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Identifying the Phenomenon of Complexity in the Sector of Industrial Automation

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Abstract
The main objective of the research work was to identify the dimensions of complexity and study the relationship between these defined dimensions in the industrial automation sector. To achieve these objectives in the study, there was assumed the following major hypothesis: With the increasing role of dynamic cross-section of the complexity there is growing importance of relationship dimension for competitive advantage.
In the study there were diagnosed four dimensions of complexity. Existence of the relationship between these four identified dimensions of complexity occurred by the use of the Fisher's exact test, which is a variant of the test of independence χ^2. Furthermore, there were calculated V-Cramer factors to estimate the intensity of the above-mentioned relationship between analyzed dimensions. The research discovered that the three out of four dimensions such as the number of elements, variety of elements and uncertainty depend on the last dimension of complexity which is the relationship between elements.
In the turbulent environment there is a growing importance of the relationship dimension. It forms competitive advantage and is a key condition of success in creating a new type of modern enterprise strategy that occurs within complexity management in the industrial automation sector.

Keywords
Industrial automation, Measurement, Complexity, Competitiveness.

Introduction

Transformations in the mechanism of creating sources of competitiveness alter and push companies into being ready to operate in the world of VUCA featured by such factors as: variability, uncertainty, complexity and ambiguity (Clegg et al., 2019; Tulder et al., 2019; Lissack, 1997).

The growth within the environmental complexity triggers the meaningful enhancement in the complexity of the enterprise. In addition, excessive advancement in a number of product and service ranges often contributes to lower profitability and increased complexity management costs.

Though the newest management notions highlight the value of complexity management in an organization, the ubiquitous lack of monitoring over complexity causes the deterioration of the company work and its costs often attain the highest levels.

The comprehension of the increasing value of the complexity in building a new kind of a modern enterprise strategy led to undertake studies on the complexity of a modern company in the sector of industrial automation.

It generated the need for studies on the dimensions of the complexity of modern enterprise.

Literature review

Contemporary economic processes as a factor dynamizing the increase in enterprise complexity

A modern enterprise, operating in a turbulent environment, becomes a complex system in which, respectively: a certain number of elements (e.g., business entities) and their diversity, interdependence and uncertainty that are arising from the operation of elements change more or less regularly the system relationships. These constantly changing system dependencies (nonlinear interactions) make the system dynamic, and

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therefore changeable and uncertain, because it prevents accurate forecasting based on extrapolation of the past events (Sargut, 2011). The complexity understood in this way creates limitations in the identification, valuation and forecasting of the factors affecting processes within the enterprise.

Thus, functioning in a complex environment (e.g. in cooperation with a larger number of suppliers) results in difficulties in the proper diagnosis and solution of problems and is burdened with a higher probability of making errors that have a direct impact on the company internal processes (Azadegan, 2013). Thinking in categories of complex systems reduces an enterprise to the unit that creates the economic environment which is undergoing change (Ginsberg, 1997). Therefore, although the increase or reduction of the internal complexity of an enterprise is usually the part of the planned activities of the enterprise, there are many external factors conditioning its dynamics. They are, e.g., (Bozarth et al., 2009; Zhang et al., 2012; Closs et al., 2008):

- globalization,
- dynamics of technological changes,
- no control of technological changes,
- fluctuations on the currency market,
- degree of competition,
- competitive pressure
- market differentiation (different power standards in the EU and the United States),
- cultural differences,
- legal regulations (also regarding export and import),
- the growing importance of ecology,
- industry standards,
- shortened product life cycle and service cycle (high stocks of spare parts),
- growing number of functions integrated in one product,
- pressure to implement new products,
- economics of new product development,
- rate of change of products or processes,
- number of customers,
- differentiation of customer needs,
- changes in demand,
- sensitivity of demand to price changes,
- rate of change in market demand,
- number of suppliers,
- long delivery times,
- supply uncertainty,
- minimum lots of orders.

When the market shapes complexity, which exerts strong impact on the enterprise activities, then there is meant the 'external' complexity, i.e., originating from the environment, so the complexity of the external situation or the environment of the enterprise. Let the individual client's needs (from the client's side) and product as well as technological innovations (generated by competitors) be examples of the reasons for the complexity arising in an economic unit coming from the environment. Similarly, the effect of, e.g., externally generated individualized customer's needs is the creation of complex 'internal' production processes, which in turn is a driving force for further development of competition. To sum up, the elements of the environment that are adjacent to the enterprise remain or, in the category of potential, may be directly or indirectly coupled with the enterprise.

Suppliers and end customers shaping the demand for goods and services on the market, as well as competition, create in the case of enterprises with service, production and commercial activities the layers of the environment with which the company can build relationships. These are direct interactions when the organization is in direct relations with the elements, or indirect when the elements are only indirectly correlated with the given organization. The greater the number of direct, existing and potential partners interacting with the company, the higher the complexity of the company's external situation.

The sources of the diversity of elements of the external situation can be seen in the diversity of demands and requirements posed by the environment. The effect of introducing multilayered global competition as one of the main global strategies distinguished by M.E. Porter, is just great diversity (Kasiewicz, 2003). The methods and tools developed by the organization may prove to be insufficient with deep differentiation of requirements. Elements of the environment create a network of connections that is constantly changing, which is why isolated nodes (elements) and separated edges (relations) cannot be analyzed in isolation from the whole (Binzberger, 1983).

The environment perceived in terms of complex systems is characterized by non-linearity and high sensitivity to initial conditions. This high sensitivity makes the effect unpredictable because it is disproportionate to the cause (Trisoglio, 1996). Non-linear common activities of factors amount more than the sum of their parts. So 'more' means 'different'. The existence of non-additive dependencies, strong sensitivity to initial conditions, individual behavior and limitations that occur within the environment lead to radically different results compared to the causes. In other words, the reasons for actions do not lead to quantitatively similar effects, because the company is very sensitive to the conditions in each time unit.

The non-linearity of interaction between the environment and the company is due to positive feedback.

W.B. Arthur argues that the negative feedback that stabilizes the economy, leading to equilibrium, does not seem to work for certain economic systems. It turns out that positive feedback introduces a multi-point balance into the market, in which not necessarily the best point (product, company location, company) is chosen from the rest. Often, the 'opportunity' is a different point on the podium, regardless of how much benefit would result from choosing another option. The chosen point, though not the most favorable after deeper analyzes, attracts further positive events multiplying profits (Arthur, 1990).

The above situation shows that the best company on the market does not always win, on the contrary, often the situation makes the option win, which from a benefit perspective is not the best solution at the moment. Despite this, the 'opportunity' makes the option a winner gaining everything, because the choice of the option entails further choices associated with it, multiplying capital.

Situations created on the basis of positive feedback are not subject to static, deterministic modelling, on the contrary, they are based on a dynamic process enriched with random events and non-linearity, the cause of which is a positive feedback.

In summary, each event and its specific random conditions require separate analysis, however, many events come down to a general pattern of non-linear interactions.

Taking into account originating from the environment factors dynamizing the increase in complexity is the key to open to change, and thus to unleash the competitive spirit of a modern enterprise.

Microeconomic determinants of increased complexity

When complexity derives from an enterprise, and thus arises within an enterprise, e.g. in the form of complex structures, IT systems, then it is the 'internal' complexity. The increase in the number of plant employees and the number of products/ services offered, although related to the company's development, from the point of view of system dynamics cannot at the same time mean an increase in the complexity of the internal situation (Mainzer, 2007). A larger enterprise need not be characterized by greater internal complexity than small enterprises (Binzberger, 1983). Size alone does not result in the dynamics of internal complexity. Enterprises with the same number of employees but different product portfolio will not be characterized by the same degree of complexity. Only after taking into account the increase or decrease in the diversity of elements and the diversity of relationships within the organization, it is possible to take into account, respectively, the increase or decrease in the complexity of the internal situation.

Within the internal complexity, the complexity of the employee team, the complexity of production methods, material production factors and the portfolio of products and services, as well as planning and control systems can be distinguished (Bozarth et al., 2009). The complexity of the employee team is determined by the diversity of employees in terms of qualifications, experience and knowledge, and hence the diversity of contracts, due to different pay thresholds, a different dimension of a full-time job, e.g. with the huge diversity of education along with the number of employees, the complexity rises. The extensive relationships within and outside the facility, including employee affiliations to various groups, and the resulting obligations and privileges, appropriately reinforces complexity. Informal channels, such as friendships, acquaintances far different from the channels formed by the structure of the organization, strengthen the flow of unofficial information. Such informal links reinforce the internal complexity of the organization.

The complexity of production methods is the result of the complexity of the production process. Process diversity depends on the degree of product portfolio diversification that a given company presents on the market. The degree of product diversification affects the number of processes, and this boils down to the number of different tools that are necessary in the production process (for the production of raw materials, semi-finished products and finished products) and the links between them.

The complexity of material production factors also boils down to a number of different materials and relationships. The deterministic nature of complementary materials results in a greater degree of complexity, since the selection of certain components in such a situation is forced and results from the relationships that exist between the components (e.g. certain materials force the use of specific binders in the right number).

After all, the complexity of the portfolio of products and services, including after-sales services (PPAC Product Portfolio Architectural Complexity) is the greater the greater is the variety of products and services that build this portfolio. Relationships occurring within the portfolio (packages, e.g. cake and coffee) are the results of the sales strategy (Binzberger, 1983). Product complexity translates into a number of product variants that results in a simultaneous increase in variants of final product components and an increase in the number of production processes (Closs et al., 2010).

The complexity of planning and controlling literature on the subject reduces to unintended complexity resulting from the lack of standards and integrated decision-making systems, as well as barriers within the enterprise, blocking access to good practices, e.g. to new product development schemes (Closs et al., 2008).

The structure of modern enterprises and the principles of functioning of individual cells are often limited to achieving stability and predictability, and removing all types of uncertainty. The complexity included in the latest competitiveness theory proposes new approaches to enterprise structures and processes. Based on the non-linear dynamics of systems, it can be concluded that contemporary value creation is not based on a hierarchical structure or central control. In terms of system theory, the condition for creating lasting value is adapting to constant changes, surprises and turbulence. Controlling complexity in a turbulent environment requires changing the perspective of analysis (from subject to relational) and taking into account the determinants of the dynamics of the phenomenon of complexity. The consequence of the above is the new management architecture.

The structural and dynamic cross-section of phenomenon of complexity

The multidisciplinary character of the phenomenon of complexity leads to a great number of notions of complexity reflected in the philosophical, physical, engineering and management as well as economical literature (Barkley, 1999; Gospodarek, 2012).

In-depth analyzes are carried out in numerous scientific fields. Multi-criteria analyzes of the above-mentioned phenomenon lead to inconsistent definitions:

- identifying complexity in terms of component numbers and non-linear interactions (Simon, 1962),
- reducing this definition to two dimensions: the number of elements and relationships (Casti, 1979),
- defining a structural complexity characterized by intricacy (e.g. machine park) and dynamic complexity, whose components are relations between many different system elements subject to change and feedback (Senge, 2012),
- listing three processes whose occurrence within the system allows the system to be considered complex. These are autoadaptation processes, non-linearity of relationships, and a multitude of paths of possible development over time (Gospodarek, 2012).

The dynamic nature of complexity is seldom the subject of research in economic and technical literature. Research in the literature on the subject concentrates on the complexity of the structure, i.e. its static form, where, in accordance with the mechanistic pattern, and thus linear dependency, the subject itself is examined, not the relationship dynamics and time, determinants of the dynamics of the notion of complexity.

The factors influencing the complexity, derived from the environment or the interior of the enterprise, affect the structural or dynamic cross-section of complexity, or partly a structural cross-section, partly dynamic. The literature on the subject differentiates determinants from the environment into those from the lower value chain and those from the upper value chain. Those from the lower value chain are e.g. the number of customers served, their diverse demand, short product life cycle. In turn, the number of suppliers, long delivery times, as well as low credibility of suppliers and poor reliability of deliveries as well as globalization of the supply chain are factors from the upper value chain. Determinants of internal origin are, in turn, e.g. the number of products and services offered on the market, the number of components from which the final product is built, short production series of certain product variants or disruptions in production plans (Bozarth et al., 2009).

The above-mentioned determinants of internal origin, which are increases in the options available on the market can only be indirectly related to the increase in individual customer orders. More often, the newly generated variants take the form of technological inventions, not quite finding coverage in the consumer demand reported. Sectors based on the latest technologies develop the latest solutions based on the dimension of technical inventions, and this rarely occurs in accordance with the dimension of real needs reported on the market. The driving force behind this process is the pursuit of competition or the passion of companies for technological inventions, and, unfortunately, a rare insightful analysis of the needs of customers (Lewanowska, 2009). Such activities have a direct impact on the increase in the complexity of the structure and its dynamic cross-section. R. Hoole concludes that enterprises place 1.7 new product types in place of one withdrawn product variant (Hoole, 2006). V. Krishnan, S. Gupta and K. Ramdas and M.S. Sawhney confirm that the factor that determines the increase in structural complexity is the growing number of diversified components and semi-finished products that negatively affects the company's operations (Bozarth et al., 2009; Gupta et al., 1996; Ramdas et al., 2001).

Such statistics pose a big challenge for enterprises in the area of increasing the complexity of the product and service portfolio. Poor control of such a process results in the loss of control over the increase in the product portfolio. What's more, the company's operational efficiency drops, along with its revenues (Jacobs et al., 2011).

T. Vollmann shows that another factor determining the increase in the complexity of the structure is the increase in the number of customers (Vollmann et al., 1997). After taking it into account, the level of customer service management and order management become less effective and directly affect the increase in the complexity of the structure and the dynamic cross-section of complexity. Moreover, according to T. Hill, J. McCreery and S. Edwards and C. Bozarth, such a situation causes disturbances in production processes and, as a consequence, decreases the efficiency of a company's production processes (Bozarth et al., 2009). Operational complexity, resulting from changes occurring outside the enterprise or in its subsystems, originates in the product and service line and spreads to all aspects of the operational activity of the enterprise. Solving problems, e.g. at the production and logistics stages, does not address the source of the problem, which is the product line. Only controlling complexity at the stage of creating innovation allows editing and simplifying the concepts of new products before complexity is permanently entered into costs and operating activities.

Simplifying the product portfolio cannot be at the expense of the customer. The company, implementing a policy of controlling the growth of the product portfolio, must find a balance point between the variety of the offer and the operational complexity. A point that will ensure greater efficiency of operational processes, will enable more profitable customer relations, improve quality and reduce costs (Lewandowska-Ciszek, 2010). P. Desai, S. Kekre, K. Srinivasan, as well as B. Meeker and M.H. Meyer and P.C. Mugge confirm by their research that additional variants of products and services generate profits provided that the complexity is effectively managed (Desai et al., 2001; Meeker et al., 2009; Meyer et al., 2001).

F. Salvador, in turn, notes the negative impact of the increase in the product portfolio on production activities. In managing such complexity, the CPFR (Collaborative Planning Forecasting and Replenishment) and ECR (Efficient Consumer Response) systems help in controlling the growth of new product variants. Effective product complexity management boils down to an effective choice of the threshold, above which the costs of generating new variants exceed the revenues from additionally introduced variants (Bozarth et al., 2009). F. Salvador outlines the need to constantly confront the benefits (profits) resulting from the increase in the number of product variants (increase in product complexity) with a possible decrease in operational efficiency (Salvador et al., 2002). This confrontation, according to M.L. Fisher with C.D. Ittner is difficult because the process of creating a product portfolio is a continuous process, created for many years in cooperation with many functional areas (Fisher, 1999). It is additionally complicated by a number of monitored, as well as unrecognized factors determining the decrease or increase in complexity (Closs et al., 2008).

According to V. Krishnan, S. Gupta, as well as K. Ramdas and M.S. Sawhney's, another factor strongly influencing the increase in the structure complexity and the process complexity is ever shorter product life cycle and the associated ever-increasing number of diverse spare parts, which due to the warranty framework must be in circulation and generally available (Gupta et al., 1996; Ramdas et al., 2001). In turn, high volatility in demand translates into dynamic complexity in supply chains. In this case, due to the complexity of coordination, the bullwhip effect may occur, which illustrates how small changes in end customer demand can generate huge fluctuations and disruptions in the areas of procurement of raw materials and semi-finished products (Bozarth et al., 2009).

T. Vollman further documents how, in the upper stream of values, the lack of reliability and credibility of suppliers, as well as their delivery time comprehensively affects material management by taking into account the longer planning times of the manufacturer, reserving larger warehouse areas with the manufacturer or blocking capital for larger supplier's production series (Vollmann, 1997). J. Cho and B. Kang argue that also globalization processes can affect the complexity of coordination as supply chains grow on a global scale (Cho et al., 2001). Import/export law fluctuations, currency market fluctuations, cultural differences, and uncertain delivery times may become factors that increase dynamic complexity.

Undoubtedly, studies on the complexity of structure dominate the literature. Only static product structure is analyzed, which fits perfectly into the company's technical subsystem. Developed analytical models support engineering sections of maintenance and production control.

However, the subsystems of the power and social enterprise are highly sensitive to the turbulence of the environment and require consideration of dynamic cross-section of research that is inherent in the phenomenon of complexity. In particular, in the face of the growing dynamics of changes in the environment and within the enterprise, the complexity of the process (dynamic complexity) is gaining importance. That is why it is so important to subject both static and process complexity tests.

The constituent elements of the enterprise and the relationships between them build a communication network, which consists of network nodes (enterprise elements, factors of the enterprise subsystems) and edges, which represent the exchange of information in both directions, constitute links between the nodes (Wadhawan, 2018). Thus, the specificity of complex systems abounding in interacting elements is revealed only at a certain scale of observation, when taken as a whole. It is only the holistic approach to the system that triggers nonlinear feedback. Those having the nature of positive, strengthen relationships or negative, weaken interactions and, as a result, silence them. The rich nature of the relationship is due to the fact that each element is influenced by many other elements (Tredinnick, 2009).

According to S.A. Kauffman, the key to obtaining optimal global solutions are the existing interdependencies within the system (Hundsens et al., 2006).

The latest patterns of relationship dynamics are based on generative interactions, i.e. those that arise based on the common goal of elements such as development and evolution. A deviation from the relationship dynamics pattern causes either stiffening of the enterprise or fragmentation of the system. Stiffening and, as a result, stagnation takes place in the case of an enterprise that is under the supervision of a strong centralized authority, and the elements within the organization do not differ from each other. In turn, the company breaks down when there are strong, independent elements under decentralized authority that reduce their number by significantly weakening relationships in the organization (Hundsens et al., 2006).

Therefore, to ensure the development of the individual in line with the latest patterns of relationship dynamics, it is necessary to ensure that under decentralized authorities, the elements that make up the organization are constantly interdependent, constantly interact with each other, and this is the key to maintaining the generative nature of interaction that integrates differences and increases the number of relationships within the company to date (Gault et al., 1996).

The process of creating generative relationships guarantees the company a wealth of forms, created on the basis of synergies of differences existing within an economic unit, in which the whole means something more than the sum of separated parts.

Relationships existing within an enterprise arise on the basis of formal or informal channels. Those created on the basis of informal channels are not fully identifiable, and thus, not fully understood. Here is born another factor conditioning the dynamics of complexity – uncertainty. The stability of information and passivity of the organization promotes the duplication of events, but thus excludes the evolution of enterprise cells and, as a consequence, the emergence of complexity, and the essence of all evolutionary models lies precisely in the non-linear nature of these models.

In a volatile environment, new business models highlight the nature of network size as well as the variety of the service portfolio, connection speed, effective and efficient communication and coordination schemes.

Relationship dynamics (non-linearity of interaction) involves building mechanisms of adjustment and self-organization. A sample of such processes is the corporation culture set up as an unintended outcome of the collective activities of company members (McKergow, 1996).

From the economic change perspective, the work focus on the inadequacy of the concept of complexity with a exclusively structural cross-section (Bozarth et al., 2009) and therefore it is proposed to involve the phenomenon of complexity of a more useful character in the context of business management rather than a structural assumption. Depicting dynamic complexity enables to perceive in this phenomenon the aspect of competitiveness of a modern corporation.

Target of the study and research hypotheses

The main goal of the hereby research paper was to recognize the dimensions of complexity and analyze the existence of the relationship between these dimensions in the industrial automation sector.

To attain these aims in the study, there was assumed the following main hypothesis:

With the rising function of dynamic cross-section of complexity there is increasing value of the relationship dimension for competitive advantage.

Methodology and testing procedures

The survey applies the following test methods:

- examination of domestic and foreign literature,
- surveys carried out among enterprises in the city of Poznan, hiring ten or more employees operating in the industrial automation sector, were preceded by a pilot survey.

The study adopted the following research tools:

- questionnaire survey sent electronically to the companies from the city of Poznan hiring ten or more employees tackling industrial automation; a questionnaire sent with a request to fill in and return by e-mail,
- Excel spreadsheet and the Statistica package (version 10), used to the analysis of the survey effects
- Fisher's exact test (Stanisz, 2007) which is a version of the test of independence χ^2.

Based on the examination of literature and interviews with experts in the field of industrial automation, complexity was involved in this study in four dimensions. The complexity of the structure consists of (Bozarth et al., 2009; McKergow, 1996; Barkley, 2010; Lewandowska-Ciszek, 2020):

- the number of elements,
- an array of items,
- the relationship between the elements,

and the dynamic complexity delivers:

- uncertainty derived from the unpredictability of the system and the links between the elements creating the system.

The questionnaire used in this study as a tool for measuring consisted of five blocks of survey questions. These were in turn:

- respondent's particulars (basic data about the company and the people filling the questionnaire),
- information indicating the complexity of the company as the number of system components,
- information indicating the complexity of the company as a variety of system components,
- information indicating the complexity of the company as the relationship between the elements of the system,
- information indicating the complexity of the enterprise as uncertainty.

Questions arranged in thematic blocks form a coherent, logical whole. They aimed to recognize the relationship between the identified dimensions of the complexity of the business on the example of the surveyed enterprises.

The questionnaire also contained closed questions, hereinafter referred to as categorical, single- or multiple-choice, including ready and in advance provided response packet, as well as semi-open questions, including, beyond the set of ready answers, space for free expression given by the respondent on the topic.

The most important test results

Four dimensions of complexity in the industrial automation sector in the study were reduced to:

- the complexity of the five (or less) identified processes in the industrial automation area (as the variety of elements),
- the overwhelming number of man-hours devoted to the execution of five (or less) identified processes in the industrial automation area (as the number of elements),
- relationships inside and outside of the enterprise (as the relationship between elements),
- the aspect of committing mistakes in audited organizations (the uncertainty).

The five identified processes which are attributed to the industrial automation field are as follows:

- preparation of the electrical drawings,
- building of electrical panels,
- software writing and software commissioning,
- start-up of equipment on plant,
- preparation of the offers on the above-specified activities.

In the study, there was used an independence test. Due to the applicability of the requirements of this test, as the basic research tool there was applied the variant thereof, i.e., the Fisher's exact test. It was determined by the small number (less than five) of cells in the constructed contingency tables. For the sequence of examined cases which were subjected to statistical verification, the significance level $\alpha = 0.05$ was used as the standard level of significance in the economic study and management.

The existence of dependency between variables, meaning thereby to reject the hypothesis of independence between the specified dimensions of complexity in favor of the alternative hypothesis confirming the relationship, decides the significance level $\alpha = 0.05$ the so-called p-value created by the program. P-value as the smallest significance level at which the tested hypothesis should be rejected, uniquely ensures to decide to reject or to apply the significance hypothesis. Therefore, it is permitted to resign from the administration of the test statistics in the description of verifiable issues.

Tables 2 and 3 list the information about the *p-value* for the sequence of analysed pairs of variables. Cells highlighted in grey represent the values of *p-value* which are smaller than the significance level $\alpha = 0.05$. They are characterized by the statistically significant relationship between the variables, which presents the respondents' opinions on information defining the complexity of the company as:

- the number of elements of the system,
- a variety of system components,
- relationships between elements of the system,
- uncertainty.

For cases for which there has been found a relationship (*p-value* $< \alpha = 0.05$) and which were indicated in grey, there were calculated *V-Cramer factors*, which take values in the range [0, 1], wherein:

Table 1
Question board

Question 5	In an enterprise preparation of the electrical drawings is on average: 1 – up to 1 month, 2 – from 1 month to 6 months, 3 – over 6 months.
Question 7	The company is dominated with programs (control software) written in time: 1 – up to 2 weeks, 2 – from 2 weeks to 2 months, 3 – over 2 months.
Question 9	The enterprise is dominated by start-up of equipment on plant: 1 – to 2 weeks, 2 – from 2 weeks to 2 month, 3 – over 2 months.
Question 13	Dominant type of electrical start-up i.e. start-up of equipment on plant: 1 – simple commissioning (generally known, common solutions), 2 – medium complicated startup (high repeatability), 3 – advanced startup.
Question 16	In situation when, according to the employee's evaluation, the offers are subject to a short date of completion of the order, the enterprise: 1 – undertakes the implementation of the order, despite the threat of delayed execution of the order, 2 – negotiations are undertaken, 3 – the order will not be carried out because of the threat of delay in completing the order.
Question 17	In the situation of understanding by the enterprise of threating factors: 1 – in order to avoid mistakes, he withdraws and does not take any action burdened with high uncertainty or risk, 2 – does not avoid errors and takes actions and monitors them in order to detect errors as quickly as possible at the lowest possible cost, 3 – ignores high risk and uncertainty, which often results in high costs and even losses.
Question 18	Errors caused by enterprise's actions: 1 – are hidden, 2 – they are not hidden, but they are not subject to analysis, 3 – are analyzed and new procedures and good practices are created.
Question 25	Enterprise employees: 1 – do not show interest in the nature of the work performed by colleagues 2 – do not know the nature of the work performed by colleagues 3 – on average they understand the sense of the work done by colleagues from the company 4 – perfectly understand the sense of work performed by colleagues from the company
Question 27	Are an informal links between employees in the enterprise who enhanced the formation of informal employee teams: 1 – no, they do not exist, employees communicate only by formal means with each other, 2 – yes, there are employee teams composed of specialists, 3 – yes, there are employee teams composed of specialists and managers from the same department, 4 – yes, there are employee teams composed of specialists and managers of various departments.
Question 28	Does company policy support team work: 1 – no, there is no team cooperation, there are only silo connections within marketing, accounting, etc., 2 – no, but strong, independent units with no communication need dominate, 3 – yes, works are carried out in employee teams, although the cooperation system still requires further improvement (e.g. within an inconsistent bonus system), 4 – yes, the work is carried out in employee teams – the cooperation system works correctly.

Table 2
P-value for the sequence of analysed pairs of variables

		Dimension 3: Information specifying the complexity of the company as the relationship between the elements		
		Question 25	Question 27	Question 28
Dimension 1: Information specifying the complexity of the company as the number of elements	Question 5	0.46304	**0.01698**	0.82484
	Question 7	**0.00376**	**0.02769**	0.49106
	Question 9	**0.00947**	0.19841	0.9107
Dimension 2: Information specifying the complexity of the company as variety of items	Question 13	**0.00236**	0.6746	0.65636
Dimension 4: Information specifying the complexity of the company as uncertainty	Question 16	**0.000995**	0.71993	0.064133
	Question 17	**0.001502**	0.58247	**0.020462**
	Question 18	**0.023708**	0.40086	**0.029044**

Table 3
V-Cramer factor for cases for which there have been found a relationship

		Dimension 3: Information specifying the complexity of the company as the relationship between the elements		
		Question 25	Question 27	Question 28
Dimension 1: Information specifying the complexity of the company as the number of elements	Question 5		0.45765	
	Question 7	0.56595	0.50553	
	Question 9	0.50145		
Dimension 2: Information specifying the complexity of the company as variety of items	Question 13	0.62353		
Dimension 4: Information specifying the complexity of the company as uncertainty	Question 16	0.69916		
	Question 17	0.75519		0.61163
	Question 18	0.50984		0.75066

- value in the range [0, 0.3] means weak relationship,
- value in the range [0.3, 0.6] means average dependence strength,
- value in the range [0.6, 1] means strong relationship.

Discussion and summary

On the basis of the preliminary research and literature studies there were attained the major cognitive outcomes of the research work which was conducted.

The action of complexity in the management of enterprises increases, nevertheless, the knowledge of this notion is highly insufficient. The adoption of this knowledge in practical functioning of enterprises generates too many objections.

Highly uncertain environment in which the company acts with high dynamics of change and the associated change in the conditions of competition exert impact on the growth of the complexity within the company.

In the study there were applied the feature definitions of complexity adequate to the research processes of these complex phenomena. Identification of the complexity within the redefinition of the notion involves not only a structural, but also dynamic cross-section. Furthermore, the essence is the result of the interaction between these four dimensions of complexity.

Identification of the complexity dimensions does not require to be reduced to the production enterprises. The research included the service sector.

There were analyzed the attitudes which are characteristic for organizations in the industrial automation sector, which handle the dilemmas of complexity.

The examination which was conducted, based on partial indicators, confirmed inter alia the value of relations as main conditions of success in the industrial automation area.

The Fisher P-value determined in the Fisher's exact test was lower than the assumed level of significance, which means that at the applied level of significance, the hypothesis stating the lack of dependency ought to be rejected in favor of the hypothesis declaring that there is the relationship between the relationship dimension of the complex system and the other three dimensions of the complexity, i.e., the number of elements, a variety of elements and uncertainty.

The value of the V-Cramer factor amounting 0.46–0.76 in the study can be assessed positively.

It is presented that in the statistical terms there is a moderate relationship between the specified dimensions of complexity.

The dimension of:

- the number of elements,
- a variety of items,
- uncertainty due to the unpredictability of the system

depend on

- relationship dimensions.

The strongest relationship in the sector of industrial automation (V-Cramer > 0.6) occurs between relationship dimension and the dimension of a variety of items. The key to generative relationships that contribute to new process properties, new behaviors and new relationships is the diversity of the elements between which the relationship arises.

The next strong relationship in the sector of industrial automation (V-Cramer > 0.6) occurs also between relationship dimensions and uncertainty. Self-organizing adaptation and emergence of behavior are the two major attributes of dynamic complex systems. The process of emerging can cause risks, but also opportunities. Nonetheless, not in every relationship there is the creative potential – the potential of emergence.

There is a mean relationship (value in the range $(0.3, 0.6]$) between the number of elements and the relationship dimensions.

The management of the complexity category such as the identification, evaluation and analysis conducted as a part of the company actions is mirrored in the enhanced competitiveness and in the quality of the complexity management.

The study concludes that in a volatile environment, there is the increasing importance of the relationship dimensions. It creates competitive advantage and is a main condition of success in forming the new type of the modern company strategy that occurs within complexity management in the industrial automation area.

Further research should concentrate particularly on other sectors of economy or developing further evaluation enabling to study the dimensions of complexity.

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