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SMART POLYMER MATERIALS AND THE DEVELOPMENT OF TECHNOLOGY ENTREPRENEURSHIP

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Purpose: The objective of the present paper is to evaluate the relationships between intelligent polymer materials and the development of technological entrepreneurship as well as the role of intelligent polymer in sustainable development in Poland.
Design/methodology/approach: The research concerned the impact of modern smart materials on the development of technology entrepreneurship in high-tech companies in Mazovia and its importance for increasing the competitiveness of enterprises. The survey research method was used as part of the lustration procedure, characteristic of the so-called nomothetic research approach used for quantitative research in management sciences.
Findings: A problem encountered during the research was the fact that it was difficult to pinpoint the number of high-technology (HT) enterprises in the Masovian province, mainly due to the fuzzy border between medium-tech and high-tech organizations.
Research limitations/implications: The research results show that advanced technology sector enterprises in the Masovian province acquire new smart materials mainly from external sources, primarily due to possessing limited resources and insufficient competences in this area.
Practical implications: Technology entrepreneurship, in connection with the using of design thinking and the concept of sustainable enterprise will able to prepare and commercialize interesting and technology advanced materials which cause that many enterprises, not only high-technology firms, the building of high competitive position on international market.
Originality/value: This article shows the importance of smart polymer materials in the development of technology entrepreneurship in high-tech companies in Mazovia.

Keywords: Smart Polymer Materials, Technology Entrepreneurship.

Category of the paper: Research paper.

1. Introduction

At a time of a global economy, skills to create and implement innovations, especially of a technological nature, are gaining particular importance, which may translate into creating and maintaining competitive advantage on the market. This is the essence of technology entrepreneurship which during the 2010s became a key competency in attaining results better than the competition. An important position among the areas of developing and implementing new technological solutions is occupied by modern materials with special physicochemical properties, referred to as "smart materials," a term that signifies the universality of their applications and implementation possibilities. Modern materials can be divided into the following three main groups: metal materials and composites, ceramics and materials based on polymers (plastics) with specific properties. In view of the wealth of the compounds, especially organic compounds, synthesized, there are practically unlimited possibilities to create materials with specific set, tailor-made properties. Due to this, it is this third group of materials that the present paper focuses on.

There are the relationships between smart materials and the development of technology entrepreneurship, especially in high-technology firms. Innovative smart materials are results of scientists, engineers and managers' technology entrepreneurship. Then smart materials cause the quick development of technology entrepreneurship in high-technology enterprises and whole branches. The objective of the paper is to present the relationships between smart polymer materials and the development of technology entrepreneurship in Poland. This importance is borne out by the results of research on high-technology enterprises operating in the Masovian province. The research concerned the impact of the advanced material technologies used on the development of technology entrepreneurship. There is a high degree of correlation between implementing modern materials and the development of technology entrepreneurship which in turn translates into an increase in the competitiveness of enterprises. The paper also presents a short characterization of selected special polymers and their impact on the development of enterprises and economies in the context of the Economy 4.0 initiative.

There is also a role of smart polymer materials in sustainable development. The concept that was first described far back in 18^{th} century and evolved through the centuries to obtain the center stage in development discourses in the latter half of 20^{th} century. Discussion about sustainability has emerged in recent years as a consequence of the growing ecological and social awareness after years of focus primarily on economic growth. The imminent ecological crisis as well as the global wealth inequality have led to a new focus on sustainability in global terms and on three dimensions (ecological, social and economic). This resulted in the Paris Agreement (Paris Climate Accord or Paris Climate Agreement) signed in 2015 within the United Nations Framework Convention on Climate Change (Paris Agreement UNFCCC, 2015), dealing with greenhouse-gas-emissions mitigation, adaptation, and finance. The role of smart materials in reaching sustainability goals is multifaceted. Among others the use of smart polymer materials helps to reduce energy consumption and CO_2 emissions, for example in the construction and transport sectors. Smart polymer materials also enable the transition from fossil fuels to renewable energy, thanks to the use of their components in wind turbines, solar panels and electric vehicles. Moreover, there is a new technology of natural polymers obtained from plants, which are also degradable (e.g. Aliphatic polyesters, polysaccharides, natural robber) in the natural environment. Such polymers are easy to form, process or modify, and the circulation of such polymers in the environment is closed.

2. Innovation in the chemical industry and modern high-tech polymer materials

The wide spectrum of innovations in the chemical industry can be categorized using the existing classification from the Oslo Manual (Gładysz, Marciniak, Chyba, 2019, pp. 68-70). In the production of chemical products, including plastic products, there is a tendency to move away from mass, widely used high-volume plastics (polyethylene, polypropylene, etc.) in favor of low-volume plastics with special physicochemical properties and functional values. This is due to environmental protection requirements related to the concept of sustainable development and the rising social awareness of the need to care for the environment. A particularly important and at the same time large group of innovative materials are biomedical polymers (plastics) and those used in pharmacy. In view of the high number of solutions in this area, it is impossible to discuss them in detail in the present paper due to space constraints. It should be noted that the chemical industry and chemical products can be classified as borderline high- and medium-tech. Certain chemical products (e.g. polymers/plastics such as poly (ethylene terephthalate), polycarbonates, polyacetals and ceramic compounds – nitrides, carbides etc.) are classified as high-tech products, while other chemicals belong to the medium-tech category. Although the adopted classifications are currently widely applicable and are developed by recognized experts, it seems that the boundaries between high and medium technology products are blurred and the classification of individual chemical products in these groups is often somewhat arbitrary. Table 1 presents the chemical industry innovation as classified in the Oslo Manual.

Table 1.
Chemical industry innovation as classified in the Oslo Manual

Innovation type		Chemical industry innovations
Product		Synthesis of new smart materials with special properties. Improvement of existing smart chemical compounds and materials (biodegradable, flame retardant materials, etc.)
Business process	Process	New smart production technologies (synthesis and modification of existing compounds, including polymer-based plastics). Improvement of medical and pharmaceutical processes (medical diagnosis, transplants, blood transfusions etc.) and other technological processes.
	Organizational	New information transmission methods with the use of chemical innovations applied in electronics and electrical engineering. Thin polymer layers, used for information processing in nonlinear optics and IT.
	Marketing	Innovative forms of promotion (including advertisements, different product packaging). The use of new printing materials and innovative printing techniques

Source: own materials based on (Gładysz, Marciniak, Chyba, 2019, p. 69).

The modern materials that play an ever-increasing role include those based on polymers (macromolecular compounds). They commonly exist in the form of plastics, which are a usable form of the polymer. To begin with, it is worth devoting some attention to plastics of structural importance (Szlezyngier, Brzozowski, 2012, vol. 2). Construction plastics have become synonymous with modernity and efficiency in the global economy. The main examples of construction plastics are polycarbonates, polyacetals, polyoxyphenylenes, polyamides, polyethylene terephthalates, polysulfones, phenylene sulfide, syndiotactic polystyrene and a number of other special polymers (Chyba, 2009, pp. 34-43). The past several years have witnessed an intensive worldwide development of thermoplastics for the production of durable machine and device components. In the literature, this group of plastics is referred to variously as engineering polymers, construction polymers, technical polymers, high-performance polymers, or special polymers. Construction polymers were introduced to cover various application areas. However, with the increase of practical experience of their use, the area of their utilization has expanded significantly, leading to a dynamic development of engineering plastics. The development of construction plastics is usually accompanied by an expansion of their selection. Despite the high competition between known and recognized engineering plastics, numerous cases of the industrial introduction of completely new polymer groups are observed. Some will probably join intensively developing ones, others will fulfil a narrow role and will not develop over certain boundaries. The new polymers with the greatest hopes for industrial development include: syndiotactic polystyrene, polyarylates, polysulfones, polyimides, polyketones and polymers with liquid crystal properties. Polycarbonates (PC) belong to the group of thermoplastic polymers (the one with the highest industrial importance is polycarbonate from bisphenol A). These compounds are among the few colorless and transparent polymers that combine very good mechanical and thermal as well as dielectric and optical properties. The above compounds, and especially bisphenol A, are seriously suspected of being toxic and harmful to health, especially in the case of coming into contact with food or being used to manufacture teethers for children. Polycarbonate (PC) possesses properties that have made it a basic engineering (construction) plastic. It has found applications in many areas, especially the electronics, machine, photo-optical, automotive and aviation industries. PC is widely used in households, medicine and packaging – also in the food industry. Recently, PC has been increasingly used in the form of plates (windows). It is one of the main substitutes of glass. Manufacturers expect that thanks e.g. to the growth of construction in the US, demand for polycarbonates will increase. Polycarbonate is used in electronics and electrical engineering not just due to its being an excellent electrical insulator and its mechanical strength but primarily because it maintains these properties over a wide range of temperatures. Polycarbonates are an example of an engineering polymer with an especially high growth rate and practically unlimited application potential. Polyacetals (POM) are a group of engineering polymers whose central chain includes an acetal group, –O-CH2-. Due to their outstanding properties, POM occupy an important place among engineering plastics. They can be used in practically all branches of industry, but particularly the automotive industry (mechanical elements of seat belts, door locks, windshield sprayers, petrol tank stoppers etc.), the electrical engineering industry (housings, gears, clutches, bearings, etc.), the electronic industry (phone keyboards, coli bodies etc.), toys and sporting goods (tennis racket handles, ski bindings etc.) and the precision industry (measurement instrument parts, precision gears, camera and microscope parts etc.). Syndiotactic polystyrene (sPS) is a particularly important achievement in the field of engineering plastics. Unlike the commonly known traditional polystyrene which has a chaotic chain structure, the regular distribution of structural units on both sides of the chain gives sPS completely different properties. Thanks to its special structure, sPS exhibits better performance properties compared to traditional amorphous polystyrenes. Unlike other engineering polymers (polycarbonates, polyamides, polyethylene terephthalates e.g. PET, PBT), sPS does not absorb moisture and does not require pre-drying prior to injection. The very low viscosity allows for reduction of the thickness of the manufactured components' walls. The basic type of sPS area usually compositions containing some sort of filler (mainly fiberglass). sPS is an example of a modern plastic which is only acquiring a niche on the engineering plastics market (Klepka, 2014). Plasma polymers are a specific group of polymers distinguished by the method of their acquisition (with the use of low-temperature plasma) as well as their properties and application. They are highly networked and form thin layers strongly connected with the substrate. Plasma polymer films stand out (apart from the very small thickness) by very good mechanical and electrical properties and the ability to control the refractive index over a wide range. Plasma polymers offer very wide application possibilities in various fields, such as: electronics (diodes, transistors, insulators in capacitors, etc.), optoelectronics and optics (solar cells, optical fibers, lenses, etc.), thin protective coatings and membranes and medical technology (surface coatings of prostheses and medical apparatus).

3. Smat polymer materials in electronics and optoelectronics

Until recently, the applications of polymers in electronics were limited to insulators and structural elements (Szlezyngier, Brzozowski, 2012, vol. 2). The materials used were generally known polymers such as polystyrene, polypropylene or Teflon. In view of the favorable utility properties of polymers, methods for the production of semi-conductive, conductive and photoconductive polymer materials have also been sought. A number of new technologies using polymers with special properties have been developed over the past two decades and their importance is constantly growing. The present part of this paper contains an overview of leading current and potential applications of polymers in electronics and optoelectronics that require new specialized polymer materials. The basic properties of selected polymers and their possible uses in other technology areas will also be discussed. The rapid development of optoelectronics and nonlinear optics which has occurred in recent years has been due to the increase in demand for information processing and transfer. Efficient cooperation of IT systems, covering entire continents requires the transfer of large amounts of information in a short time and without disturbances. Traditional methods using metal cables or radio waves are insufficient to satisfy the growing needs. A possibility to increase the throughput of communication lines is created by modulation of light signals transmitted by optical fibers. Electrical signals are converted into optical signals and vice versa using lasers and special optoelectronic systems. Their operation is based on the use of the nonlinear optical properties of the appropriate materials (Szlezyngier, Brzozowski, 2012, Vol. 3). Thanks to the development of special polymers known as "technical plastics," the plastics industry is making a significant contribution to the dynamic growth of the electrical engineering and electronic industries. The basic advantages of technical plastics used in electronics are resistance to creep currents, the possibility of soldering electronic components without deformation, high temperature resistance and the possibility of radiation crosslinking, meeting the requirements of limited VO flammability, the possibility of laser inscriptions, good filling of forms, very high fluidity and limited flammability, and safe discharging of static electricity. New electroconductive polymer coatings have been developed within this group of materials. In addition to their good anti-static properties, these coatings are characterized by good transparency and resistance to weathering. They are non-toxic and cause no problems in recycling. These properties outweigh those polymers filled with carbon black or graphite (the products obtained from them, e.g. packaging foils, do not stain). In addition, they show a similar range of electrical (surface) conductivity as polymer coatings filled with carbon black. It has been shown that organic semiconducting polymers can replace inorganic materials in many electronic and optoelectronic devices (such as electroluminescent diodes). An optical laser has been successfully used to cause luminescence, i.e. stimulated emission of radiation, in approximately 10 different polymers containing conjugated bonds, with the light emitted by them exhibiting many characteristics of laser light. In recent years, significant interest has been devoted to a new class of polymer semiconductors that also exhibit high photoconductivity (Ehrenstein, Brocka-Krzemińska, 2016). These are photoconductive polymers containing silicon or germanium heteroatoms in the main chain. Their photoconductivity can be increased markedly through appropriate doping. Good photoconductors are materials which after exposure to light exhibit conductivity several orders of magnitude greater than that they possess in the dark. They are used mainly in electronics and electrophotography (xerography). The concept of shielding composites is a new alternative to traditional shielding against electromagnetic interference and provides protection against electrostatic discharge. Shielding composites Shielding composites are used in the miniaturization of electronic devices and for developing compact pocket-size devices such as laptop computers or cell phones. Their casings are usually made of these plastics because they ensure freedom of design and material economies while at the same providing effective conductivity. This in turn ensures good screening and product protection. Another significant advantage that shielding composites have over conductive coatings is that they can be re-used (through recycling) wherever there is a danger of electromagnetic interference and electrical discharge. Shielding composites are used in such areas as data processing, telecommunications, medicine, control systems, automotive electronics and household electronics.

4. The concept of technology entrepreneurship and smart materials

Technology entrepreneurship is a phenomenon which is attracting wide interest, both of management practitioners and theoreticians. Even though the term “technology entrepreneurship” has been known in the literature for several decades, a particularly intensive increase in the number of publications on this subject did not occur until the 2010’s. The theoretical foundations of the concept in its modern understanding appeared in the "Technology Entrepreneurship" (Beckman, Eisenhardt, Kotha, Meyer, Rajagopolan, 2012, No. 2 and 3) special edition of the "Strategic Management Journal" from 2012, with scientific edition by Ch. Beckman, K. Eisenhardt, S. Kotha, A. Meyer and N. Rajagopolan. Attempts to clarify the concept are also included in the publication of (Bailetti, 2012, No. 2). There have also been numerous Polish publications on this subject in recent years. The Polish authors define the term “technology entrepreneurship” in different ways. According to (Lachiewicz et al., 2012, p. 18) “technology entrepreneurship can be understood as a process combining elements of academic and intellectual entrepreneurship with the entrepreneurship of commercial and business support organizations and the entrepreneurship of owners, managers and employees implementing technologies and the innovations associated with them in the sense of the application and distribution of their effects in the market environment”. In the opinion of (Grudzewski, Hejduk, 2008, p. 80) “technology entrepreneurship is a condition for the enterprise's success. It signifies the process of developing new products, applying modern technology, reacting flexibly to the changes occurring in the market as well as implementing innovations in all areas of the operations of the firm and its partners". According (Kordel, 2018, p. 37) "technology entrepreneurship occurs when progress in science or engineering creates a key element of an opportunity which is then transformed into a new investment. A technology undertaking based on the latest engineering knowledge is the direct outcome of technological entrepreneurship". Technology entrepreneurship should be viewed in the wider context of an organization's strategy and especially the development strategy of an enterprise. Therefore, the efficiency and effectiveness metrics of technological entrepreneurship must be those that relate to competitive advantage (e.g. market share, profitability ratios, etc.) (Chyba, 2016, pp. 103-104). When talking about technology entrepreneurship, one should also consider the conditions of the internal environment and the surroundings of the organization. Table 2 presents the three levels of determinants of technology entrepreneurship.

Table 2.
Determinants of technology entrepreneurship in three levels

Technology entrepreneurship level	Key determinants
Environmental conditions (external)	Research institutions
	Commercialisation support centres
	Commercial sector partners
Internal environment conditions	Organisational culture
	Intellectual capital
	Decision-making effectiveness
Enterprise's technology potential	Technology portfolio
	R&D effectiveness
	Creativity and technology competencies of the management

Source: own materials based on (Chyba, 2015, pp. 87-96; 2016, pp.103-104)

Technology entrepreneurship is highly dependent on an organization's surroundings, and especially those and entities that support the commercialization of new technological solutions. A significant role is also played by the internal environment including the organization's specific characteristics and identity expressed in the organizational culture developed, as well as the organization's intellectual capital, with special consideration of its human capital. An additional important factor is the enterprise's technology potential with its current set (portfolio) of technologies and the ability to develop new technologies thanks to the effectiveness of the R&D department and creativity of the employees. At this point it is worth taking a closer look at those conditions that relate to an organization's internal environment. Intellectual capital and organizational culture are important internal factors conditioning the development of technological entrepreneurship. The "soft" aspects of management, in particular those mentioned above, are significant sources of inputs into the company's strategic resources. At the same time, the competences and resources at the enterprises' disposal are also an important component of their technology potentials. It is after all difficult to build an enterprise's technology potential without their knowledge and technology competences of its employees or their creativity and dedication.

5. The concept of sustainable development and the role of smart polymer materials in reaching sustainability goals

The negative environmental impact of economic growth was already described in the ancient Roman, Greek, Egyptian, and Mesopotamian civilizations (Du Pisani, 2007, pp. 83-96). Nevertheless, the concept of sustainable development (as we understand it now) dates back to the 18th century when it solely concerned foresting (Meadows, 1972). The German forestry scientist Hans Carl von Carlowitz described in 1713 in his book Sylvicultura Oeconomica the phenomenon of the massive consumption of wood for ship-building, construction, mining and others leading to a risk of shortages of wood in Europe (Van Zon, Kuipers, 2002). The 19th century shifted to coal and 20th century to oil as most important natural resource and source of energy and brought the subject of non-renewable resources (Du Pisani, 2007, pp. 83-96). For two centuries, the concept of sustainability evolved but it was only in the second half of the 20th century that its significance raised drastically. At that time, the term sustainability was for the first time defined in the Oxford Dictionary as "The ability to be maintained at a certain rate or level" (Paris Agreement, 2015). In 1987, the World Commission on Environment and Development defined SD as an ethical concept and provided its definition: "Sustainable Development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Ebner, Baumgartner, 2014). The definition contains two key concepts: the concepts of "needs" and the concepts of "ability" (Durbach, Lixinski, 2017). The needs are on one hand the needs of the world's poor and on the other hand the needs of unlimited development of organizations with the use of technology. At the same time, it defines the ability of the environment to meet changes by technology over a long time horizon, concerning not only current abilities and needs but also those of future generations. Thus, the goals of economic and social development must be defined in terms of sustainability in developed countries as well as in developing ones (Ebner, Baumgartner, 2014). Discussion about sustainability has emerged in recent years as a consequence of the growing ecological and social awareness after years of focus primarily on economic growth. The imminent ecological crisis as well as the global wealth inequality have led to a new focus on sustainability in global terms and on three dimensions (ecological, social and economic). This resulted in the Paris Agreement (Paris Climate Accord or Paris Climate Agreement, 2015)) within the United Nations Framework Convention on Climate Change (UNFCCC), dealing with greenhouse-gas-emissions mitigation, adaptation, and finance. The countries adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable

Development Goals. For that purpose, the United Nations has adopted the same definition of sustainable development as the World Commission on Environment and Development (The Sustainable Development Goals Report, 2017). The subject of sustainability is also widely described in scientific literature. N.J. Schrijver states that in a relatively short time the concept of sustainable development has become firmly established in the field of international law and proves that without grounding the concept in the law of the states as well as in the international law, sustainable development cannot be achieved (Schrijver, 2008). M. Ziolo, B.S. Sergi tackle the issue of assessing the efficiency of sustainable development financing from a theoretical and methodical point of view, sustainable finance and sustainable financial systems, environmental, social and governmental risk and individual and institutional motivations of financial managers in the sustainability concept (Ziolo, Sergi, 2019). The sustainable development goals however signed by majority of countries, cannot be reached without corporate involvement. G. Blokdyk proves in *Sustainable Development Goals A Complete Guide*, how important is sustainable development goal to the organization's mission and how companies should be involved in the process (Blokdyk, 2000). O. Osuji, F.N. Ngwu, D. Jamali in *Corporate Social Responsibility in Developing and Emerging Markets: Institutions, Actors and Sustainable Development*, show linkages between corporate social responsibility and sustainable development and how it has emerged as a tool for public and private institutions to promote sustainable development in developing and emerging markets (Osuji, Ngwu, Jmali, 2020). They also describe with normative factors, theoretical models, policy strategies as well as corporate practices best facilitate effective corporate social responsibility and sustainable development.

R. Kemp, D. Loorbach, J. Rotmans in *Transition management as a model for managing processes of co-evolution towards sustainable development* state that sustainable development requires changes in socio-technical systems and wider societal change – in beliefs, values and governance that co-evolve with technology changes (Kemp, Loorbach, Rotmans, 2009). The measures of sustainable development are also widely described in literature as well. D. Pearse proves in *Measuring Sustainable Development* that environmental issues can only be solved after economic issues and the policies to eliminate ecological, social and economic distortions include re-pricing policy of goods and services through pollution taxes, revising investments e.g. in roads construction and revising the measures of economic growth versus sustainable growth (Pearse, 2013). In *Characterizing and Measuring Sustainable Development* T.M. Parris and R.W. Kates conclude that there are no indicator sets that are universally accepted, backed by compelling theory, rigorous data collection and analysis, and influential in policy. This is due to the ambiguity of sustainable development, the plurality of purpose in characterizing and measuring sustainable development, and the confusion of terminology, data, and methods of measurement (Parris, Kates, 2003). In parallel, there are numerous analyses, research projects and studies performed at the level of European Union as there is an increasing awareness of the issue (Bjerkem, Pilati, Dheret, Giuli, Sipka, 2019). The Committee on

Transport and Tourism European Parliament regularly reports on the sustainable development in the field (www.europarl.europa.eu, 2019) Moreover, to better tackle the major challenges in the field of sustainability and to deliver on the Sustainable Development Goals, it is not just necessary to conduct research and development but at that stage to also implement innovation as the real driver of sustainable growth (Kemp, Loorbach, Rotmans, 2009). Despite the extensive research in the field of sustainable development, this article aims to draw attention to the significant impact of smart polymer materials on sustainable development.

6. Smart materials and the development of technology entrepreneurship. Findings

The research concerned the impact of modern smart materials on the development of technology entrepreneurship in high-tech companies in Mazovia and its importance for increasing the competitiveness of enterprises. The survey research method was used as part of the lustration procedure, characteristic of the so-called nomothetic research approach used for quantitative research in management sciences. A problem encountered during the research was the fact that it was difficult to pinpoint the number of high-technology (HT) enterprises in the Masovian province, mainly due to the fuzzy border between medium-tech and high-tech organizations. Such a classification has been attempted several times in recent years. A. Skala suggested classifying HT organizations in the form of a so-called "technological cloverleaf" (Skala, 2014, pp. 109-127) (the number of high-tech enterprises in the Masovian province was estimated at 200), and subsequently K. Rostek and A. Skala conducted a segmentation analysis of the organizations included in the Warsaw HT group (Rostek, Skala, 2016, pp. 155-167) (with the analysis covering 229 organizations). Currently the number of HT entities in the Masovian province is estimated at ca. 300. The number of survey respondents was 65, accounting for ca. 22% of the total number of organizations (Chyba, 2021). Their classification with respect to the number of employees and legal form is presented in Figures 1 and 2.

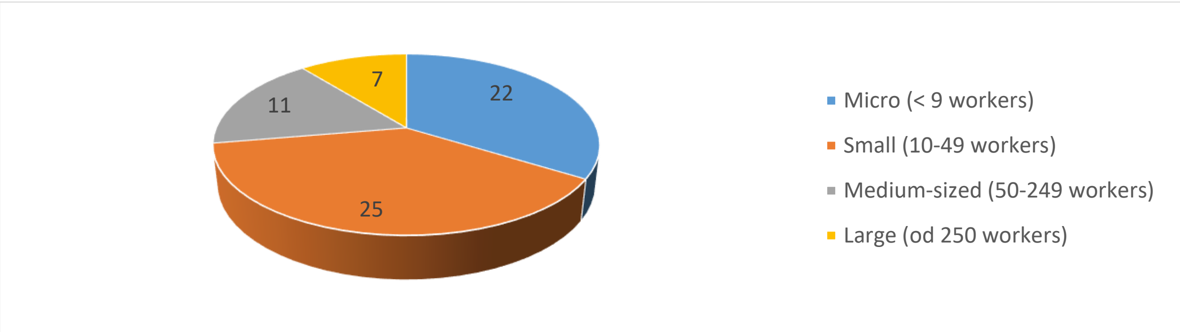

Figure 1. Classification the size of organizations.

Source: own materials based on (Chyba, 2021).

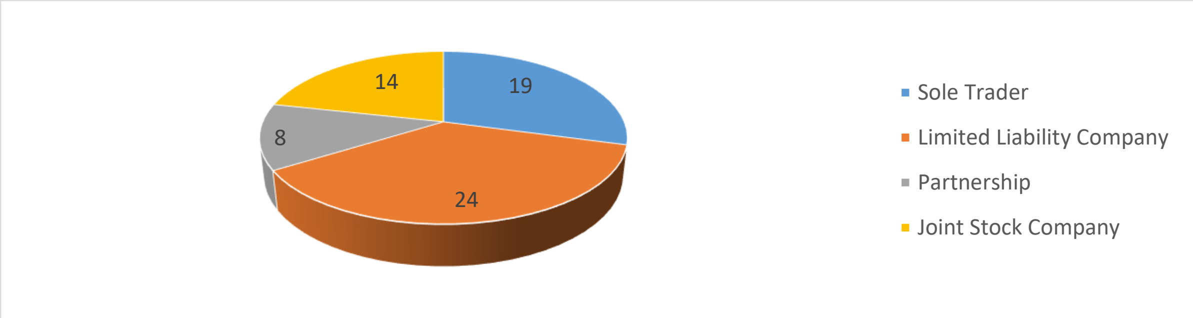

Figure 2. Classification the legal form of organizations.

Source: own materials based on (Chyba, 2021).

In terms of legal form, the one that is dominant are limited liability companies, which is particularly characteristic for small innovative entities in the early stages of the organization's life cycle. Micro enterprises are usually natural persons or civil law partnerships. The group of medium-sized and large enterprises is dominated by joint-stock companies or civil law partnerships (Chyba, 2021). Figure 3 presents the results of studies on the sources of acquisition of new smart materials.

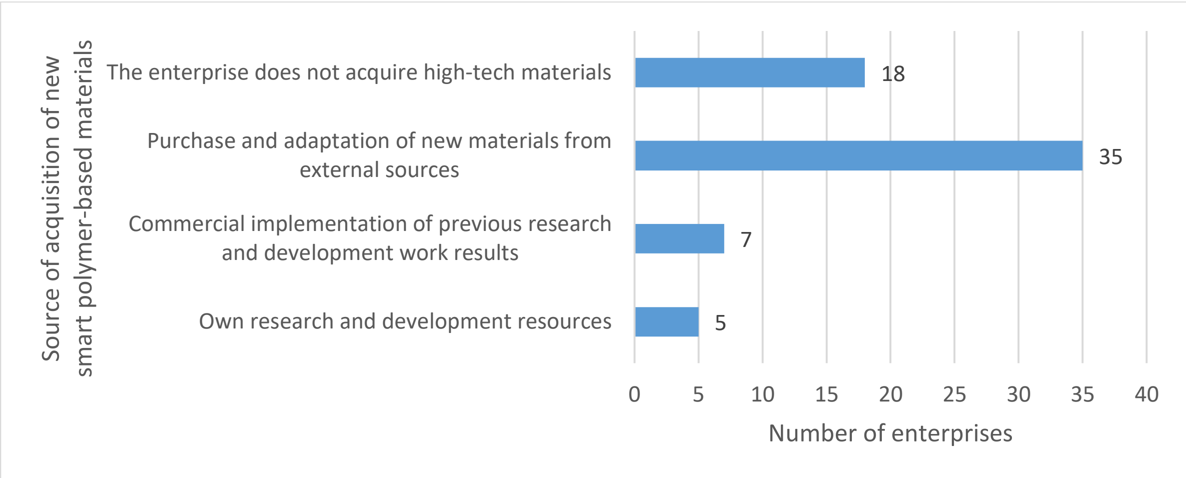

Figure 3. Source of acquisition of new smart polymer materials.

Source: own study.

The research results show that advanced technology sector enterprises in the Masovian province acquire new smart materials mainly from external sources, primarily due to possessing limited resources and insufficient competences in this area. What is more, over ¼ of the enterprises surveyed did not acquire innovative plastic/polymer-based materials. Only five enterprises reported that they develop and implement such materials based on their own R&D resources, while another seven said they use their technology knowledge for the commercial implementation of results of previous research and development work (Chyba, 2021).

Taking into account the relation between the size of the enterprise measured by number of employees and source of acquisition of new smart polymer-based materials, micro enterprises do not perform own research and development in the field, while small, medium and large enterprises perform their own research and development in the field of new smart polymer-based materials for their further production though only to a limited extent: 2 out of 5 companies that answered positively in that category belong to the small and 2 to medium-sized enterprise category. Only one large company answered that the source of acquisition of new smart polymer-based materials is their own research and development.

Out of 7 enterprises which indicated that the new smart polymer-based materials they use come from commercial implementation of previous research and development work results, 3 were medium sized, 2 small enterprises, one each belonged to the micro- and large enterprise categories. The highest number of responses (35) stated that the smart polymer-based materials were purchased from external sources and adapted, with more than half of respondents (18) in that group being small enterprises. The second-largest group of respondents (10) were micro companies. Only 4 large and 3 medium-sized enterprises indicated that the source of acquisition of new smart polymer-based materials was purchasing and adaptation from external sources. 18 enterprises did not acquire high-tech materials at all, amongst which the biggest group (11) were micro companies. 3 small and 3 medium-sized enterprises also gave the same response. Only one large company that took part in the research answered positively in this part. The detailed results on relation between size of the enterprise measured by number of employees and source of acquisition of new smart polymer-based materials are presented in Table 3 and Figure 4.

Table 3.
Source of acquisition of new smart polymer-based materials in relation to the size of the enterprise measured by number of employees

Source of acquisition of new smart polymer-based materials	Number of enterprises	Micro (< 9 workers)	Small (10-49 workers)	Medium-sized (50-249 workers)	Large (above 250 workers)
Own research and development resources	5	0	2	2	1
Commercial implementation of previous research and development work results	7	1	2	3	1
Purchase and adaptation of new materials from external sources	35	10	18	3	4
The enterprise does not acquire high-tech materials	18	11	3	3	1

Source: own study.

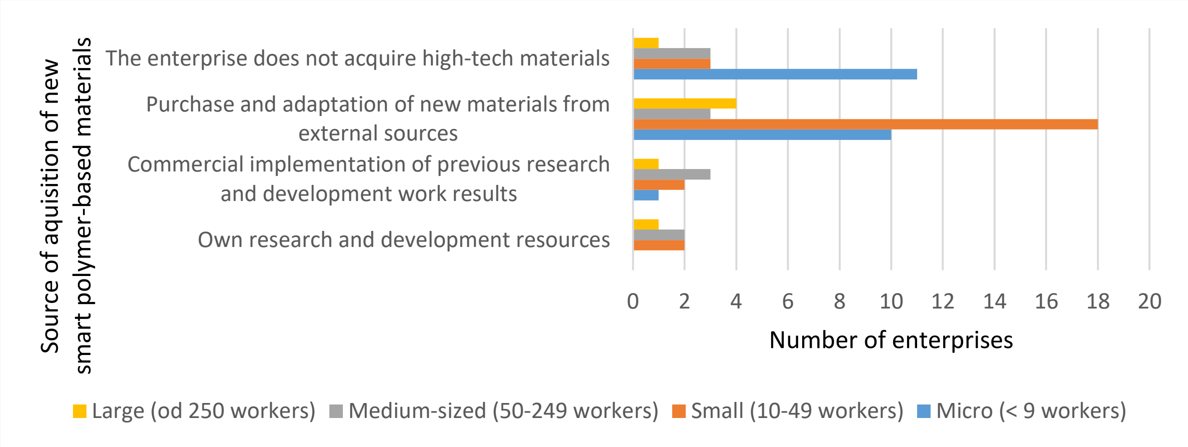

Figure 4. Source of acquisition of new smart polymer-based materials in relation to the size of the enterprise measured by number of employees.

Source: own study.

Data collected during research regarding the source of acquisition of new smart polymer-based materials in relation to the size of the enterprise measured by number of employees and gathered in Table 1 was the subject of further statistical analysis. The full statistical analysis regarding sources of acquisition of new smart polymer materials in relation to the size of the enterprise measured by number of employees is presented in Table 4.

Table 4.
Statistical analysis of sources of acquisition of new smart polymer-based materials in relation to the size of the enterprise measured by number of employees

Coefficient	Value
The whole research group	
ind_av	4,06
ind_med	2,50
ind_mode	1,00
ind_min	0,00
ind_max	18,00
ind_range	18,00
ind_stdev	4,82
n	65
Micro companies	
ind_av	5,50
ind_med	5,50
ind_mode	N/A
ind_min	0,00
ind_max	11,00
ind_range	11,00
ind_stdev	5,80
n	22
Small enterprises	
ind_av	6,25
ind_med	2,50
ind_mode	2,00
ind_min	2,00
ind_max	18,00

Cont. table 4.

ind_range	16,00
ind_stdev	7,85
n	25
Medium sized enterprises	
ind_av	2,75
ind_med	3,00
ind_mode	3,00
ind_min	2,00
ind_max	3,00
ind_range	1,00
ind_stdev	0,50
n	11
Large enterprises	
ind_av	1,75
ind_med	1,00
ind_mode	1,00
ind_min	1,00
ind_max	4,00
ind_range	3,00
ind_stdev	1,50
n	7

Source: own calculations.

Taking into account relation between the legal form of respondents and source of acquisition of new smart polymer-based materials, sole traders do not perform own research and development in the field, while partnership and joint stock companies perform their own research and development in the field of new smart polymer-based materials for their further production though to a limited extent: 1 out of 5 companies in each category of legal form that answered positively in that category. 3 limited liability companies answered that the source of acquisition of new smart polymer-based materials is their own research and development.

Out of 7 enterprises which indicated that the new smart polymer-based materials they use come from commercial implementation of previous research and development work results, 3 were limited liability companies, 2 joint stock companies, one was a sole trader and one a partnership. The question that received the highest number of affirmative responses (35) concerned purchasing and adaptation of new smart polymer-based materials from external sources; more than one third of the respondents (12) in that group were sole traders, with the second biggest group (10) being joint stock companies, followed by 8 limited liability companies and 5 classified as partnerships. 18 enterprises do not acquire high-tech materials at all, amongst which the biggest group (10) are limited liability companies and 6 are sole traders. Only one partnership and one joint stock company that took part in the research answered this question in the affirmative. The detailed results on the relationship between the respondents' legal form and source of acquisition of new smart polymer-based materials are presented in Table 5 and Figure 5.

Table 5.
Source of acquisition of new smart polymer-based materials in relation to legal form of respondents

Source of acquisition of new smart polymer-based materials	Number of enterprises	Sole Trader	Limited Liability Company	Partnership	Joint Stock Company
Own research and development resources	5	0	3	1	1
Commercial implementation of previous research and development work results	7	1	3	1	2
Purchase and adaptation of new materials from external sources	35	12	8	5	10
The enterprise does not acquire high-tech materials	18	6	10	1	1

Source: own study.

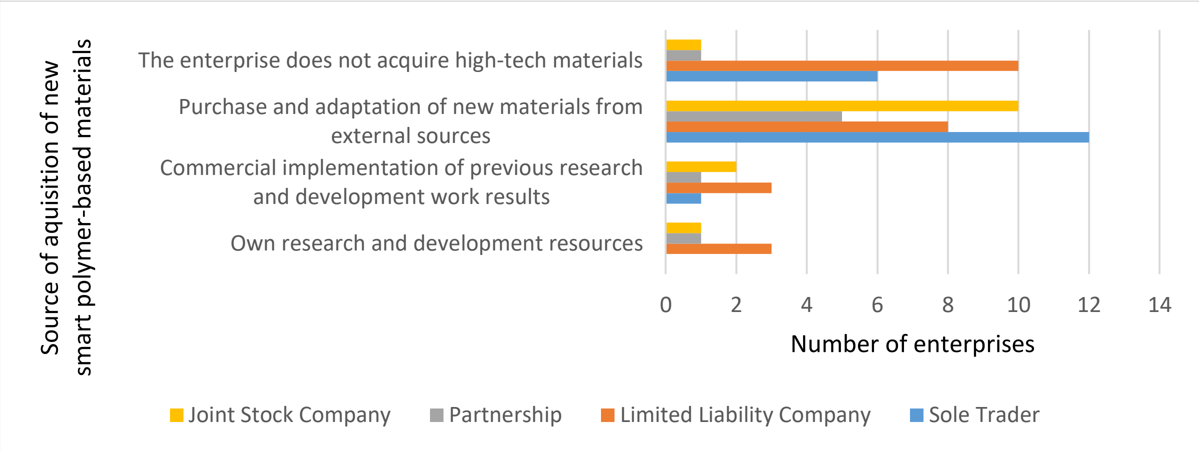

Figure 5. Source of acquisition of new smart polymer-based materials in relation to legal form of respondents.

Source: own study.

Data collected during research regarding the source of acquisition of new smart polymer-based materials in relation to legal form of respondents and gathered in Table 3 was the subject of further statistical analysis. The full statistical analysis regarding sources of acquisition of new smart polymer materials in relation to the legal form of respondents is presented in Table 6.

Table 6.
Statistical analysis of sources of acquisition of new smart polymer - based materials in relation to the legal form of respondents

Coefficient	Value
The whole research group	
ind_av	4,06
ind_med	2,50
ind_mode	1,00
ind_min	0,00

Cont. table 6.

ind_max	12,00
ind_range	12,00
ind_stdev	3,94
n	65
Sole Trader	
ind_av	4,75
ind_med	3,50
ind_mode	#N/A
ind_min	0,00
ind_max	12,00
ind_range	12,00
ind_stdev	5,50
n	19
Limited Liability Company	
ind_av	6,00
ind_med	5,50
ind_mode	3,00
ind_min	3,00
ind_max	10,00
ind_range	7,00
ind_stdev	3,56
n	24
Partnership	
ind_av	2,00
ind_med	1,00
ind_mode	1,00
ind_min	1,00
ind_max	5,00
ind_range	4,00
ind_stdev	2,00
n	8
Joint Stock Company	
ind_av	3,50
ind_med	1,50
ind_mode	1,00
ind_min	1,00
ind_max	10,00
ind_range	9,00
ind_stdev	4,36
n	14

Source: own calculations.

The influence of modern high-tech materials on the development of technology entrepreneurship which may lead to an increased global market competitiveness is presented in Figure 4. It can be seen that a definite majority of the enterprises that use smart materials acquired from external sources are aware of their impact on the development of technology entrepreneurship and see them as a potential source of competitive advantage.

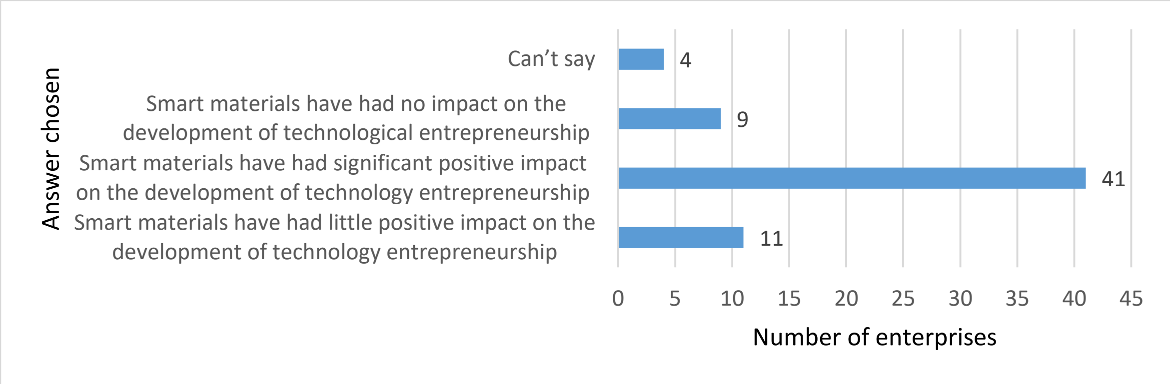

Figure 6. Influence of smart materials acquisition on the development of technology entrepreneurship. Source: own study.

The presented results indicate that more than half of the organizations surveyed perceived the impact smart materials had on the development of technology entrepreneurship as significant. In the opinion of 1/6 of those surveyed, the positive impact was not significant. Only nine enterprises did not perceive such an impact, while four had no opinion. The above results indicate that even though most advanced-technology sector enterprises do not possess key competences in developing smart materials, they are aware of the importance of adapting them and try to acquire them from external sources. They understand the connection between the adaptation of smart materials and the development of technology entrepreneurship in their enterprises which may lead to increasing their competitiveness on international markets.

Taking into account the influence of smart materials acquisition on the development of technology entrepreneurship in relation to the size of the enterprise measured by the number of employees, the majority of respondents (41 out of 65) answered that smart materials have had significant positive impact on the development of technology entrepreneurship. That answer was provided by 12 micro enterprises, 19 small, 7 medium and 3 large enterprises. 11 respondents indicated that smart materials have had little positive impact on the development of technology entrepreneurship. In this category highest score (4) was observed in medium sized enterprises, only one response fewer was indicated by large and small enterprises. Only one micro company gave a positive answer in this category. Out of 65 enterprises that took part in the research, only 9 indicated that smart materials have had no impact on the development of technological entrepreneurship. In this category the majority (7 out of 9) of respondents belong to the group of micro companies. One enterprise each from the small and one large enterprise category gave a positive answer. The detailed results on relation between size of the enterprise measured by number of employees and influence on smart materials acquisition on the development of technology entrepreneurship are presented in Table 7 and Figure 7.

Table 7.
Influence on smart materials acquisition on the development of technology entrepreneurship in response to the size of the enterprise measured by number of employees

Answer chosen	Number of enterprises	Micro (< 9 workers)	Small (10-49 workers)	Medium-sized (50-249 workers)	Large (> 250 workers)
Smart materials have had little positive impact on the development of technology entrepreneurship	11	1	3	4	3
Smart materials have had significant positive impact on the development of technology entrepreneurship	41	12	19	7	3
Smart materials have had no impact on the development of technological entrepreneurship	9	7	1	0	1
Can't say	4	2	2	0	0

Source: own study.

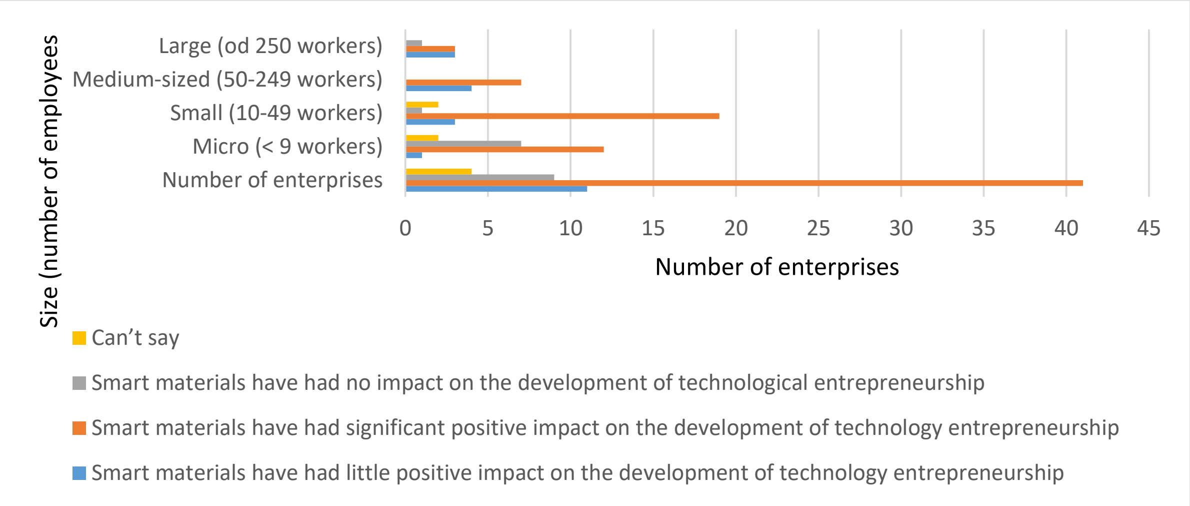

Figure 7. Influence on smart materials acquisition on the development of technology entrepreneurship in response to the size of the enterprise measured by number of employees.

Source: own study.

Data collected during research regarding the influence of smart materials acquisition on the development of technology entrepreneurship in relation to the size of the enterprise measured by number of employees and presented in Table 5 was the subject of further statistical analysis. The full statistical analysis regarding sources of acquisition of new smart polymer materials in relation to the legal form of respondents is presented in Table 8.

Table 8.
Statistical coefficients on influence on smart materials acquisition on the development of technology entrepreneurship in relation to the size of the enterprise measured by number of employees

Coefficient	Value
The whole research group	
ind_av	4,06
ind_med	2,50

Cont. table 8.

ind_mode	1,00
ind_min	0,00
ind_max	19,00
ind_range	19,00
ind_stdev	5,12
n	65
Micro companies	
ind_av	5,50
ind_med	4,50
ind_mode	#N/A
ind_min	1,00
ind_max	12,00
ind_range	11,00
ind_stdev	5,07
n	22
Small enterprises	
ind_av	6,25
ind_med	2,50
ind_mode	#N/A
ind_min	1,00
ind_max	19,00
ind_range	18,00
ind_stdev	8,54
n	25
Medium sized enterprises	
ind_av	2,75
ind_med	2,00
ind_mode	0,00
ind_min	0,00
ind_max	7,00
ind_range	7,00
ind_stdev	3,40
n	11
Large enterprises	
ind_av	1,75
ind_med	2,00
ind_mode	3,00
ind_min	0,00
ind_max	3,00
ind_range	3,00
ind_stdev	1,50
n	7

Source: own calculations.

Taking into account the relation between the legal form of respondents and influence on smart materials acquisition on the development of technology entrepreneurship, the highest number of respondents - 41 – stated that smart materials have a significant positive impact on the development of technology entrepreneurship. 18 responses belonged to limited liability companies and 14 to sole traders. The rest of the responses are spread over categories and legal entities with low scores. The detailed results on the relation between legal form of respondents and influence on smart materials acquisition on the development of technology entrepreneurship are presented in Table 9 and Figure 8.

Table 9.
Influence of smart materials acquisition on the development of technology entrepreneurship in relation to legal form of respondents

Answer chosen	Number of enterprises	Sole Trader	Limited Liability Company	Partnership	Joint Stock Company
Smart materials have had little positive impact on the development of technology entrepreneurship	11	1	3	6	1
Smart materials have had significant positive impact on the development of technology entrepreneurship	41	14	18	2	7
Smart materials have had no impact on the development of technological entrepreneurship	9	3	2	0	4
Can't say	4	1	1	0	2

Source: own study.

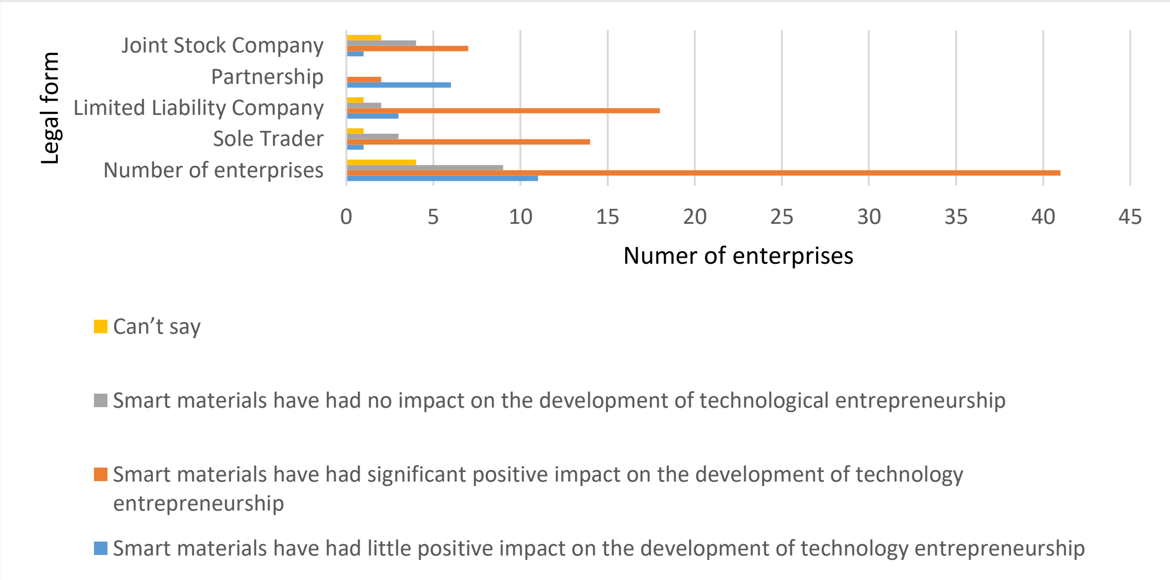

Figure 8. Influence of smart materials acquisition on the development of technology entrepreneurship in relation to legal form of respondents.

Source: own study.

Data collected during research regarding the influence of smart materials acquisition on the development of technology entrepreneurship in relation to legal form of respondents and gathered in Table 7 was the subject of further statistical analysis. The full statistical analysis regarding sources of acquisition of new smart polymer materials in relation to the legal form of respondents is presented in Table 10.

Table 10.
Statistical coefficients on influence of smart materials acquisition on the development of technology entrepreneurship in relation to legal form of respondents

Coefficient	Value
The whole research group	
ind_av	4,06
ind_med	2,00
ind_mode	1,00
ind_min	0,00
ind_max	18,00
ind_range	18,00
ind_stdev	5,11
n	65
Sole Trader	
ind_av	4,75
ind_med	2,00
ind_mode	1,00
ind_min	1,00
ind_max	14,00
ind_range	13,00
ind_stdev	6,24
n	19
Limited Liability Company	
ind_av	6,00
ind_med	2,50
ind_mode	#N/A
ind_min	1,00
ind_max	18,00
ind_range	17,00
ind_stdev	8,04
n	24
Partnership	
ind_av	2,00
ind_med	1,00
ind_mode	0,00
ind_min	0,00
ind_max	6,00
ind_range	6,00
ind_stdev	2,83
n	8
Joint Stock Company	
ind_av	3,50
ind_med	3,00
ind_mode	#N/A
ind_min	1,00
ind_max	7,00
ind_range	6,00
ind_stdev	2,65
n	14

Source: own calculations.

The last part of the research focused on the concept of sustainability. The same research sample of 65 companies was surveyed regarding their knowledge in the field. The response with the highest score (23 out of 65, which is 35% of respondents) shows that the concept of sustainability is well known and has been implemented in the company, but 17 out 65 surveyed companies (26%) answered that the concept is barely known. 22% of the companies (14 of 65) responded that sustainability is a well-known concept to them but has not been adopted in the company. 17% of a research group, which is 11 of 65 surveyed companies does not know the concept of sustainability at all. The detailed results are presented in Figure 9.

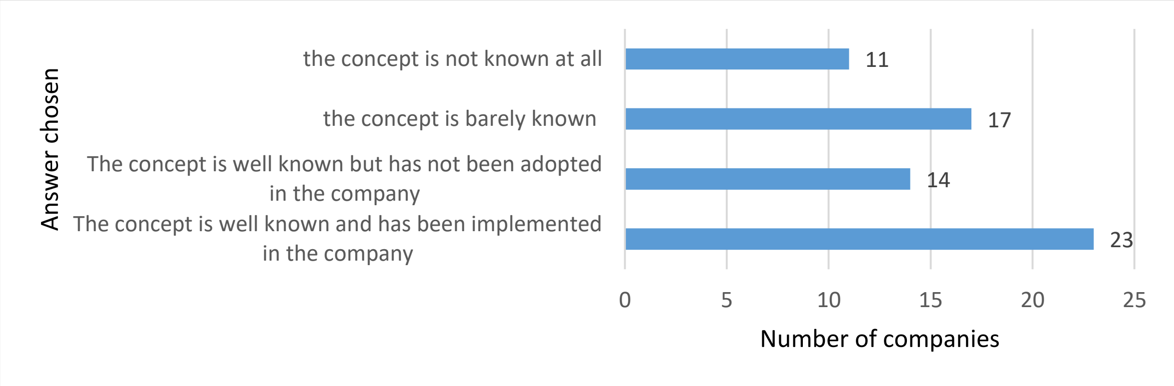

Figure 9. Familiarity of the concept of sustainability.

Source: own study.

Taking into account familiarity of the concept of sustainability in relation to the size of the enterprise measured by number of employees, largest number of responses (23 out of 65) proves that the concept of sustainability is well known and has been implemented in the company. That answer was provided by 7 micro enterprises, 9 small, 4 medium and 3 large enterprises. Out of 17 respondents that indicated that the concept of sustainability is barely known, highest score (7) was observed in small enterprises and second highest (6) by medium – sized enterprises. Second highest single score was obtained by micro companies in the category the concept of sustainability is well known but has not been adopted in the company. The detailed research results are presented in Table 11 and Figure 10 below.

Table 11.
Familiarity of the concept of sustainability in response to the size of the enterprise measured by number of employees

	Number of enterprises	Micro (< 9 workers)	Small (10-49 workers)	Medium-sized (50-249 workers)	Large (as of 250 workers)
The concept is well known and has been implemented in the company	23	7	9	4	3
The concept is well known but has not been adopted in the company	14	8	3	0	3
the concept is barely known	17	4	7	6	0
the concept is not known at all	11	3	6	1	1

Source: own study.

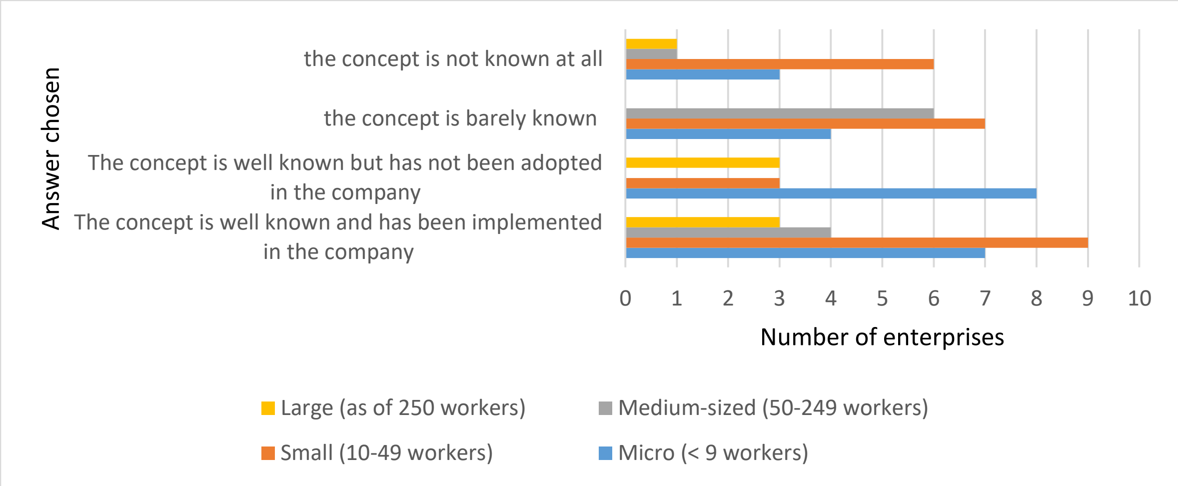

Figure 10. Familiarity of the concept of sustainability in response to the size of the enterprise measured by number of employees.

Source: own study.

Data collected during research regarding familiarity with the concept of sustainability in relation to the size of the enterprise measured by number of employees and gathered in Table 11 was the subject of further statistical analysis. The full statistical analysis regarding sources of acquisition of new smart polymer materials in relation to the legal form of respondents is presented in Table 12.

Table 12.
Statistical coefficients on familiarity of the concept of sustainability in response to the size of the enterprise measured by number of employees

Coefficient	Value
The whole research group	
ind_av	4,06
ind_med	3,50
ind_mode	3
ind_min	0
ind_max	9
ind_range	9
ind_stdev	2,84
n	65
Micro companies	
ind_av	5,5
ind_med	5,5
ind_mode	#N/A
ind_min	3
ind_max	8
ind_range	5
ind_stdev	2,38
n	22

Cont. table 12.

Small enterprises	
ind_av	6,25
ind_med	6,5
ind_mode	#N/A
ind_min	3
ind_max	9
ind_range	6
ind_stdev	2,50
n	25
Medium sized enterprises	
ind_av	2,75
ind_med	2,5
ind_mode	#N/A
ind_min	1
ind_max	6
ind_range	5
ind_stdev	2,75
n	11
Large enterprises	
ind_av	1,75
ind_med	2
ind_mode	3
ind_min	0
ind_max	3
ind_range	3
ind_stdev	1,50
n	7

Source: own study.

Taking into account familiarity of the concept of sustainability in relation to legal form of respondents 23 out 65 surveyed companies indicated that the concept of sustainability is well known to them and has been implemented in the company. In this category highest score (12) was observed amongst limited liabilities companies. Second highest single score at the level of 7 was obtained also by limited liabilities companies but indicating that the concept of sustainability is well known to them but has not been adopted in the company. The detailed research results are presented in Table 13 and Figure 11 below.

Table 13.
Familiarity with the concept of sustainability in relation to legal form of respondents

	Number of enterprises	Sole Trader	Limited Liability Company	Partnership	Joint Stock Company
The concept is well known and has been implemented in the company	23	6	12	4	1
The concept is well known but has not been adopted in the company	14	2	7	3	2
the concept is barely known	17	7	3	1	6
the concept is not known at all	11	4	2	0	5

Source: own study.

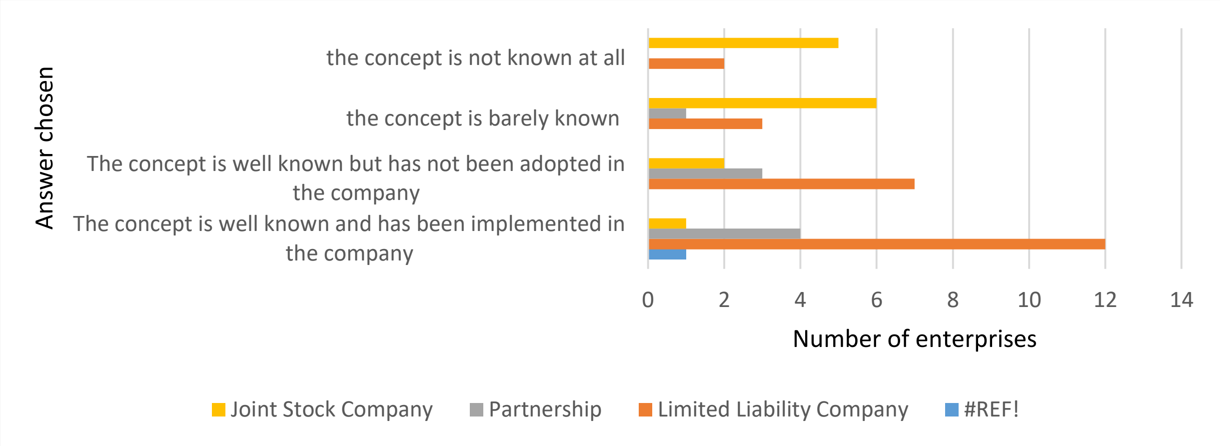

Figure 11. Familiarity with the concept of sustainability in relation to legal form of respondents.

Source: own study.

Data collected during research regarding familiarity of the concept of sustainability in relation to legal form of respondents and gathered in Table 13 was the subject of further statistical analysis. The full statistical analysis regarding familiarity of the concept of sustainability in relation to legal form of respondents is presented in Table 14.

Table 14.
Statistical coefficients on familiarity of the concept of sustainability in relation to legal form of respondents

Coefficient	Value
The whole research group	
ind_av	3,83
ind_med	3
ind_mode	2
ind_min	0
ind_max	12
ind_range	12
ind_stdev	3,04
n	65
Sole Trader	
ind_av	4,75
ind_med	5
ind_mode	#N/A
ind_min	2
ind_max	7
ind_range	5
ind_stdev	2,22
n	19
Limited Liability Company	
ind_av	6
ind_med	5
ind_mode	#N/A
ind_min	2
ind_max	12
ind_range	10
ind_stdev	4,55
n	24

Cont. table 14.

Partnership	
ind_av	2
ind_med	2
ind_mode	#N/A
ind_min	1
ind_max	4
ind_range	3
ind_stdev	1,83
n	8
Joint Stock Company	
ind_av	3,5
ind_med	3,5
ind_mode	#N/A
ind_min	1
ind_max	6
ind_range	5
ind_stdev	2,38
n	14

Source: own study.

The last part of the research concerned the relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship. The majority of responses (33 out of 65, which is 51% of respondents) proves that sustainable solutions have not been implemented in the surveyed companies at all, but 17 out 65 surveyed companies (26%) gave the exact opposite answer, indicating that the implementation of the concept of sustainability had a significant impact on the development of technological entrepreneurship.

The detailed results are presented in Figure 12.

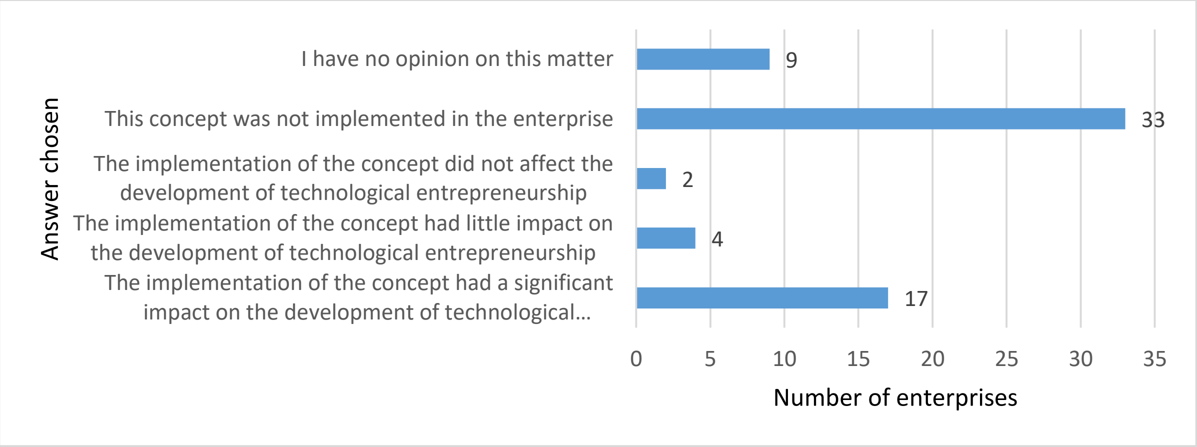

Figure 12. The relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship.

Source: own study.

Taking into account the relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in relation to the size of the enterprise measured by number of employees, the largest number of responses (33 out of 65) proves that the concept of sustainability was not implemented in the enterprise. That answer was provided by 13 micro enterprises, 11 small , 5 medium and 4 large enterprises. Out of the 17 respondents that indicated that the implementation of the concept of sustainability had a significant impact on the development of technological entrepreneurship, the highest score (8) was observed in small enterprises and the second highest (6) in micro enterprises. The detailed research results are presented in Table 15 and Figure 13 below.

Table 15.

The relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in response to the size of the enterprise measured by number of employees

	Number of enterprises	Micro (< 9 workers)	Small (10-49 workers)	Medium-sized (50-249 workers)	Large (as of 250 workers)
The implementation of the concept had a significant impact on the development of technological entrepreneurship	17	6	8	2	1
The implementation of the concept had little impact on the development of technological entrepreneurship	4	0	2	1	1
The implementation of the concept did not affect the development of technological entrepreneurship	2	0	1	1	0
This concept was not implemented in the enterprise	33	13	11	5	4
I have no opinion on this matter	9	3	3	2	1

Source: own study.

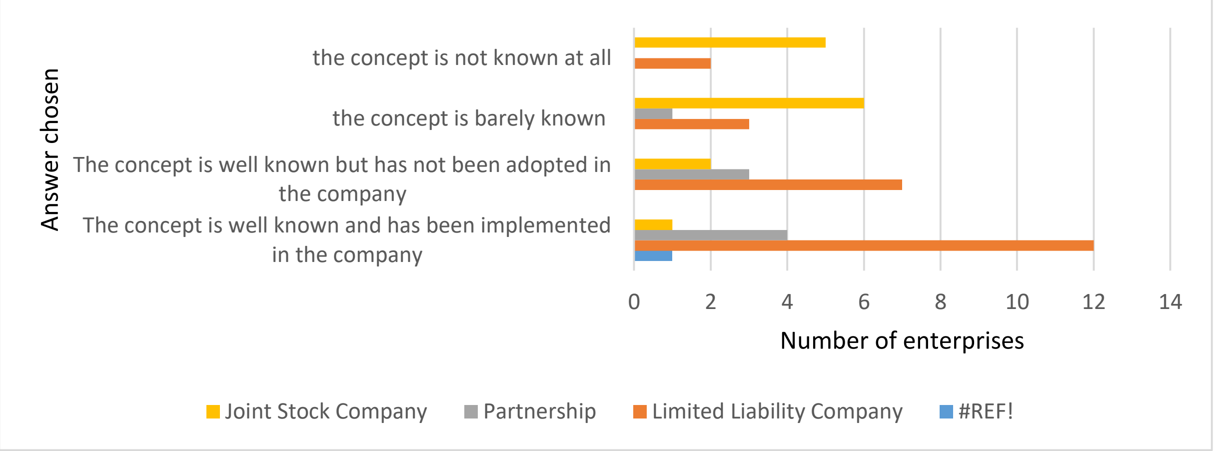

Figure 13. The relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in relation to the size of the enterprise measured by number of employees.

Source: own study.

Data collected during research regarding the relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in response to the size of the enterprise measured by number of employees and gathered in Table 15 was the subject of further statistical analysis. The full statistical analysis regarding sources of acquisition of new smart polymer materials in relation to the size of the enterprise measured by number of employees is presented in Table 16.

Table 16.
Statistical coefficients on the relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in response to the size of the enterprise measured by number of employees

Coefficient	Value
The whole research group	
ind_av	3,25
ind_med	2
ind_mode	1
ind_min	0
ind_max	13
ind_range	13
ind_stdev	3,67
n	65
Micro companies	
ind_av	4,4
ind_med	3
ind_mode	0
ind_min	0
ind_max	13
ind_range	13
ind_stdev	5,41
n	22
Small enterprises	
ind_av	5
ind_med	3
ind_mode	#N/A
ind_min	1
ind_max	11
ind_range	10
ind_stdev	4,30
n	25
Medium sized enterprises	
ind_av	2,2
ind_med	2
ind_mode	1 and 2
ind_min	1
ind_max	5
ind_range	4
ind_stdev	1,64
n	11
Large enterprises	
ind_av	1,4
ind_med	1
ind_mode	1
ind_min	0
ind_max	4
ind_range	4
ind_stdev	1,52
n	7

Source: own study.

The last part of the research concerned the relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in relation to legal form of respondents. The highest single responses in this category indicated that the concept of sustainability was not implemented in the enterprise at all and was pointed out by 13 limited liabilities companies and 12 sole traders. Detailed responses are collected in Table 17 and Figure 14 below.

Table 17.
The relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in relation to legal form of respondents

	Number of enterprises	Sole Trader	Limited Liability Company	Partnership	Joint Stock Company
The implementation of the concept had a significant impact on the development of technological entrepreneurship	17	5	7	2	3
The implementation of the concept had little impact on the development of technological entrepreneurship	4	1	1	1	1
The implementation of the concept did not affect the development of technological entrepreneurship	2	1	1	0	0
This concept was not implemented in the enterprise	33	12	13	2	6
I have no opinion on this matter	9	0	2	3	4

Source: own study.

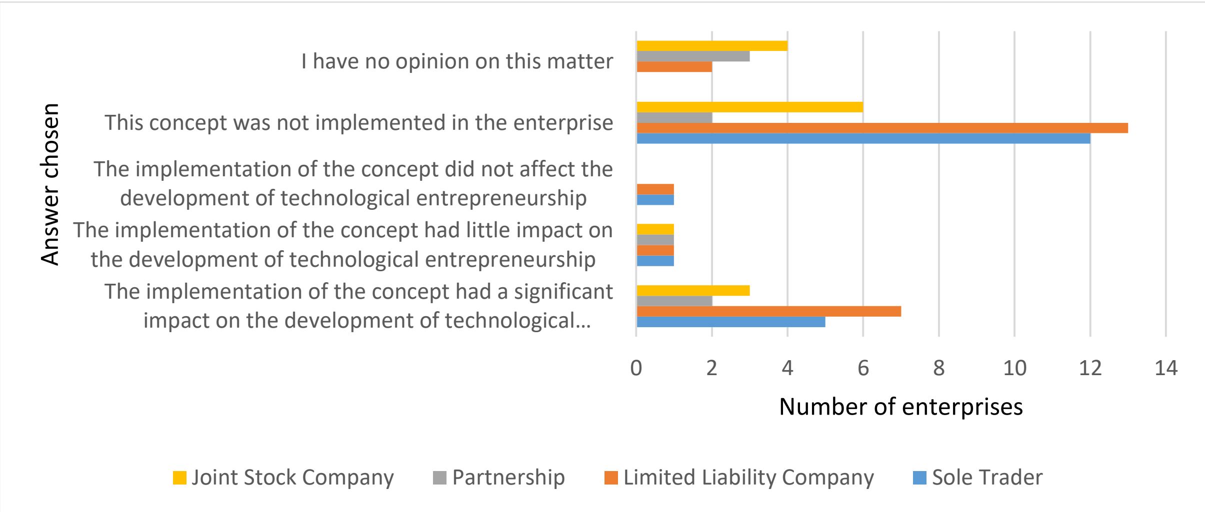

Figure 14. The relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in relation to legal form of respondents.

Source: own study.

Table 18.
Statistical coefficients on the relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in relation to legal form of respondents

Coefficient	Value
The whole research group	
ind_av	3,25
ind_med	2
ind_mode	1
ind_min	0
ind_max	13
ind_range	13
ind_stdev	3,73
n	65
Sole Trader	
ind_av	3,8
ind_med	1
ind_mode	1
ind_min	0
ind_max	12
ind_range	12
ind_stdev	4,97
n	19
Limited Liability Company	
ind_av	4,8
ind_med	2
ind_mode	1
ind_min	1
ind_max	13
ind_range	12
ind_stdev	5,22
n	24
Partnership	
ind_av	1,6
ind_med	2
ind_mode	2
ind_min	1
ind_max	3
ind_range	2
ind_stdev	1,14
n	8
Joint Stock Company	
ind_av	2,8
ind_med	3
ind_mode	#N/A
ind_min	0
ind_max	6
ind_range	6
ind_stdev	2,39
n	14

Source: own study.

Data collected during research regarding the relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in relation to legal form of respondents and gathered in Table 17 was the subject of further statistical analysis. The full statistical analysis regarding sources of acquisition of new smart polymer materials in relation to the legal form of respondents is presented above in Table 18.

Summary

The development of advanced technologies creates the possibility of producing and commercializing smart materials with special physicochemical properties and valuable functional characteristics, which significantly contributes to the progress of humanity. This is borne out by studies of high-tech enterprises operating in the Masovian province. The studies point to the following conclusions:

- The research results show that advanced technology sector enterprises in the Masovian province acquire new smart materials mainly from external sources, primarily due to possessing limited resources and insufficient competences in this area.
- Taking into account the relation between the size of the enterprise measured by number of employees and source of acquisition of new smart polymer-based materials, micro enterprises do not perform own research and development in the field, while small, medium and large enterprises perform their own research and development in the field of new smart polymer-based materials for their further production though only to a limited extent.
- Among innovative products and technologies, an important position is occupied by intelligent materials based on high-molecular chemical compounds (polymers) due to their physical and chemical properties and the huge scale of their synthesis and modification.
- Most of high-technology sector enterprises acquire smart materials from external sources by purchasing and adapting them, and less often by using their own research and development departments.
- A definite majority of the enterprises in the study sample are aware of the importance of using smart materials for increasing international competitiveness.
- There is a connection between the use of smart polymer materials and the development of technology entrepreneurship in high-tech sector enterprises and this may facilitate development of new innovative solutions.
- The development and/or use of smart materials facilitates the dissemination of knowledge within the organization, leading to an increase of its intellectual capital.

- Technology entrepreneurship is a way to the creation and commercialization new smart materials.
- The use of innovative smart materials supports the development of technology entrepreneurship in high-technology firms and branches.
- The concept of sustainable enterprises is not well known among many high-technology enterprises in Mazovia.
- The influence of modern high-tech materials on the development of technology entrepreneurship which may lead to an increased global market competitiveness.
- The majority of the enterprises that use smart materials acquired from external sources are aware of their impact on the development of technology entrepreneurship and see them as a potential source of competitive advantage.

To sum up, the research results concerned the relation between implementation of the concept of sustainability and its impact on the development of technological entrepreneurship in relation to legal form of respondents. The highest single responses in this category indicated that the concept of sustainability was not implemented in the enterprise at all and was pointed out mainly by limited liabilities companies and sole traders. Nevertheless the concept of sustainable enterprise is an innovative one and high-tech firms start to know much more than in previous days. As it was previous said, nowadays the goals of economic and social development must be re-defined in terms of sustainability. Discussion about sustainability has emerged in recent years as a consequence of the growing ecological and social awareness after years of focus primarily on economic growth. The imminent ecological crisis as well as the global wealth inequality have led to a new focus on sustainability in global terms and on three dimensions (ecological, social and economic). The innovative materials are one of the ways to reach sustainable goals.

Smart modern materials, especially based on polymers, plays a key role in the development of world economy, taking into account its contemporary challenges. The development of innovative materials causes many enterprises to support their competitive positions and consequently gives chances for creating and sustaining superior performance. The more innovative smart materials are, the bigger technological chances they create. Of course, innovations should take into account, except economical aspects, both ecological and social ones. Technology entrepreneurship, in connection with the using of design thinking and the concept of sustainable enterprise will able to prepare and commercialize interesting and technology advanced materials which cause that many enterprises, not only high-technology firms, the building of high competitive position on international market.

Innovation and entrepreneurship are key factors of creating the competitive advantage on global market. The development of science and technology gives the entrepreneurs the unique opportunity to use the research results and commercialization in order to support the competitive positions of their enterprises and consequently to gain the new added values for creation new technological or/and competitive advantages in turbulent environment. Due to fact that contemporary challenges of competition are more and more unexpectable and difficult, modern enterprises should be more intelligent and their materials and products more smart. This is the result of core competences and special skills of entrepreneurs and all employees. Nowadays among many sources of competitive advantage, the previous ones are the most important.

The presented research results may contribute to a wider discussion on the role of advanced or intelligent materials, not just those based on polymers, in the development of technological entrepreneurship of the organization and building their competitive advantages on the global market.

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Appendix

Abbreviations

ind_av	-	indicator of average value of data sample
ind_med	-	indicator of median value of data sample
ind_mode	-	indicator of mode value of data sample
ind_min	-	indicator of minimal value of data sample
ind_max	-	indicator of maximal value of data sample
ind_range	-	indicator of range value of data sample
ind_stdev	-	indicator of standard deviation value of data sample
n	-	indicator of number of observations in data sample