ISSN: 2723-9535

Available online at www.HighTechJournal.org

# HighTech and Innovation Journal

Vol. 6, No. 2, June, 2025

# Innovation Process and a Model for HighTech Companies within an Industrial District

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Received 30 December 2024; Revised 21 May 2025; Accepted 27 May 2025; Published 01 June 2025

**Abstract**

High-tech companies innovate through complicated and dynamic interactions with other shareholders willing to form a "Technology Innovation System." There is extensive literature on the formation of such systems; however, most such studies have not considered their dynamic features, R&D intensity, and other factors. Innovation dynamics should be framed upon the activities of R&D for technological development and then transferred into commercial economic values. This work aims to develop a model to improve the understanding of the dynamic behavior of high-tech companies within an industrial district in İstanbul, Turkey. This research outlines innovative approaches along with other features such as R&D intensity within the companies, the availability of scientific and technological personnel, the collaboration with scientific organizations, and initiatives in intellectual property rights. Extended interviews were conducted with the upper management of 8 high-technology companies using a structured and in-depth interviewing technique. As a result, based on specific indicators and scoring data, this study reveals the importance of a "technology innovation system" within such an industrial district for high-tech companies for the company's business processes and indirectly within the company's management approach. This research outlines innovation systems along with other features such as R&D intensity, the availability of scientific and technological personnel, and their involvement through scientific research collaborations.

*Keywords:* High Technology; Technology Innovation System; Research and Development; Innovation Process; Industrial Zone.

## 1. Introduction

There have been numerous studies on the concepts of innovation processes and dynamics, and an ample amount of models have already been suggested in the relevant literature [1-5]. Innovation has become an effective term focused on relentlessly, and its importance has been emphasized and underlined in countless ways. It is a highly critical subject, considering it brings social and economic changes, especially with its function and role in high technology fields. The impact of digitalization and AI-powered innovations, along with the application of IoT and blockchain technology on integrating innovation and industrial chains in high-tech manufacturing, is increasing. Some of the studies [6-8] examined the interaction between digitalization and the application of IoT and blockchain technology on the innovation dynamics. They revealed that digital technologies and AI-powered techniques have also created a significant transformation in innovation processes. It is shown that technological advancement has led to digital transformation as a strategic driver for firms seeking to enhance innovation and competitiveness. Digital transformation improves both dynamic capabilities and innovation performance. In this context, research on the effects of new-generation digital technologies on the innovation ecosystem is critical for high-tech companies to achieve sustainable competitive

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http://dx.doi.org/10.28991/HIJ-2025-06-02-06

advantage. The Technology Innovation System approach for the high-tech and emerging new tech areas would be the framework to understand the complex and complicated nature of the high-tech innovation process [9-12]. The innovation system dynamics for high-tech areas should be attended explicitly to the surrounding actors and players, networks, and institutions within the system, along with the severe competition within such emerging high-tech areas. It should be defined as a system comprised of a variety of factors such as skilled personnel, organizational resources for information, science, and technology, financial supporting mechanisms, intellectual property, and materials [13-15]. As such, it directly affects the value and commercial status of industrial companies and pushes companies to be more effective regarding innovative activities such as R&D intensity, national and international collaboration, collaboration with academia (including research institutions, universities, colleges, and vocational schools), and others.

However, as is very well known, there is certainly no 'ready-to-use' innovation system recipe that can be considered "effective and successful" at the industrial, institutional, regional, sectoral, and firm levels. There are different conditions and different factors affecting them at each stage of the technology innovation system and related processes. Considering the innovation dynamics and processes in high-tech industries, which are gaining particular importance in products, processes, and services, the subject is still in an investigative phase. Essential in-depth treatment of innovation dynamics and models that lead to the adoption and diffusion of high-tech by society and the market needs to be much more revealed [16-20]. The concept of "High Technology" and the nature and characteristics of a high-tech company based on sector-specific features are defined and explained in the literature [21, 22].

"Continuous innovation" is undoubtedly one of the most important focal activities of high-tech companies and organizations that distinguishes and differentiates a company operating in high-tech fields. It is also pointed out that promoting high-tech innovation abilities may also accelerate the development of high-quality and efficient economic mechanisms as well [23]. In this regard, knowledge and innovation management are also extremely important in developing new and emerging high technologies and gaining a competitive advantage in the market. The performance and effectiveness of the company in the production of high-tech products/processes are closely related to the availability of knowledge-based/intellectual assets to be developed in this context. Continuous innovation dynamics should be framed upon the activities of R&D in technological development and then transferred into commercial economic values. Such an innovation chain process is the structural base for the effective and efficient transformation of commercial high-tech products. In this process, technology digestion and absorption through R&D intensity are essential factors for high-tech companies [8, 24]. Scientific knowledge and technologies, new ideas, and approaches must be transferred into the market as products, processes, and services.

As the corporate culture becomes visible in an environment of innovation and creativity, the company will constantly achieve competitiveness. For instance, effective human resources management is an essential factor that increases employee productivity in innovative high-tech companies. Studies on how AI-based human resources applications are used in businesses and how they support innovation processes show that in addition to increasing employee experience, they also improve organizational innovation capacity [25, 26]. It is crucial for the organization to adapt to the ever-changing market conditions and relentlessly advancing technological developments and to take new high-tech outputs as a basis for reorienting the organization through change, adaptation, and assimilation. The basic process is knowledge- and technology-based innovation and turning them into products that can be marketed [17-19]. It is well known that high-tech companies can achieve rapid development due to their flexible and innovative system, unrivaled relationship with skilled personnel, culturally innovative environment, and continuous innovation for their personnel. In this regard, it should be noted that the technological innovation system could only effectively and efficiently function and operate in high-tech companies [27].

As a result of the radical developments in high technologies, the innovation system has begun to cover almost every aspect of society, government, finance & economy, and industry. Technology transfer, one of the basic components of innovation, is of great importance for economic development [28]. For high-tech companies, innovation is not only limited to developing new products or services; technological knowledge sharing and collaborations are also critical factors. In this context, how the technology innovation systems discussed in our study affect the knowledge transfer processes between companies was also analyzed. Based on the technological developments in electronics & communication, informatics, artificial intelligence, IoT, robotics, intelligent and autonomous systems, mechatronics, nanotechnologies, advanced materials, and intelligent transportation in recent years, the system is becoming more complicated and complex. A dynamically developing innovation system is now providing opportunities for companies to communicate with different and varying regions, locations, actors/players, institutions, and networks, including industrial zones and technoparks, academia/research-vocational schools, and technical colleges. In this regard, it is demonstrated that innovation capacity in high-tech industries lies in the efficiency of transforming capabilities, adapting to geographical location, and the R&D and technology development level of each region [29].

With the advancement of high technologies, the severe competition between companies operating in high-tech fields has increased enormously, and companies with the ability to bring the most innovative/creative high-tech products to the market in the fastest way have begun to prevail. This capability depends on the companies' innovation and R&D vision, capacity and capabilities, and their ability to implement this vision in every aspect of their business processes. High-tech companies innovate through complicated and dynamic interactions with other stakeholders who are willing to be part of the technology innovation system. Creating new and high-technology products is directly linked to

companies' innovation activities (including R&D studies and others). In this regard, the literature has not covered other factors such as scientific and technical personnel, scientific collaboration, intellectual property issues, etc., to fully clarify the complexity of the innovation system and dynamics. There is extensive literature on the formation of such systems. However, the majority of such studies have not taken into account their dynamic and interactive, interconnected features and properties. This work specifically aims to develop a model to improve the understanding of the dynamic behavior of high-tech companies within an industrial district in Istanbul, Türkiye. This research outlines innovative approaches along with other features such as R&D intensity within the companies, the availability of scientific and technological personnel, and their involvement through scientific research, university collaborations, and initiatives in intellectual property rights.

Previous theoretical models based on scientific and technological policies connected to innovation efficiency may not elucidate highly complex high-tech dynamics. Highly connected interactions and interrelationships between the actors/players/shareholders should be framed in an integrated model underlying the system dynamics.

## 2. Innovation Dynamism in High-Tech Companies and Organizations

The development of new high technologies in all kinds of companies and their implementation as industrial/commercial products is possible within a functioning, dynamic, and effective R&D-intensive and innovative environment. In a way, this is what makes new high-tech companies different from traditional, medium- and low-tech companies. As an indispensable and vital element of new high-tech fields, within the scope of innovation, the relevant processes must be planned, created as a solution within the scope of high-tech, and explored for the strategic benefits of the organization, rather than being introduced randomly and out of nowhere [18]. There has been much investigation and research on the development of high-tech industries, mainly evaluating technological innovation. It is pointed out that the dynamic evolutionary relationship, specific characteristics, and mechanism between science and technology resources and high-tech industries have not been investigated in depth, and there is very little work on the dynamism of the relationship for high-tech systems [13, 30-32].

High-tech companies are constantly facing severe and complex challenges within very fast-paced global high-tech industries [33, 34]. Some of those key challenges can be outlined as follows: i. Costs; ii. Rapid Product Innovation; iii. Slow Transition of R&D Results Into Commercial Products; iv. Shift From Products Into More Services; v. Lack of High-Quality Scientific and Technical Personnel in R&D Activities.

The basic initial phase of the innovation process is the "Research & Development" phase, which is the most crucial element of new high-technology companies and is of vital importance and quality [20, 35-37]. At the same time, this is the main issue that distinguishes a high-tech enterprise from the classical-traditional structures, and the criterion is monitored and measured by the expenditure and investment made in this field. This stage ensures that starting from the generation of the new high-tech conceptual idea, the relevant creative idea is evaluated, tested with experimental measurements, improved with scientific principles, and turned into a product. Following this, the product/process created and detailed in the design must be "implemented" as a demo, prototype, or trial and delivered to the market. The following methods are continued with the steps of growth, perfection, dissemination, and maturation within the company's scope. At these stages, it is extremely important to continue the ongoing cycle with the steps in question in the form of intellectual sprouting, birth, and creation of another new, more developed, original, and advanced product in a lively and dynamic way. The future of a new high-tech company that cannot provide this continuity will be uncertain, suspicious, risky, and unclear. The model that will be outlined in this work will address these interactive factors that are lacking in the relevant literature. A variety of different aspects of dynamic and interactive characteristics should be handled in an integrated approach for a more direct and clearer understanding.

With the development of high technologies in recent years, the trends of consumers have also begun to change, and we are now facing a certain consumer base that looks for existing products to be renewed very quickly and expects continuous innovation with new versions and brands. This situation has changed companies' understanding of their internal processes. In the past, companies used raw materials, workers, stocks, etc., while competing with other companies on such issues. This situation has now changed, and recently companies have started to compete based on innovative scientific and technological research and R&D studies.

As it was underlined on theoretical bases defining the technology innovation system, other than the creation of new knowledge through the R&D process, other factors such as service-providing firms, supporting units, universities and the research labs, the government, patent offices, and other institutions should be taken into account [16]. Collaboration, interconnection, and interaction between such actors are vital to improving the gains of a dynamic high-tech environment. Other challenges, such as intense price pressure, highly rapid technological change, and severe turbulence in national and international markets, are also becoming very hard and complex problems all over the high-tech industries [38].

This study was carried out in the leading industrial district of Istanbul, Türkiye: “Istanbul Dudullu Organized Industrial Zone (IDOIZ)” established in 1982. In this regard, the local environment within this district can certainly become a critical source of knowledge creation, sharing, supporting, and processing. The support and help of local firms

(mostly SMEs and plain workshops providing practical solutions and services) could help them acquire competitive advantages, benefiting firms of all sizes in different industrial sectors. It is an indispensable source for technical and practical innovations. It has also been demonstrated that innovation capacity in high-tech industries lies in the efficiency of transforming capabilities and adapting them to geographical location, R&D, and technology development levels of each region [29].

Currently, most technological innovations are brought by such SME-type companies, and this dynamic is now very well understood by medium- and large-sized companies [39]. In addition, the implementation and execution of new ideas and projects are possible within such a zone with a huge variety of different financial and organizational contributions. The clustering of effective supporting units within a specific zone is an extremely important factor and promotes the innovation and competitiveness of high-tech industries [40]. Technological innovation processes are affected not only by internal company dynamics but also by macroeconomic and political factors. Developmental Network State theory is a necessary approach that examines the role of the state in supporting technology and innovation [41]. Especially in the case of the USA, the state's technology policies and financial support mechanisms have accelerated innovation processes. Similarly, certain advantages and incentives for organized industrial zones in Türkiye can increase the global competitiveness of high-tech firms by creating mechanisms that encourage innovation. It should also be noted that the existence of a culture that highly values sharing, supporting, and solving problems within the zone is highly valuable. In such an industrial district that supports high-tech activities at the technological edge, enabling innovations and creating competitive advantages that will be critical in the understanding of high-tech dynamism for the upcoming few decades [39].

As observed in recent literature, there is very limited research on the mechanism of technological innovation dynamics for high-tech companies operating within industrial districts, driving the innovation capabilities [42]; in this regard, no framework has yet been provided for the innovation mechanisms of high-tech companies operating within industrial districts.

Istanbul Dudullu Organized Industrial Zone (IDOIZ) covers an area of 265 hectares, including “the Factories Zone” and other SME-based companies in machinery, manufacturing, and automotive industrial sites. It should be noted that, unfortunately, the IDOIZ is not a high-tech sector-specific zone, and random varieties of companies from all different sectors are operating within the district (machinery, food, furniture, textiles, manufacturing, etc.). The eight companies operating in various high-tech fields (electronics, communication, nanotechnology, advanced materials, autonomous vehicles, and satellites) in this area were carefully selected. Structured and lengthened dialogues/interviews with the upper-level managerial staff, including CEOs, general managers, department heads, and R&D experts, were conducted to evaluate the following features for a high-tech company:

- Innovation and creativity characteristics;
- Effect of the R&D within the company;
- Human resource issues for a high-tech company;
- Effect of the proximity and cooperation within an industrial district;
- Scientific and technological collaboration with universities, labs, and/or other relevant institutions.

This research outlines innovative approaches along with other features such as R&D intensity within the companies, the availability of scientific and technological personnel, the collaboration with scientific organizations, and initiatives in the field of intellectual property rights. Extended interviews were conducted with the upper management of 8 high-technology companies using a structured and in-depth interviewing technique. Findings are measured based on a scale showing the overall dynamism of innovation in high-tech, and a model is constructed accordingly. As a result, based on certain indicators and scoring data, this study reveals the importance of a “technology innovation system” within such an industrial district for high-tech companies for the company's business processes and indirectly within the company's management approach. This study showed that for high-tech companies, innovation, R&D, and talented personnel profiles are major concepts that must be understood and expertly applied in every process of the company, including business and managerial issues. Applying these concepts correctly is the major objective that will enable high-tech companies to be successful both in local and international markets.

## 3. Material and Methods

This study was conducted in the leading industrial district of Istanbul, Türkiye: Istanbul Dudullu Organized Industrial Zone (IDOIZ). This industrial zone includes “the Factories Area” along with other large industrial sites of SMEs. Around 3000 SMEs and 110 major medium- and large-sized companies continue their activities within the proximity of IDOIZ. The 8 most successful high-tech companies operating in various high-tech fields were selected. Companies were contacted and investigated in the study, among which one additional company, a conventional medium-tech company, was chosen as “the witness/control” company operating in the traditional machinery-manufacturing sector. This

"witness/control" company is a well-established and prestigious company within the IDOIZ with over 40 years of experience in national and international markets. This company was chosen for the control, as it is out of the scope of "hi-tech" and will be referred to as "Company A" throughout the study.

This study aims to consolidate the theoretical concept of "Technology Innovation System" In the context of an industrial district where a variety of actors/players are within proximity. This research also intends to fill the gap on how such industrial interactions influence innovation performance for high-tech companies. The flowchart depicted in Figure 1 elucidates the screening and selection of these high-tech companies, along with the selection of a witness/control company. Such a screening procedure based on "Technology Innovation System" theory demonstrates that extended interactions of those players/actors within the district further generate a dynamic enhancement of innovation. By empirically interrelating these relationships, the dynamic model outlined in this study provides a better understanding of the "Technology Innovation System" and contributes to innovation performance for high-tech companies.

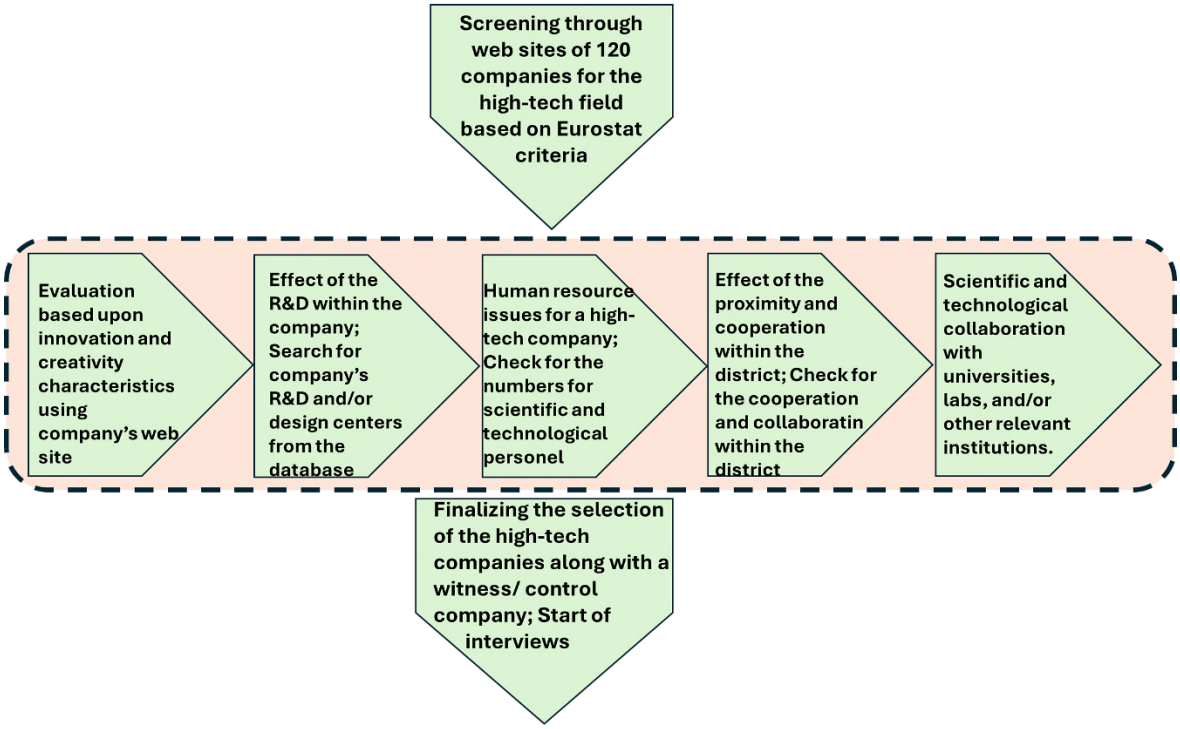


**Figure 1. The flowchart showing the screening and selection of the high-tech companies and the witness/control company**

To briefly introduce the companies that will be examined and evaluated;

1. Sintermetal (Advanced Materials): Founded in 1967, the company produces various complex machine parts and components with sintering technology via advanced powder metallurgy techniques. With their R&D studies, they aim to maintain their leadership in sintering and become a globally recognized company. It seeks to reduce human error in production and quality and strengthen the importance given to occupational safety with the full automation studies they have recently carried out both at home and abroad [43].

2. Assan Elektronik (Electronics): Assan Elektronik, which entered the sector in 1980 by producing devices in industrial electronics, started to manufacture LED lighting modules in 1990. After establishing a company partnership with DMY Group, it has focused on electronic card production since then, especially for defense sectors. There is an R&D Center within Assan Elektronik, which continues its activities in aviation, automotive, telecom, energy, and medical [44].

3. Entes Elektronik (Electronics): The company, which started its activities in 1980, introduced Turkey's first web-based energy monitoring software. It offers its customers solutions in energy efficiency and quality, measurement, compensation, protection, and control. It also produces hardware for a wide range of products in respective fields. There is an R&D Center within Entes Elektronik [45].

4. Quantag Nanotechnologies Development and Production (Nanotechnology): Established in 2014 as a subsidiary of Opet Petroleum Company with the partnership of Koç Holding and Öztürk Group, Quantag company enables the identification and verification of products by using quantum dots that cannot be copied for quantum labels in customer products with the quantum tagging technology (QTT) they developed. These quantum punctuations can only be read and decoded by ultra-sensitive quantum sensors. Thus, high-security authentication is provided. Quantum labeling technology was developed by the Quantag company for the first time globally [46].

5. Adastec (Autonomous Vehicle): Adastec, a company that carries out R&D and autonomous testing studies, has developed the world's first Level 4 autonomous electric bus/midi bus software. With the software they developed, production for the first autonomous electric buses started in partnership with KARSAN. As a result of the traffic road tests, it has successfully driven in live traffic and is the first autonomous electric bus in the world [47].

6. Asis Automation (IT): The company entered the sector in the IT field in the 1990s, and after 2000, it concentrated on studies on automation in fuel systems. The company, which has an R&D center, has started to produce solutions in automation, software, and hardware for many sectors over time, as a result of intensive R&D studies. The main works they do include satellite and payment systems, mobile applications, the Internet of Things, artificial intelligence, robotics, embedded systems, image analysis, and sensor Technologies [48].

7. Mertech Electronics (Communication, Electronics): The company has been operating for more than 25 years, developing products such as control, communication, embedded systems, power electronics, and industrial automation systems in the fields of automotive, marine and industrial electronics. The company, which has an R&D center, provides services to many large companies [49].

8. Satelcom (Satellite and Telecomm): Founded in 2014 to provide distributorship, production, integration, and technical services in areas such as telecommunications, cellular mobile network, satellite communication, and telemetry technologies, the company is affiliated with DMY Group companies operating in many different sectors [50].

9. Medium Technology Company Operating in the Machinery - Manufacturing Sector Machinery-Company A": The name of this company, which is the last of our interviews and operates in conventional machinery - manufacturing, will not be disclosed. The company is a well-established company with a history of over 40 years and continues its activities within IDOIZ. The company, which produces flow equipment and heat transfer systems for industries, exports many products domestically and to nearby geographies and has wide stock facilities. The relevant company will be referred to as "Company A". This company was also considered as a "witness/control" compared to the other 8 "high-tech" companies. The company is highly successful in the traditional machinery-manufacturing sector and has been evaluated as a reference in comparison with our criteria within the scope of "high technology".

Table 1 gives the areas of high technologies in which these selected companies operate. It is observed that the fields in which the companies operate are under the high- and medium-technology fields published by Eurostat.

**Table 1. Areas In Which Companies Operate**

| Areas of high tech in which companies operate | Companies within IDOIZ |
|---|---|
| Electronic-Electrics | Entes, Assan Elektronik, Mertech |
| Automation, Autonomous Vehicle systems | Adastec, Asis Otomasyon |
| Advanced Materials | Sinter Metal |
| Nanotechnologies | Quantag |
| Satellite, Telecom | Satelcom |
| Manufacturing Machinery | "Company A" |

During the study, a structured interview, one of the qualitative research techniques, was conducted with the managerial levels of the selected companies. The interview method is a controlled conversation for a purpose [51]. Interview questions are grouped under six main themes. These are: High Technology, Innovation, Application, Feedback, Human Resources, and Material Resources. In addition, another set of interview questions was also created and asked based on the interactions of the leading innovation indicators that are expected to be implemented in high-tech companies. These indicators were obtained from the previous literature in this field and documents published by official organizations. The relevant indicators used in the study are stated in Table 2.

**Table 2. Table of Indicators to Be Used for the Innovation of High Technology Companies**

| | |
|---|---|
| ***Multitechnological*** | *R&D Intensity* |
| ***Future-oriented Technologies*** | *Design Intensity* |
| ***Intellectual Property*** | *Design Investment* |
| ***National Cooperation*** | *R&D Investment* |
| ***International Cooperation*** | *Technological Investment* |
| ***Collaboration Intensity*** | *Employing High-Level Scientific and Technical Personnel* |
| ***University Collaboration*** | *Continuous Learning* |
| ***Customer Demands and Inquiries*** | *Multidisciplinarity* |
| ***Feedback Mechanism*** | *Creativity* |
| ***Product Potential*** | *Rapid Diffusion of Innovation and Knowledge* |
| ***Scientific Research*** | - |

In light of the indicators in Table 2, 37 structured interview questions were directed to the participants. Interviews lasted approximately 40-80 minutes with each company. The answers were recorded and then transcribed. Some of the interview questions are as follows;

1. As a company, in high-tech fields, such as artificial intelligence, cloud, internet of things, robotics, quantum computing, etc. Do you have any studies on any of these subjects?
2. Does your company have a "Networking Approach" at national and/or international levels?
3. On average, how many new products, features, or services do you introduce annually?
4. How often has your company launched a unique product, process, or service in your sector?
5. How many patents or utility models/useful designs does your company have?
6. How many personnel does your R&D team consist of?
7. As a high-technology company, what are your criteria for training a qualified workforce in terms of innovation? (High School, Associate Degree, Bachelor's Degree, Master's Degree, Doctorate, etc.)
8. As a high-tech company, do you provide motivational rewards, incentives, etc. to ensure that the innovation-qualified workforce works long-term and efficiently within the company?
9. What percentage of your annual turnover does your company's budget allocate to R&D expenses?
10. Is the technology you are using the most advanced technology available in your sector? Is this checked regularly?

## 4. Results and Discussion

### 4.1. Indicator Analysis

Below are the 21 indicators used in the evaluation. Each indicator was assigned a coefficient value between 1 and 3, appropriate to the degree of importance observed in the research. In the explanation section, the main idea of the relevant questions asked of the companies is stated against the indicators for which they are suitable. Some questions within the innovation theme are not included in the table to avoid affecting the results of the questions about the actual processes that companies carry out in real time. Finally, the responses given by the companies for each indicator will be scored between 0 and 10, and the coefficients by which the resulting score will be multiplied are written next to them in Table 3.

**Table 3. A Section from the Indicator Scoring Table to Be Used for the Innovation of High Technology Companies**

| Topics | Indicators (I) | Coefficient (k) | Explanation | (Min Score - Max Score) |
|---|---|---|---|---|
| Future Technologies | Multi-technological | 3 | You have studied in high technology fields such as artificial intelligence, the Internet of things, quantum computing, and robotics. | (0-10) |
| Future Technologies | Future-Oriented | 2 | You have a plan to work on artificial intelligence, cloud, internet of things, quantum computing, robotics, and similar subjects in the short or medium-term | (0-10) |
| Future Technologies | Future-Oriented | 2 | Artificial intelligence, cloud, internet of things, robotics, quantum computing, etc. The issues are important for the company | (0-10) |
| Intellectual Property Rights | Intellectual Property Rights | 3 | You have a basic approach within the scope of intellectual property (patent, utility model, trademark, etc.). | (0-10) |

After the scoring, the average indicator scores for each company were analyzed. The 24 indicators listed were calculated for each company one by one using the formula below.

$$I_{1,company} = \left(Score_{1,company}\right) * k_1 \quad (1)$$

Then, all the scores obtained by a company from the indicators were summed and divided by 9, which is the number of companies, thus the average scores of each company were revealed.

$$I_{med.company} = \frac{I_{total,company}}{9} \quad (2)$$

The maximum score that a company can receive from all Indicators is calculated as 65 [52]. After calculating the companies' average scores from the indicators, the average scores of the indicators were analyzed.

24 indicators, for each indicator, the scores of 8 high-tech companies were added up and then divided by 8, which is the total number of companies, to find the average score of that indicator. The results were calculated with the formula below.

$$I_{1,Total} = \left([Score_{I1,company1} * k1] + [Score_{I1,company2} * k1] + \cdots + [Score_{I1,company8} * k1]\right)$$
$$I_{1,med} = \frac{I_{1,Total}}{8} \quad (3)$$

The maximum score that all indicators can receive is calculated as 30.

An additional set of interview questions based on the interconnections and interactions of those indicators is also arranged as a matrix that affects the innovation process. The analysis of the average scores of the indicators among themselves, including the responses by Company A, is also presented in Table 4 for comparison.

Figure 2 shows the average scores of the technology fields based on the indicator scaling.

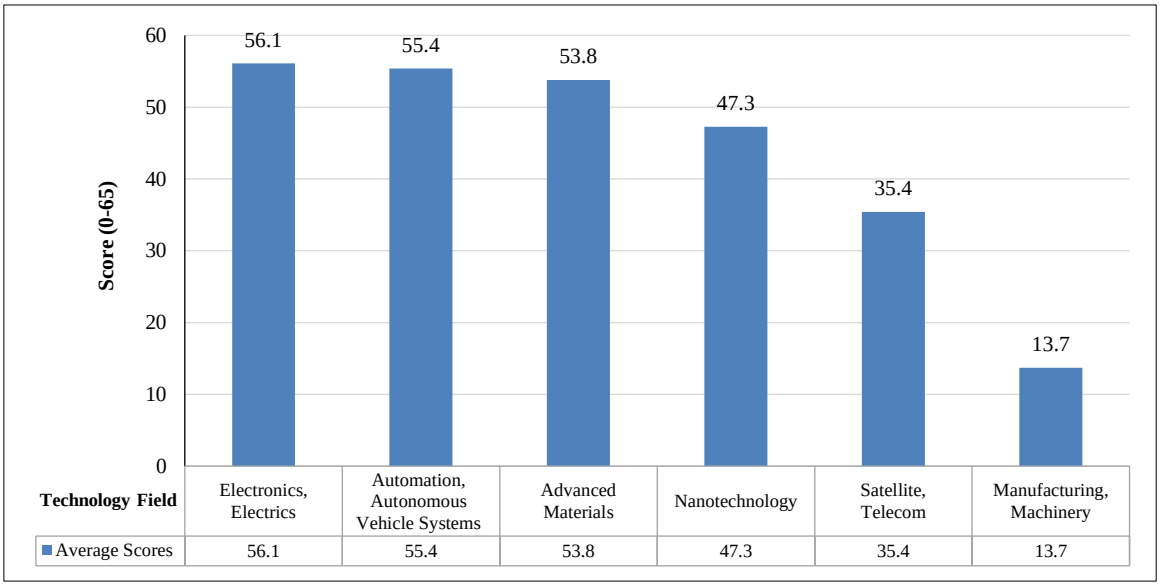


**Figure 2. Average Scores of High-Tech Fields in Which Companies Operate**

In Figure 2, the field with the highest score is the Electronics and Electrics field, with a score of 56.1. According to the guide published by Eurostat, this sector includes electronic card and printed circuit production, electronic device and component manufacturing, consumer electronics, etc. It is undoubtedly included in the high-tech field, and this field is ranked the highest in the guide.

Then, the Automation and Autonomous Vehicle Systems fields come in second place with 55.4 points. Typically, motor vehicle manufacturing is considered medium-high technology. However, the companies in this investigation also carry out automation, autonomous driving, and control areas. While one company develops its software and systems for fully autonomous buses and midi-buses, the other company develops software that fully automates the pump systems in fuel stations. From this perspective, it is understood that both companies work in the field of computer technologies and software development. Computer technologies surely fall into the high-tech class and were the field that achieved the second-highest score in the study.

The Advanced Materials field comes in third place with 53.8 points, and nanotechnology comes in fourth place with 47.3 points. Although nanotechnology is expected to become a significant field in high-tech, it lags behind other fields worldwide since various sectoral applications and innovations in this field have just begun.

The Satellite-Telecom field comes in fifth place with 35.4 points, and the Machinery-Manufacturing field comes in last place with 13.7 points, which creates a big score difference.

Electronics and Autonomous Vehicle companies Entes Elektronik and Adastec are ranked 1st and 2nd, with success rates of 94.5% and 92.7%, respectively. These companies are successful high-tech companies that exist in global markets and have made it their mission to be sustainable; they have also made quite a brand name for themselves both in national and international markets. They have been operating with the vision of innovation and R&D for many years. Entes Elektronik applies the concept of innovation in every process of its company, thanks to its innovative vision, which it has had for many years. Adastec has become a company with no rivals worldwide yet (in the autonomous bus and midibus), thanks to the autonomous bus systems they developed, which are the first in the world.

Sinter Metal and Mertech companies follow them with success rates of 83.2% and 82.7%. Although these companies have very similar understandings to the other two companies, they aim at innovation and growth in global markets.

Sinter Metal stands out both for its innovative work in the field of robotics and for the fact that its production technologies are still a niche field in the world. Mertech, on the other hand, stands out in terms of constantly carrying out innovative studies, as it is an R&D company, in addition to its work on artificial intelligence.

**Table 4. Average Scores of the Companies with the Success Rates**

| Company | Average Score for the Companies | Success Rates of Innovation for Companies in Hi-Tech, % |
|---|---|---|
| Entes Elektronik | 61.4 | 94.5 % |
| Adastec | 60.3 | 92.7 % |
| Mertech | 54.1 | 83.2 % |
| Sinter Metal | 53.8 | 82.7 % |
| Assan Elektronik | 52.7 | 81.1 % |
| Assis Otomasyon | 50.4 | 77.5 % |
| Quantag | 47.3 | 72.8 % |
| Satelcom | 35.4 | 54.5 % |
| "Company A" | 13.7 | 21.1 % |

The database information is based on a government incentive given explicitly for setting up R&D centers, used for the selection and filtering of the firms active within the district. Based on the conditions and requisites for such R&D centers, emphasize the following: Active R&D projects, R&D investments, the number of scientific and technical personnel, and the sizes of labs and spaces. R&D intensity is classified based on these conditions. The main factors listed below that also influence the technological innovation dynamics of high-tech companies are significant forces. Some of the crucial features and characteristics of these companies may be listed as follows in achieving success in terms of innovative products and processes:

- The abundance of investments and monitoring the future technology trends;
- They work intensively on intellectual property rights and attach importance to this issue. All the high-tech companies selected within the industrial district work with patent law offices in the region. Similarly, support is received on intellectual property rights, including patents and utility models, from universities where cooperation and close work are carried out. International registration in respective global markets is also considered and closely followed by these patent attorneys. In this regard, intellectual property rights have a significant promoting impact on the R&D intensity and efficiency.
- Strong and official relationships they have developed in specific networks, locally, nationally, and internationally;
- Their intensive work and investments in R&D (almost all of them have their own research centers and/or design centers) and scientific and technological research. Selected firms have close cooperations and collaborations with universities, vocational schools, and test labs, mainly for R&D projects, summer internships, and technical analysis to track skilled young undergraduates. Such collaborations are also part of the requisites for being classified as "R&D Centers" for receiving government funding.
- The number of personnel with high qualifications in terms of science and technology and the incentives and support provided to these personnel;
- A highly successful leadership and teamwork environment that they have created and operate with the utmost efficiency. Most firms employ various incentives and activities, such as frequent brainstorming sessions based on newly developed project ideas, seminars, and open forum discussions to solve technical difficulties faced during the project.
- They closely monitor and apply the recent technology trends in the world.

As for the score of "Company A" as the witness/control in this study, it is in the last place with a score of 13.7 points and a success rate of 21.1%. This success rate was very low compared to other companies. Although this company operates in medium-high technology, it does not have an innovative perspective on business processes. Stating that they will not make any breakthroughs in terms of innovation in the future, the company showed a performance far behind the other companies in the study. This "Company A" has a more traditional way of working and cannot be considered an innovative high-tech company.

### 4.2. Evaluation of Scores Based on Indicators

Since Company A in this study does not demonstrate the characteristics of being an innovative high-tech company, it was not included in the evaluation process of scores on an indicator basis regarding innovative and high-technology determinants.

As seen in Figure 3, the indicator that received the highest score in innovation and high-tech determination was the employment of advanced scientific and technical personnel with a score of 27.7. Although the minimum learning criterion in almost all of the companies that are the subject of this study, operating in the high-tech field, is a bachelor's degree, in the companies in the top four, this criterion is an MSc degree or above. In addition, great importance is given to criteria such as vocational training and language education. When deemed necessary by these companies, employees receive significant support and incentives to complete their deficiencies at home or abroad.

The second highest scoring indicator was the number of employees working in the R&D team under the heading of "R&D Intensity," with 27 points. Because of the intensive R&D studies carried out in innovative high-tech companies, the high number of personnel working in this field is essential regarding human resources. The most critical resource in the field of R&D is highly qualified people.

The third highest scoring indicator is "Intellectual Property," with 26 points. Relevant companies take this field very seriously and regularly continue their intellectual property rights studies to claim material and moral rights based on the innovative ideas and solutions they propose as a result of their R&D studies.

The fourth highest scoring indicator was the "Scientific Research" indicator, with 24.6 points. This indicator shows the importance of personnel's access to up-to-date information sources. In today's world, where access to information has become so easy, accessing the most up-to-date scientific and technological information sources and using them in innovative studies has become very important for the competitiveness of innovative high-tech companies.

The indicator that received the fifth highest score was "the Speed of Innovation and Knowledge Diffusion" with 24 points. Relevant high-tech companies attach great importance to the intensive transfer of information among their employees and aim to ensure that everyone who works can obtain information in the fastest and widest possible way. Quick access to information within the company provides more effective and efficient results from employees and contributes to faster outcomes of the work done. This helps companies bring innovative products/processes/services to the market before their competitors.

As can be seen, the five most important indicators for innovative high-tech companies in the high-tech field have been revealed. In the resulting ranking, all relevant indicators are interconnected. Such extensive interconnections and interactions between the indicators were also questioned through interviews, and the results are given in Table 5.

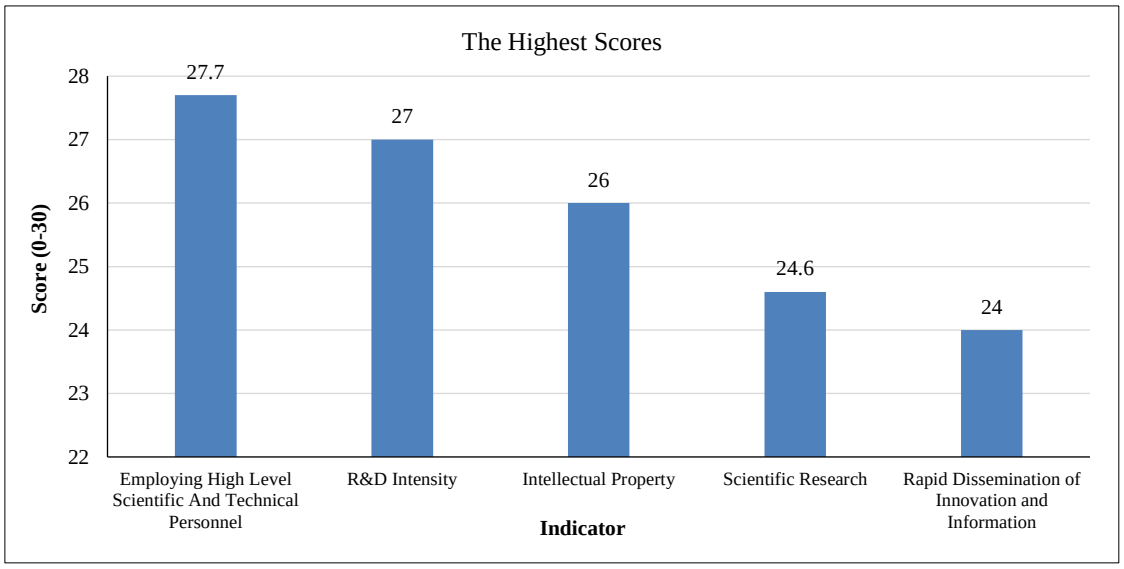


**Figure 3. The Top Five Indicators with the Highest Scores in Terms of Determination of Innovation and High Technology as the Most Important High-Tech Indicators**

**Table 5. The Top Five Indicators and Their Explanation**

| Indicator | Explanation |
|---|---|
| Employing High-Level Scientific and Technical Personnel | Innovation - your criteria for learning in a qualified workforce in terms of innovation |
| R&D Intensity | The R&D team is over 15 people |
| Intellectual Property | You have a basic approach within the scope of intellectual property (patent, utility model, useful design, trademark, etc.). |
| Scientific Research | You encourage your scientific research personnel to follow current academic information sources and events (seminars, conferences, congresses). |
| Rapid Dissemination of Innovation and Information | You have a technological information management system that will ensure intensive information transfer/sharing among your personnel |

After the first 5 indicators with the highest score, the evaluation of the last 5 with the lowest score is in Figure 4. The indicator with the lowest score was product potential, with 10.8 points. This indicator evaluated the importance of determining whether sufficient customer demand exists for the new product, feature, or service to be introduced or the sales potential in the market. It has been seen that the companies that are the subject of this study do not suffer from customer demand in terms of the uniqueness of the products they work with and develop in niche areas. In this respect, it should be noted that they produce products with high sales potential in the market. Although most companies state that they are in communication with their customers and care about incoming demands, their innovation and development of the products and services they produce are even more critical.

The indicator with the second lowest score is the feedback indicator, with 11 points. The aim here is to evaluate the existence of a feedback method followed when a product or production process fails. The study showed that only 2 companies trace back and detect errors made in their processes thanks to the camera imaging system. In other companies that do not engage in mass production, employees work to determine where the mistake was made by repeating all the process steps backward.

The lowest scores in the third and fourth ranks were received by the national cooperation and international cooperation indicators, with scores of 12.3 and 12.4, respectively. Network structuring functions when companies, institutions, and organizations operating in similar sectors come together to carry out joint scientific and technological collaborations and contribute to each other in terms of resources, information, and personnel. This concept is still not given the necessary importance within the IDOIZ. It was seen in this study that, except for 3 companies among eight companies. However, various breakthroughs were made in network structuring in other companies; the network created remained short-term and temporary, and its continuity could not be maintained. Companies are more inclined to international network structuring, since the research and development data related to the product or service developed in the national structuring may be leaked, financial losses may occur, etc. (see also Table 6).

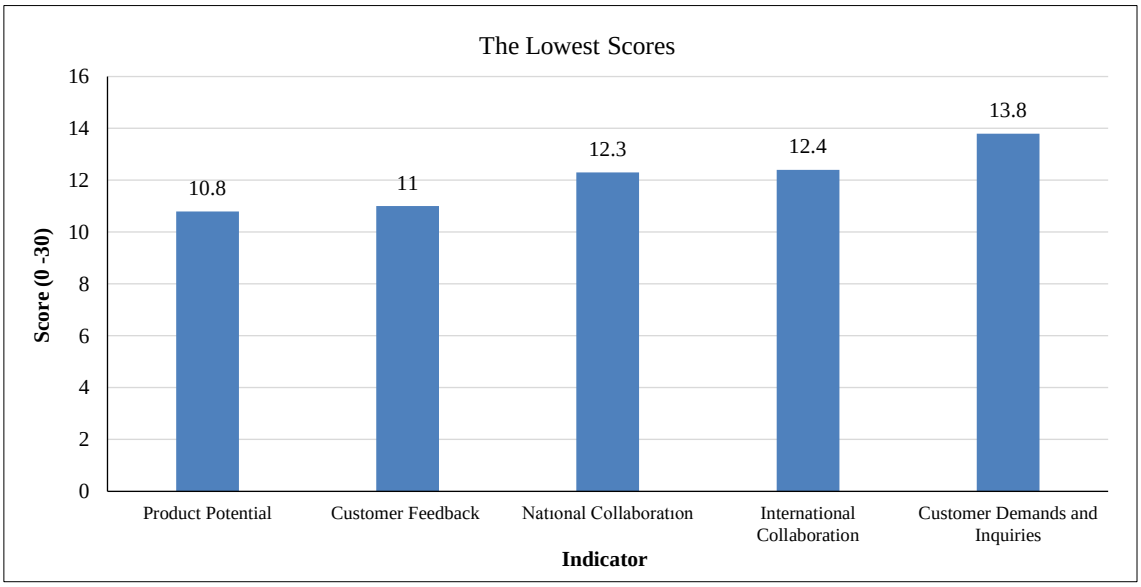


**Figure 4. The Last Five Indicators with the Lowest Scores in Terms of Determination of Innovation and High-Tech**

**Table 6. The Last Five Indicators and Their Explanation**

| Indicator | Explanation |
|---|---|
| Product Potential | Sufficient customers for the new product, feature or new service to be introduced. Determining the demand and/or sales potential in the market |
| Customer Feedback | There is a feedback method we follow when a new product or manufacturing process fails. |
| National Collaboration | Your company has a domestic networking approach. |
| International Collaboration | Your company has a Networking approach abroad. |
| Customer Demands and Inquiries | Customer Requests During or before the product development process, you regularly meet with customers or potential customers and receive opinions or requests from them. |

In fifth place is the customer demands indicator, which has the lowest score, with 13.8 points. This indicator, which is related to regular meetings with customers and receiving opinions or requests from them during or before the product development process, has not been given the utmost importance by companies. In the study, although the relevant companies stated that they gave priority to customers' opinions and demands, they indicated that they had the most advanced technology and functions available in terms of the products and services they developed and that customers

generally found them satisfactory, and that their existing customer base was happy to work with them and that they did not experience any problems in this area.

The interactions/interconnections of those indicators for high-tech companies and Company A are arranged as a matrix that affects the innovation process. Table 7 presents the average scores of the interacted indicators, including the responses by Company A, for comparison.

**Table 7. Interactions in between the indicators**

| Indicators | | Employing High Level Scientific /Technical Personnel | R & D Intensity | Intellectual Property | Dissemination of Innovation /Information | Product Potential | National Collaboration | International Collaboration | Customer Demands & Inquiries | Average Values |
|---|---|---|---|---|---|---|---|---|---|---|
| **Employing High Level Scientific and Technical Personnel** | Hi Tech Comp. | | **4.8** | **3.7** | **4.1** | **3.9** | **1.98** | **4.2** | **1.3** | **3.42** |
| | Witness Comp | | ***0.50*** | ***0.1*** | ***2*** | ***4*** | ***1.0*** | ***1.5*** | ***2.0*** | ***1.58*** |
| **R & D Intensity** | Hi Tech Comp. | **4.15** | | **4.1** | **4.0** | **4.2** | **2.98** | **4.55** | **1.11** | **3.58** |
| | Witness Comp | ***0.10*** | | ***0.10*** | ***1.5*** | ***2*** | ***1.5*** | ***1.0*** | ***1.0*** | ***1.02*** |
| **Intellectual Property** | Hi Tech Comp. | **2.1** | **3.85** | | **2.1** | **4.20** | **1.85** | **3.1** | **0.96** | **2.59** |
| | Witness Comp | ***0.2*** | ***0.1*** | | ***0.5*** | ***2*** | ***0.1*** | ***1.0*** | ***0.50*** | ***0.62*** |
| **Rapid Dissemination of Innovation/ Information** | Hi Tech Comp. | **4.2** | **3.95** | **4.15** | | **3.16** | **3.20** | **3.45** | **1.3** | **3.34** |
| | Witness Comp | ***0.10*** | ***0.1*** | ***0.1*** | | ***1.0*** | ***1.0*** | ***1.5*** | ***1.0*** | ***0.68*** |
| **Product Potential** | Hi Tech Comp. | **1.1** | **1.53** | **3.54** | **3.2** | | **1.15** | **2.35** | **4.95** | **2.54** |
| | Witness Comp | ***1.0*** | ***0.5*** | ***2.5*** | ***1.5*** | | ***2*** | ***2.5*** | ***5*** | ***2.14*** |
| **National Collaboration** | Hi Tech Comp. | **2.10** | **3.3** | **1.25** | **2.10** | **1.55** | | **3.55** | **4.10** | **2.56** |
| | Witne Comp | ***2.0*** | ***1.0*** | ***0.5*** | ***1.0*** | ***4*** | | ***3.5*** | ***2.0*** | ***2.0*** |
| **International Collaboration** | Hi Tech Comp. | **3.55** | **4.1** | **3.2** | **3.55** | **2.0** | **4.10** | | **0.86** | **3.05** |
| | Witne Comp | ***2.5*** | ***2*** | ***3.5*** | ***2.0*** | ***2.0*** | ***2.50*** | | ***0.5*** | ***2.14*** |
| **Customer Demands and Inquiries** | Hi Tech Comp. | **1.85** | **3.2** | **3.4** | **0.75** | **4.55** | **1.05** | **1.55** | | **2.33** |
| | Witne Comp | ***2.5*** | ***3*** | ***4.0*** | ***0.5*** | ***4.5*** | ***1.0*** | ***1.0*** | | ***2.35*** |

Table 7 illustrates the fact that the most influential interactive and interconnected indicators with the most impactful scores for those high-tech companies with high scores are as follows:

1. R&D Intensity, 3.58
2. Employing High-Level Scientific and Technical Personnel, 3.42
3. Rapid Dissemination of Innovation/Information, 3.34

These scoring and listing of indicators for high-tech companies demonstrate several factors as follows:

- An environment and culture of highly intense technology development is the leading factor for a high-tech organization;
- R&D investment and exploiting high-level scientific and technical personnel have a significant effect on the overall innovation efficiency;
- High-tech development requires innovation and creativity based on rapid dissemination of information and knowledge.

On the other hand, the interactive highest scores for Company A are also listed as,

4. Customer Demands and Inquiries, 2.35
5. Product Potential, 2.14
6. International Collaboration, 2.14

The scoring and listing of indicators for a medium-tech "Company A" as the "control" reveals the following factors:

- For a medium-tech company, such as a conventional manufacturing company, "customer demands and inquiries" are surely the most determining factors, along with "product potential".
- Other indicators such as "Employing High-Level Scientific and Technical Personnel", "R&D Intensity", and "Intellectual Property" are low, 1.58, 1.02, and 0.62. These scores reflect the significant differences compared to high-tech companies.
- The score for "International Collaborations" is due to Company A's efforts to find exporting partners in neighbouring countries.

### 4.3. The Model

Here, three concepts that are indispensable for companies producing in the field of high technology come to the fore. The first is the concept of an innovation system, which is vital today, especially for high-tech companies. A high level of innovativeness is essential for a high-tech organization, and the ability to continuously generate innovations and creativity should be the leading characteristic of a high-tech company [21]. The second is the R&D concept required to successfully realize this innovation based on product, process, and service. As for the third concept, employing highly skilled technical personnel is vital for a high-tech company. In this regard, Figure 5 presents the technology innovation system within a medium and an environment and culture continuously supporting and feeding high-tech companies. A variety of shareholders, supporting units, service companies, information/knowledge sources, test and analysis providers, relevant government offices, and financial support bodies are included within this innovation system (see Table 8).

**Table 8. Major/Minor Components within the Innovation System of the Istanbul Dudullu Organized Industrial Zone IDOIZ**

| PROVIDERS | SUPPORTING BODIES | NON-TECHNICAL SUPPORTS | KNOWLEDGE & INFO SOURCES |
|---|---|---|---|
| Service providers, equipment, maintenance, tooling, and test analysis providers, machine shops, die makers, design offices, software services, raw material suppliers | Regional management support, gym, sports club, kids' club, food stores, cafes, mosque, security units, maintenance, infrastructure, energy, water supply, traffic control | Local and government support institutions, finance, banking, patent offices, and attorneys, medical services | Dogus University, Technopark, Incubation Center, vocational school, student training, seminars, conferences, MSc opportunity, R&D projects, educational activities, consulting firms |

As mentioned above, it is essential to apply innovation and technology management with effective leadership correctly to compete with other companies and achieve success in globalizing commercial markets. Increasing the number of such successful high-technology companies is essential in the country. The growth of these companies and the strengthening of their place in global markets means economic development for the region and for the government and an increase in social welfare [53].

In the most advanced and contemporary model of the institutional development of the concept of innovation in a continuous cycle in a high-tech company, the following five important elements come to the fore (as given in Figure 5):

1. Effective Leadership;
2. Research & Development; Innovation-Creativity;
3. Highly Skilled Science & Technology Personnel;
4. Intellectual Property focused operations;
5. Science and Technology Collaboration (with universities and/or scientific institutions);

These five elements are a process model that constantly develops and progresses around innovation. Developing new high-tech products and creating processes or services are highly complex and challenging. Here, both tacit knowledge specific to individuals and existing accessible knowledge are required. It is critical that tacit knowledge and experience, especially based on individuals, be transferred as concrete information to the organization's knowledge pool. From here on, teams and the organization itself participate in the creation of new ideas and innovations that start with individuals (Figure 5). Efficient and effective implementation of R&D and/or P&D-based infrastructure and activities with a systematic approach is also an indispensable part of high-technology organizations. Therefore, the compliance of individuals, project groups, teams, and the organization with the requirements of this information/technology innovation process becomes key. A continuous positive cycle is formed and stabilized with new high technologies created by turning tacit knowledge into concrete institutional knowledge, and then technological combinations based on institutionalized knowledge and technology accumulation and memory.

In this study, a dynamic model demonstrating an efficient and effective innovation process as the integrated variable within an industrial district is presented in Figure 5. Major factors outlined before are the independent variables, such as R&D, scientific collaborations, intellectual property, highly skilled personnel, and leadership. Other support for regional management and government incentives, such as conventional control variables, are shown within the model. In this sense, this model explored the impact and interaction of technological innovation, constituting a medium, environment, and culture to boost the cooperation and collaboration for more creative and innovative results.

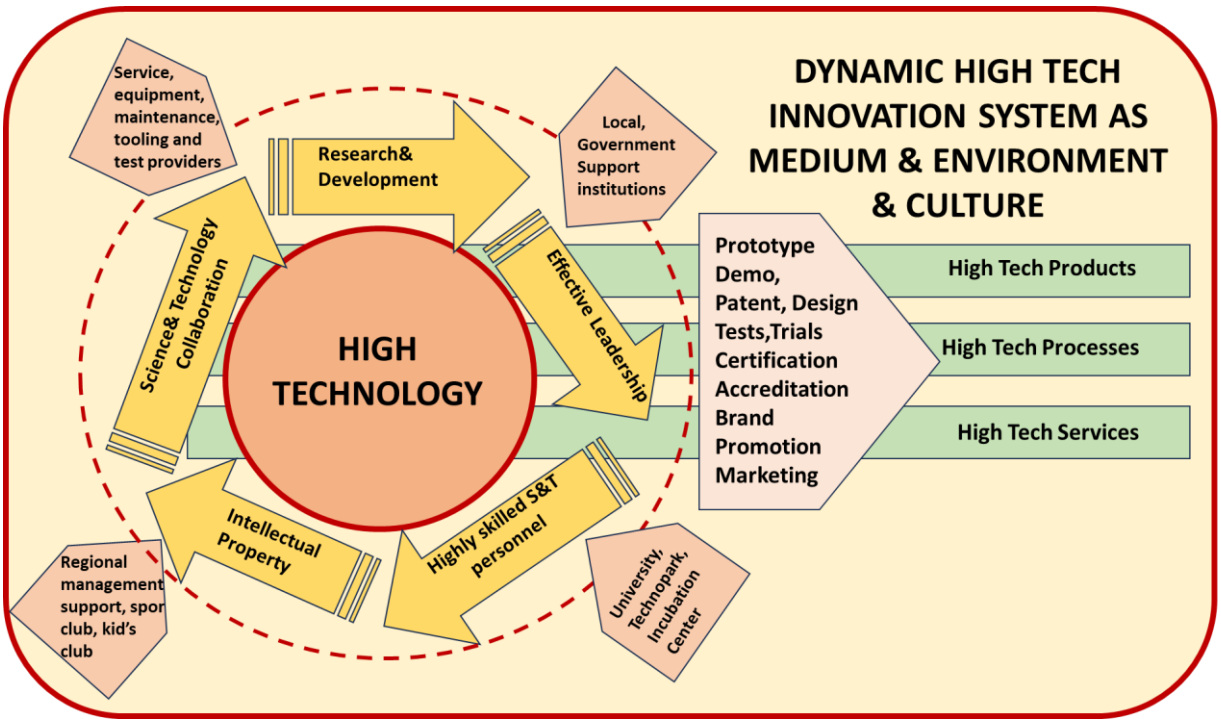


**Figure 5. A model of a dynamic high-tech innovation system as the surrounding medium, environment, and culture**

## 5. Conclusion

Our study revealed the difference between the business processes and, accordingly, the management approaches of innovative high-tech companies operating in the high-tech field and those of traditional companies. In addition, the innovation indicators that are most important for successful high-technology companies have been analyzed, and the indicators with the highest importance have been revealed as a result of the evaluation.

R&D studies are the key for high-tech companies to produce innovative products. Here, R&D activities in technological development and their transfer into commercial economic values are essential. Such an innovation chain process is the structural base for the effective and efficient transformation of commercial high-tech products. Subsequently, the necessary intellectual property rights for the innovative products and services obtained from the relevant studies should also be obtained, and material and moral damage should be prevented.

As a result of the evaluation, the last five indicators that received the lowest score among the innovation criteria from the relevant high-tech companies were revealed. As a result of these indicators, it has been seen that the relevant companies do not attach much importance to the area of sufficient customer demand for the product and service they produce and/or the potential of the product in the market and the location of meeting with customers and receiving requests and opinions, compared to other indicators. These companies do not experience much concern in this area as they launch the most innovative products and services in their fields.

When a new product or service fails, feedback methods are followed in both companies. An established technological system is used in one company, while in other companies, feedback methods are primarily carried out through backward iteration of the process and brainstorming.

What stands out among the criteria with the lowest scores is the low importance given to national and international network structuring. Network structuring is a concept that is of great importance in the world. Especially if we look at it from a national perspective, it is obvious how beneficial it would be for companies working in similar fields, private or state institutions, and organizations to come together and provide contributions and assistance to each other at the necessary points in the development of innovative high-tech products and services and their presentation to the world markets. Carrying out these structures for a long time contributes to the results of the studies being more robust. For national economic growth to reach the technological development level of highly developed countries, it is critical to increase the number of such cooperation structures and to establish longer-term and more robust structures in official terms.

As a result, this study showed that for companies working in the field of high technology, innovation is a concept that must be understood and expertly applied in every single process of the company. Applying this concept correctly is the primary factor that will enable high-tech companies to succeed in local and international markets. High-tech companies can achieve development due to their innovation system along with their effective management of skilled personnel, a culturally innovative environment, and continuous innovation for their personnel. In this regard, it should be noted that the technological innovation system could only effectively and efficiently function and operate in such high-tech companies.

# 6. Declarations

## 6.1. Author Contributions

Conceptualization, T.B. and D.A.U.; methodology, D.A.U.; formal analysis, T.B. and D.A.U.; investigation, D.A.U.; writing—original draft preparation, T.B. and D.A.U.; writing—review and editing, T.B. All authors have read and agreed to the published version of the manuscript.

## 6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

## 6.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

## 6.4. Institutional Review Board Statement

Not applicable.

## 6.5. Informed Consent Statement

Not applicable.

## 6.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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