, but its efficiency is not high. In other words, good coordination and coherence are not seen between academic research, research centers, and industrial centers in the country. This may be due to the lack of integration between the research system and the industrial system of the country. These two systems need to be re-engineered to become integrated. Here, integration means the informational unity of these systems, in such a way that research centers conduct research to meet the needs of industrial centers, and industrial centers turn their research into technology and tools. We need to establish a steel technology organization. Academic research is strong in the field of chemistry, and industrial research is strong in the field of technology. The two should integrate their results and strengthen each other.
4. Establishing technology preparation and compilation offices with the participation of universities and companies: These offices are parts of an integrated technology and research system in the country. The Technology Preparation Office is responsible for shaping

research processes and following them up until they reach technology and the application of technology. The Technology Compilation Office is responsible for preparing technology documentation, providing documentation, keeping the documentation up-to-date, and finally preparing different versions of the technology and obsoleting the old versions.

## 3.5. The Research Validation

The validity of the research comes from two sides. First of all, the research has been done based on SSM, that already proved its usefulness. Second, the results have been suggested and proved by some experts in the steel field. Moreover, the base for the judgment of the experts, are the statistics from the Iranian steel inventions. So, the validity could be trustworthy.

## 4. Conclusions

In this article, the soft systems methodology was used to investigate the domain of steel industry patents in Iran. The analysis of patents in various fields from 2003 to 2024 indicates significant diversity and fluctuations in the distribution of the number of patents. These fluctuations are due to various reasons such as economic changes, government policies, and industrial needs. Fields such as "Technology" and "Chemistry", compared to other fields, have the highest number of patents, and especially in the years 2007-2008, a significant increase in the number of patents was observed.

In analyzing the data, by examining the statistics, we conclude that inventions have a steady trend, except for the year 2007, perhaps due to pressure from the government at the time to show Iran's improving scientific status. This rise the concern that there is no integrated system for research and innovation. This concern was emphasized by the experts. Therefore, an integrated system in this regard was proposed. Also, the expert opinions showed that "Technology" should be considered to originate from within industries and from experience combined with thought, and thought combined with experience, mainly emerging from within the industry and by industrialists (Iron and steel's industrial experts). Thus, with the maturity of the steel industries, inventions will also increase, and it seems that the future path of steel technology will be through this route. That is, it is predicted that the future of steel technology is intertwined with the maturity of current industries and government investment. If the government's economic situation improves, inventions will also increase. However, in order for the practical knowledge gained in industries to be transformed into technology and benefit the country, the need for an integrated system is evident, and this system has been proposed. In the field of "chemistry", steel inventions are related to the growth of academic centers in the field of chemistry. Therefore, the growth of inventions in this field is in sync with the growth of universities and will continue. However, the practical use of these types of inventions depends on the growth of investment in the steel industry. The existence of a system that can bring inventions in this field to fruition through investment from existing Iranian industries or even from abroad is necessary and recommended. We recommend more research to find out the reason for high fluctuations in some areas like "Recycling", "Automotive", and "Smelting", and to stabilize those area's inventions. Moreover, the recent significant reduction in innovations should be analyzed (the years' 2023-2024), and some motivations regarding to increasing the innovation activities should be considered. This research could help the Iranian steel industries to know their areas of strength (mainly "chemistry" and "Technology"), and focus their investment on them. To this end, in particular, the research and development departments of steel companies should be tasked with employing expert craftsmen in the field of technology and, at the same time, investing so that universities can transform their industrial's research in the field of steel chemistry into practical industrial and applied stages. It is suggested that further research be conducted in areas with high volatility such as "recycling", "automobiles", "molding", and "steel boilers" to identify the reasons for the fluctuations and provide appropriate solutions to increase stability and inventive activities in these areas. Government and industrial policies and support need to be strengthened in areas with high growth and activity. In particular, more support in areas such as "technology" and "chemistry" that have higher invention activity can help increase innovation and sustainable growth. For areas with limited activity such as "mold making" and "steel boiler", it is recommended that further research and development be conducted to identify and address limiting factors and create new opportunities for innovation. The sharp decline in the number of inventions in recent years (2023-2024) should be investigated.

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