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Complexity of a modern enterprise and its flexibility in the sector of industrial automation

A. LEWANDOWSKA-CISZEK*

State University of Applied Sciences in Konin, Przyjaźni 1, 62-510 Konin, Poland

Abstract. The awareness of the growing importance of the complexity in creating a new type of a modern enterprise strategy and in introducing changes within planning, control and organizational structures contributed to undertaking studies on relationships occurring between the complexity of a modern enterprise and its flexibility in the sector of industrial automation, as well as filling the gap relating to the cognitive impact of poor complexity management on the flexibility of the company. The main objective of the research work is to check whether there is an important relationship between the complexity of the business and its flexibility in the industrial automation sector. Quantification of the relationship between these two quantities – the complexity and flexibility – happened by the use of the Multidimensional Correspondence Analysis (MCA) and Perceptual Maps. The study which has been carried out indicated that the flexibility and complexity functions in the enterprise management rise, however, the knowledge of these issues is highly insufficient. The research discovered that the obstacles which hamper striking a balance between the flexibility and complexity in their advanced stages exert a devastating impact on the quality of the process management. Reducing the flexibility at its higher levels generates a context in which the market risk is enhanced. Companies characterised by improper flexibility management bear higher workforce costs and their processes of decision-making last longer. Methodical and systematized study of flexibility and complexity will decrease the destructive influence of the interaction between these two categories.

Key words: industrial automation, measurement, complexity, flexibility, competitiveness.

1. Introduction

Changes in the formation mechanism of the sources of competitiveness are forcing companies into readiness to function in turbulent and unpredictable environment, that can be depicted as a VUCA world characterized by volatility, uncertainty, complexity, ambiguity [1–3]. The need to take into account the requirements of efficiency and competitiveness of the markets characterized by discontinuity and irregularity of events allows some companies to operate on the market only for a relatively short time, while other companies can get the benefits in the long term [4–5].

In the pursuit of growth, profits and market value – the key objectives of the company – companies are under constant pressure to show innovation in the field of market offers, launch new products and services resulting in the ubiquitous trend explosion of innovation [5]. Innovation, the driving force of growth, plays an increasingly important role. The consequence of this is the extension of the product and service line of the companies. The increase in the complexity of the environment results in a significant increase in the complexity of the company. Among the many aspects of the inherent complexity of the business, practices have confirmed uncontrolled growth of the portfolio of products and services, manufacturing methods and material factors of production. This results in a situation where the rate of production of new options of products and services is at odds with building transparent financial policy and with the awareness of the consequences of the system posed by even the smallest portfolio change of company products and services. In practice, the excessive growth of products and services range often leads to a decline in profits and increased costs of complexity management.

The latest concepts in management underline the importance of the complexity within the company, however, lack of control of this category makes the company work deteriorate and the costs they generate often reach record levels.

The risk associated with the growing complexity is therefore very high. However, the internal complexity can also bring major benefits. It can be measured not only in hazard categories, but also in terms of opportunity [6–9]. Reliable identification and measurement of the complexity of the company, consistent with the dynamics of the environment, influence today on the competitiveness of enterprises, especially in the face of a multitude of global factors boosting its complexity. The complexity which is properly monitored and controlled can be an important attribute of the competitiveness of the modern enterprise [1].

2. Literature review and the research gap

The awareness of the growing importance of the complexity in building new types of strategies, in the implementation of changes, in the planning, control and organizational structures, as well as observing the attitudes of managers to uncontrolled growth options of products and services, contributed to denoting the research problem [10–14].

*e-mail: lewandowska.anna@poczta.fm

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It created a need for studies on relationships occurring between the complexity of modern enterprise and its flexibility, as well as filling the gap on the cognitive impact of poor complexity management on the flexibility of the company.

The great number of complexity formulas presented in economic and technical literature undoubtedly originates from the multidisciplinary nature of the phenomenon of complexity [10, 15]. In numerous scientific areas, including philosophy, physics, engineering and management as well as economics, complexity is the subject of in-depth analysis [11]. The significant similarity between the domains in identifying and modelling the notion of complexity results in the transfer of certain concepts from one field to others [12]. The consequence of the above is the inconsistency of definitions and the multitude of approaches representing extreme world-views, i.e. mechanistic and evolutionary, as well as intermediate positions, placing the complexity between these two polar views.

In this paper, such definitions of complexity are presented, which from the perspective of fast economic changes are of the key importance for the study and practice of business management. In addition, the usefulness of some definitions of complexity, which involve only the static side of the phenomenon, i.e. structure, without taking into account the time parameter, is discussed. The aspect of dynamics, inextricably linked to the complexity, is rarely analysed in the economic and technical literature. And although the factors of development and evolution are inscribed in the phenomenon of complexity, research is mainly limited to the complexity of the structure, where – according to the mechanistic paradigm based on linear and deterministic dependencies – the object, i.e. its static structure, is usually analysed [16].

A significant part of the research on the prediction and control of complex systems is introduced to the theory of organization by R.D. Stacey [6, 7]. In turn, T.Y. Choi [8] transfers the Adaptive Complex Systems (CAS) model to identify logistics chains. The rules of adaptive complex systems are adopted by A. Suran [9] for the needs of the supply chain management research and improvement of their functioning. H.A. Simon [17] identifies complexity in terms of component numbers and non-linear interactions.

In view of the pace of economic changes, the work emphasizes the inadequacy of the definition of complexity with a purely structural cross-section [11] and therefore it proposes to include the phenomenon of complexity of a more useful nature in the context of business management rather than a structural approach. Showing dynamic complexity allows to see the attribute of competitiveness of a modern enterprise in this phenomenon.

Complexity in the concepts of achieving competitive advantage can be considered in the context of industry rivalry (complexity of the external situation), resource rivalry (internal complexity, with particular emphasis on the complexity of the employee team, material production factors, product and service portfolio), process rivalry (complexity of the internal situation with special consideration of the complexity of manufacturing methods) and strategic rivalry (complexity of the strategy and structure within the corporate management subsystem) [18].

Depending on the origin of the phenomenon the complexity formed inside the enterprise is referred to as internal complexity, in economic literature it is also called the complexity of the internal situation of the enterprise. It consists of the complexity of the employee team, the complexity of production methods, the complexity of material production factors and the portfolio of products and services. The literature also details the complexity of planning and control systems [11].

The environment, while influencing the company's activities, shapes the external complexity of the external situation. It results from a significant number of elements that should be included in strategic planning and their mutual relations [19]. Given the cross-section of the phenomenon which is examined, there are two types of complexity. The former refers to the structure and the latter refers to the behaviour of the system [13]. P.M. Senge defines them, respectively, as 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.

In the literature, the complexity of the structure is also interchangeably referred to as elementary or static and the complexity related to behaviour is dynamic or simply operational, functional or developmental.

The features of structural complexity are:

- the number of elements,
- variety of elements,
- relationships between elements.

For example, the complexity of the company's product structure consists of the number of production departments of the company.

Functional complexity refers to the process and can be characterized by:

- behavior dynamics in time,
- relationship dynamics,

in other words, its unpredictability in time. P.M. Senge depicts that the complex dynamics of actions causes specific local consequences and completely different ones in another part of the system [20].

H.A. Simon proposes a definition of a complex system as a system whose components are a large number of elements that remain in a complex relationship with each other [17]. J.L. Casti reduces this definition to two dimensions: the number of elements and relationships [21]. In turn, S. Vachon and R. Klassen, combining a structural and dynamic cross-section of the phenomenon of complexity, present a three-dimensional definition of complexity [22]. It consists of the number of elements, interaction between elements and uncertainty. Then researchers reduce these three dimensions to two: complexity and uncertainty.

T. Gospodarek lists 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 [15].

Complexity entails the uncertainty of dynamic cross-section [23]. The uncertainty results from the inability to predict changes in the environment and limited access to information on external conditions. Literature reduces the uncertainty to two dimen-

sions: simple – complex and stable – unstable. The first dimension refers to the diversity or number of elements and their differences from the corresponding elements that contribute to the enterprise's processes. The second dimension defines the dynamics of changes in the environment [24]. P.G. Benson defines the uncertainty as the degree of competition, the rate at which market demand changes, or the rate at which products or processes change [25]. S.B. Sitkin identifies three sources of uncertainty: project, product/process and the organisational uncertainty [26]. In turn, the research related to quality management suggest the following main sources of the uncertainty: changes in demand, changes in requirements and competitive pressure.

B. Wernerfelt and A. Karani present the uncertainty of the environment in four dimensions as the uncertainty of demand, the uncertainty of supply, the uncertainty of competition and the external uncertainty [27]. In turn, G. Dess and D. Beard define two factors important for entrepreneurs that shape the environmental uncertainty [28]. These are dynamics and complexity. At the same time, dynamics is defined as the pace and magnitude of changes occurring in the environment. Furthermore, sources of the uncertainty are seen in the multitude of suppliers and input materials as well as the multitude of products and consumers in the output.

Relationship dynamics (non-linearity of interaction) consists of creating mechanisms of adaptation and self-organization. An example of such processes is the enterprise culture created as an unintended result of the collective action of enterprise members [13]. R.L. Flood and E.R. Carson prove that the unpredictability of adaptive systems and its dynamic approach results, inter alia, from non-linearity and asymmetry of events [29]. The enterprise remains in an open configuration, i.e. it can exchange resources with the environment and its boundaries are blurred. The company and its elements are characterized by a desire to survive. Adaptation is only possible due to the system's response (interaction) to non-linear and dynamic feedback, and it can never be reduced to the functioning of isolated elements. Self-organizing adaptation and emergence of behaviour are the two main attributes of dynamic complex systems. The process of emerging can bring risks, but also opportunities. However, not all relationships carry the creative potential – the potential of emergence.

The key to generative relationships that lead to new process properties, new behaviours, and new relationships is the diversity of the elements between which the relationship arises [30]. In addition to diversity, a common goal, which unites despite existing differences, is also needed [14].

The dynamic dimension of complexity is rarely the subject of research in economic and technical literature. Research in the literature on the subject focuses on the complexity of the structure, i.e. its static form, where, in accordance with the mechanistic paradigm, and thus linear relationships, the subject itself is analysed, not the relationship dynamics and time, determinants of the dynamics of the phenomenon of complexity.

The introduction of the issues of the structure of system dynamics by J. Forrester to explain the functioning of the company, highlights new environmental attributes such as volatility, randomness, unpredictability and instability, which guarantee development and change [31]. The non-linear dynamics of systems presents that the efforts of many enterprises to remove any uncertainties in order to develop a state of stability and full predictability is possible only in an environment marked by the features of symmetry, additivity and linearity. Meanwhile, economic reality is a constant change in time, processes of constant transformation, constant 'becoming' or re-emerging and disappearing, a variety of behaviours over time, a constantly changing configuration of the system, constantly changing connections. The result of the above is the need for the enterprise to open up to changes and it includes a dynamic cross-section of complexity. Only by taking into account the determinants of the dynamics of complexity, i.e. thereby adapting the company to constant changes over time, can the enterprise build lasting value.

In the face of challenges facing managers and entrepreneurs nowadays, the tools used in management sciences, based on the mechanistic paradigm and reductionism, turn out to be insufficient and the mechanistic paradigm proves to be incomplete.

Reality in terms of nonlinear system dynamics is characterized by sensitivity to initial conditions [30]. With only a small change taking place in the system, there are huge deviations in the behaviour of the system. The cumulative result of non-linear actions of the components of the system results in more than the sum of their parts. This fact excludes the company from achieving full predictability and stability. Therefore, in terms of system theory, a necessary condition for value creation by a modern enterprise is its adaptation to turbulence and the continuous process of 'becoming'. This, in turn, involves changing the perspective of planning, analysis and control from objective to relational and taking into account the main determinants of the dynamics of the phenomenon of complexity. Such an action allows the company to avoid stagnation and contribute to development.

Showing above the inadequacy of defining complexity formulas solely based on the structural dimension, below I present the definition of complexity which takes into account the structural and dynamic dimensions, with a more useful character in the context of enterprise management research, because it is more suited to the dynamics of changes in the environment and the enterprise itself. To reach the dynamic dimension of complexity, materials from the Santa Fe Institute have been used. Within the Institute, W.B. Arthur, S.N. Durlauf and D. Lane have developed six complexity attributes that can be used to define complexity. They are as follows:

- the existence of relationships between various agents that primarily interact locally with each other in various ways,
- lack of a central supervisor who potentially has access to the best solutions or could potentially recommend the best relationships,
- functioning of the enterprise on the principles of a matrix structure with many additional dependencies,
- the possibility of continuous adaptation due to the education and development process,
- the emergence of continuous innovations in the technological, behavioural and institutional sphere,
- company dynamics towards a point distant from equilibrium, with the option of multiple equilibrium points or no equilibrium point.

This type of complexity strongly linked to research at the Santa Fe Institute focuses on complex adaptive, learning and developing systems through the use of acquired information. These are systems that distinguish randomness from regularity.

The concepts developed within cybernetics (N. Wiener) and systems theory (Bertalanffy, J. Forrester) contributed to the definition of the self-organization process and the emergence of advanced structures in isolation from lower-order structures. As part of the chaos theory, the butterfly effect trend was created, which brought high unpredictability and randomness of events to the economy, and in consequence, undermined the rationality of expectations [10]. Even simple economic models characterized by high dynamics of behaviour of economic entities are equipped with a higher degree of complexity in comparison with models from the areas of exact sciences (physics) or biology, because it is the richness of dynamics of social behaviour that is seen as a fundamental source of complexity. The above-mentioned approaches to complexity outline the dynamic perspective of the complexity phenomenon analysis.

The literature on the subject presents various formulas for defining enterprise flexibility. Their diversity and different interpretations result from the complex and multidimensional nature of this phenomenon. The analysis of the definition of flexibility presented in the work of S. Kasiewicz, J. Ormiańska, W. Rogowski, W. Urban presents four sections of flexibility. They concern: the reasons for flexibility, the essence of flexibility, scope and additional conditions. The analysis shows that the causes of flexibility are seen in the environment or the market. Its essence was defined from the perspective of the ability to react, introduce changes or adapt the enterprise to changing conditions. From the scope of impact point of view, three impact objects have been defined. To achieve the desired level of flexibility, the company influences the system, the resources or products it consumes. The fourth section presents additional conditions helpful in forming the definition of flexibility. These are e.g. time, quality, cost/efficiency.

The variety of definitions results from different approaches that ignore the additional conditions [32]. The essence of flexibility as the ability to react as well as introduce changes and adapt to changes in the environment is included in the definition of J. Hyun and B. Ahn [33]. For the purposes of the study, a definition of flexibility was adopted that matches the profile of enterprises from the industrial automation sector subjected to the study. Although the type of business activity dominates in the industrial automation sector, the modern enterprise, due to the specificity of the industrial automation sector, carries out services, production and commercial profiles. In addition, the definition of flexibility following S. Kasiewicz [32] and R. Krupski [19] is consistent with the definition of complexity adopted in the study. The analysed categories of flexibility and complexity present such an approach that allows them to be combined and to examine the relationships between them based on the industrial automation sector.

So far, there are few studies which take into account the dynamic aspect of the complexity in defining the phenomenon. Moreover, no studies were devoted to the complexity in companies with a dominant portfolio of services. There is also the problem of quantification of multidimensional complexity addressing the dynamic and structural cross-section. These problems require extensive examination, which was the subject of this research.

3. Aim of the study and research hypotheses

The main objective of the research work was to check whether there is an important relationship between the complexity of the business and its flexibility in the industrial automation sector.

To achieve these objectives in the study, the following major hypothesis was assumed:

With the increasing complexity there is growing importance of flexibility management for competitive advantage.

4. Methodology and testing procedures

The survey uses the following test methods:

- analysis of domestic and foreign literature,
- surveys conducted among companies in the city of Poznan, employing ten or more workers dealing with industrial automation, which were preceded by a pilot survey,
- Multidimensional Correspondence Analysis.

The study used the following research tools:

- questionnaire survey sent electronically to the businesses from the city of Poznan employing ten or more workers dealing with industrial automation; a questionnaire sent with a request to complete and return by e-mail,
- Excel spreadsheet and the Statistica package (version 10), applied to the analysis of the survey results and preparation of Perceptual Maps in the two-dimensional coordinate system,
- Fisher's exact test [34] which is a variant of the test of independence χ^2.
- Perceptual Maps created by using the Multidimensional Correspondence Analysis in order to grasp the relationship between the respective variants of analysed features.

Quantification of the relationship between two quantities – the complexity and flexibility happened by the use of Multidimensional Correspondence Analysis and Perceptual Maps.

The choice of Multidimensional Correspondence Analysis used was justified by the:

- multidimensional character of the analysed categories of complexity and flexibility,
- possibility of reducing the multi-dimensional nature on the low-dimensional Cartesian space,
- character of the studies designed to identify and analyse the relationship between two variables,
- qualitative nature of the variables,
- possibility of a relatively simple and intuitive reasoning about the relationship between categories.

Based on the analysis of literature and interviews with experts in the sector of industrial automation in the study of the relationship between complexity and flexibility, partial measures were adopted. The complexity was included in this study

in four dimensions. The complexity of the structure comprises [11–13]:

- the number of elements,
- the variety of items,
- the relationship between the elements,
- and the dynamic complexity provides:
- uncertainty due to the unpredictability of the system and the links between the elements forming the system.

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

- the complexity of the five (or less) defined processes in the industrial automation sector (as a variety of elements),
- the overwhelming number of man-hours devoted to the completion of five (or less) defined processes in the industrial automation sector (as the number of elements),
- relationships between the surveyed companies with investors, subcontractors (as a relationship between elements),
- aspect of making mistakes in audited companies (the uncertainty).

The five defined processes which are attributed to the industrial automation sector are as follows:

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

Flexibility manifested as the ability of reaction (in terms of reactive, inertial and anticipation flexibility) or creative ability (in terms of creative flexibility) is determined by partial measurement which verify the [34, 35]:

- disposal and use of flexible technologies by the company,
- use of modular design systems by the company,
- delay during the operation differentiating within the executed business processes,
- intensification of communication among employees of the company (as the degree of understanding of the nature of the work performed by workmates, as the co-existence of informal relations conducive to the emergence of informal work teams, as supporting collaboration within the framework of the policy business, as strengthening relations within the company as part of the company).

Because of the formulated test area, as well as the nature of the population studied, this study used an indirect technique of statistical observation. Statistical observation, called in this survey as the work measurement, by using a measurement tool, which is a questionnaire, allowed to acquire the necessary information for the study. Mail survey allowed the respondents to respond at any time and at any pace. The possibility of long self-reflection in any individually specified period of time in the study of the population was the overriding criterion for selecting measurement techniques and the survey resulted directly in the low rate of refusal to participate in the study.

In the study, an independence test χ^2 was used. Due to the applicability of the requirements of this test, as a basic research tool there was used a variant thereof, i.e. Fisher's exact test [34]. It was conditioned by the small number (less than five) of cells in the constructed contingency tables. For the sequence of analysed cases which were subjected to statistical verification, the significance level $\alpha = 0.05$ was adopted as the standard level of significance in economic research and management.

The existence of dependency between the two studied features, meaning thereby rejection of the hypothesis of independence between the complexity of the business and its flexibility in favour of the alternative hypothesis confirming a relationship, decides the significance level $\alpha = 0.05$ the so-called *p-value* generated by the program. *P-value* as the smallest significance level at which the tested hypothesis ought to be rejected, uniquely enables to decide to reject or to adopt the significance hypothesis. Therefore it is allowed to resign from the administration of the test statistics χ^2 in the description of verifiable issues.

5. The characteristics of the research sample

The analyzed population is a finite group with the number of one hundred and sixty enterprises from the city of Poznan, employing ten and more employees, and covering the sector of industrial automation. In this study the sector of industrial automation has been defined on the basis of eight codes taken from the Code List of Classification of Business Activities in Poland specifying the profile of business enterprises.

These are successively:

- Manufacture of electricity distribution and control apparatus,
- Repair and maintenance of machinery,
- Installation of industrial machinery and equipment and outfit,
- Works related to construction of transmission pipelines and distribution networks,
- Works related to construction of telecommunications and electricity lines,
- Computer programming activities,
- Computer consultancy activities,
- Other information technology and computer service activities.

The sampling method used in the present study is targeted. In this paper, it was decided on purposeful selection, as the assumption of the research is to analyze the relationship between complexity and flexibility in the area of service activities.

What is more, the sector under study is a deeply diversified sector. This allows careful and thorough identification of the relationship between complexity and flexibility. The surveyed enterprises are characterized by a diversified level of enterprise complexity while taking into account the low, medium and high level of flexibility at the same time. In the industrial automation sector, there are widespread tools increasing the flexibility of the company, for example, modular designed systems and Information Technologies that support the course of processes, which is visible in the quality of an attempt to measure the relationship between the complexity and flexibility of enterprises.

In the purposeful selection, the technique of quota sampling was applied. Quota sampling is recognized in the literature as the most mature technique of non-random sampling, because it

provides not only representativeness of the sample due to distinguished variables included in the score sheet, but also, based on the experience of the person conducting the research, allows to use the knowledge and information about the surveyed group possessed a priori. The technique of quota sampling does not specify how to select the units representing individual subpopulations of the entire population, it only emphasizes the essence of the appropriateness of the sample structure.

In summary, the study retains the representativeness of the target sample due to the two accepted control characteristics, i.e. the size of employment and the dominant type of business activity.

The study, in accordance with the non-probabilistic sampling technique, assumes defining the characteristics of the entire population, and then selecting the groups in the sample that reflects the structure of the entire population determined on the basis of the specified characteristics. The number of units in the sample representing individual groups in the population reflects the structure of particular subpopulations in the entire population.

The quota sampling in this study was constructed on the basis of the two following control characteristics:

- employment in a group of enterprises employing ten or more employees, divided into: a small enterprise employing from ten to forty-nine employees; a medium enterprise employing from fifty to two hundred and forty-nine employees; a large enterprise employing over two hundred and forty-nine employees,
- the dominant type of business activity with the division into: production activity, commercial activities, service activity.

6. The most important test results

The conducted research allowed formulation of a number of conclusions. To start with, three tools for increasing flexibility in an enterprise show connections with various dimensions of complexity. These are:

- disposal and use of the flexible Information and Communication Technologies by the company,
- the use of modular design systems by an enterprise,
- increasing communication between employees of the company (as the degree of understanding of the nature of the work performed by workmates, as the co-existence of informal relations conducive to the emergence of informal work teams, as supporting collaboration within the framework of the policy business, as strengthening relations within the company as part of the company).

With low complexity (expressed in quantitative dimension), enterprises do not show the need to use flexible information technologies, even in spite of having them. The lack of flexibility of such enterprises is additionally expressed by the lack of interest in the nature of the work performed by colleagues and the tendency to hide mistakes made during the implementation of projects. Such enterprises either ignore high risk and uncertainty, which often causes loss or does not undertake high-risk task. The analysis is different in relation to modular design systems, which are widespread even on the level of low complexity of the project. Similarly, with low complexity, an exceptionally high flexibility was observed, manifested by the formation of employee teams based on informal relations between the employees of the company. This pro-development attitude is highly recommended in the dynamic sector of industrial automation.

Along with the increased complexity of enterprises expressed in more man hours for a given project, enterprises confirm the possession and use of information technology. Similarly, in the case of the increasing complexity of the undertaken enterprises and the greater demand for man hours allocated for the preparation of technical documentation and creating a control program, enterprises declare the use of modular design systems. Along with the increase in complexity, the importance of informal connections in the enterprise as well as the awareness of the work carried out by co-workers is also growing.

The conducted analyzes show that with the increase of complexity expressed in uncertainty, the employees of the enterprise retain a rational attitude: they show high awareness of work done by colleagues, do not hide mistakes and take actions to detect errors as quickly as possible at the lowest possible costs, analyze mistakes to develop good practices and use flexible Information Technologies. At the same time, the company supports team work and the process of continuous improvement of the existing cooperation system.

Among the surveyed enterprises, some declare that the limitation of the use of information technology affects such areas as the increase of quantitative complexity, the inability to analyze errors and the access to a more accurate information flow, which consequently negatively affects the following process parameters: time, quality and cost. Lack of synchronization between complexity and flexibility reduces the quality of the process. The growing complexity in this case does not harmonize with the growing demand for the use of tools to increase flexibility.

Similarly with regard to modular design systems, companies declare the use of modular solutions rarely in highly complex projects of an innovative nature. This is an undesirable relationship. Probably it results from the erroneous belief that standardization destructively affects creative and innovative solutions. Lack of awareness of the consequences of 'temporary' innovative solutions, not showing consistency with applicable modular design systems, adversely affects the basic factors of competition, such as cost, time and quality. Similarly, the innovative and advanced high complexity commissioning conducted by enterprises is accompanied by a low level of understanding of the work done by colleagues and the lack of interest in these tasks. This approach, limiting the mechanisms of enterprise flexibility, slows down the team's dynamics and reduces the potential for generative relations.

The analyzes also indicate a group of enterprises characterized by high flexibility on one hand, and the reluctance to conduct activities burdened with any uncertainty on the other.. Enterprises, limiting the increase of complexity with dynamic cross-section (dimension: uncertainty) reduce the pace of the dynamics of the company's relations.

7. Presentation of the results of the relationship between flexibility and complexity using the map of perception

The main purpose of the application of multidimensional data analysis technique, so called Correspondence Analysis, is to examine the coexistence of variables and to capture the relationships between the respective variants of the analyzed features. The results provide a graphical presentation of the results in the form of Perceptual Maps in a two-dimensional coordinate system. When analyzing the graphical presentation of variants of the analyzed features, the position of the points in relation to other points representing variants (categories) of the same feature and location of the point in relation to the points representing the variants (categories) of the other feature are taken into account. The close location of points representing variants of the same feature means that their profiles are similar.

In turn, analysis of the distance between points representing variants of different features allows to give an answer as to whether there is a relationship between variants of different features, or whether there is no such relationship. The close position of points indicates the existence of such a dependence, and the disjoint occurrence of points presenting variants of various features means no dependence.

The research conducted on the target group allows to examine the relationship between the complexity expressed in four dimensions (number of elements, variety of elements, relations between elements, uncertainty) and flexibility. The mapping of these two features (complexity, flexibility) along with their variants (low, medium, high) in a two-dimensional space allows to verify the existence of a dependency or lack thereof based on the distances between points representing variants of these two features.

Between complexity and flexibility there is proved the statistically significant dependency. The Fisher P-value determined in the Fisher's exact test was 0.01 and is lower than the assumed level of significance, which means that at the adopted level of significance, the hypothesis about the lack of dependency should be rejected in favor of the hypothesis stating that there is a relationship between complexity and flexibility. This is a moderate relationship, as evidenced by the value of the V-Cramer coefficient of 0.49. The map of perception obtained with the use of Correspondence Analysis confirms the existence of the relationship between flexibility and complexity.

The enterprises surveyed declare low flexibility of the enterprise with low enterprise complexity, while with medium enterprise complexity, employees declare high flexibility. In turn, high complexity means medium flexibility.

Highly unpredictable environment in which the enterprise operates with high dynamics of change and the associated change in the conditions of competition affects the growth of the complexity inside the company. Even if the increase or reduction of the inherent complexity of the company belong to the planned activities of the company, there are many external factors determining the dynamics of complexity, for example, the dynamics of technological change for industrial automation. Studies have shown that with a high level of complexity, flexibility decreases to the average level. The main barrier to further

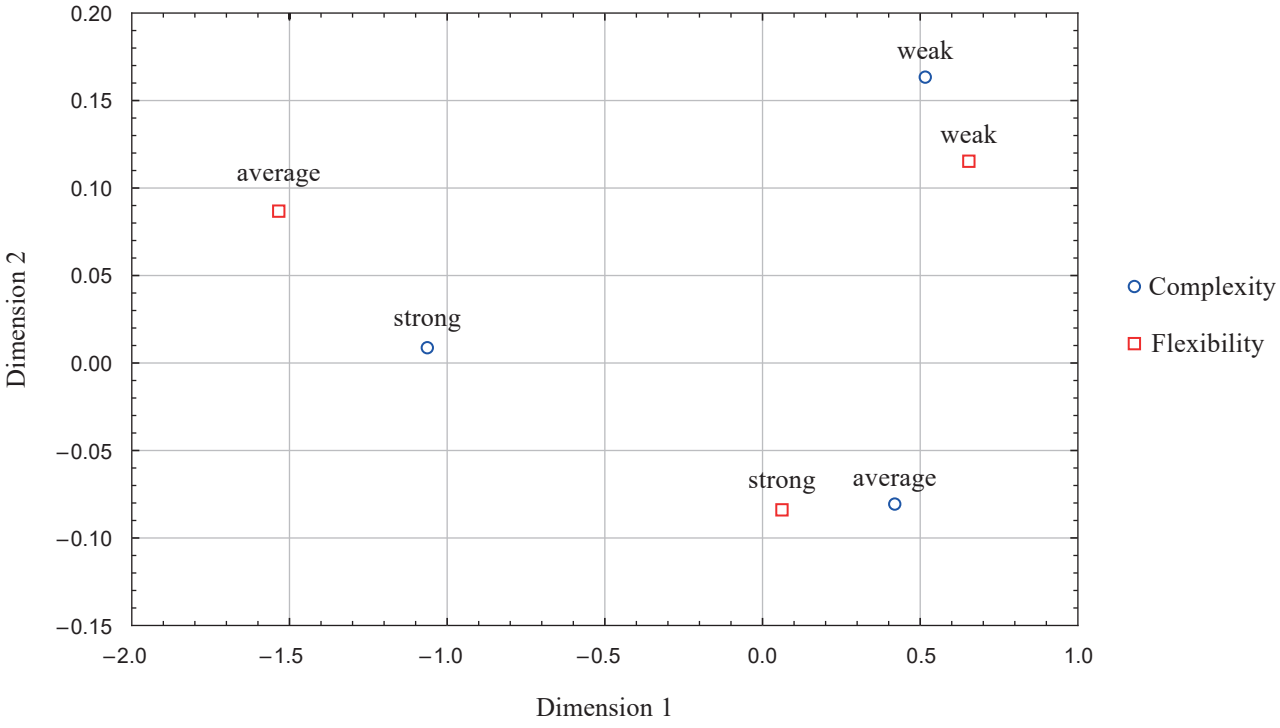

Fig. 1. Perceptual Maps created by using the Multidimensional Correspondence Analysis

increase of the flexibility is the poor management of the complexity or its complete ignorance in the process of management.

The graphic representation of the results confirms that the importance of managing flexibility increases with increasing complexity. Obtaining a competitive advantage in periods of discontinuity underlines the importance of remaining flexible in the rivalry on the market. The perception map shows that with an average level of complexity, a high level of flexibility can be maintained. However, a further increase in the internal complexity of the company results in a decrease in its flexibility. Therefore, flexibility cannot be limited by the determinants of the complexity growth in the enterprise. To improve the competitiveness of the company, it turns out to be necessary to include complexity in management and to synchronize it with flexibility. Such a rational attitude is taken by enterprises that do not ignore the complexity issues in management, thanks to which they do not incur additional costs and take full advantage of the company's developmental potential.

8. Hypothetical scenarios of companies' attitudes towards balancing the effects of complexity and flexibility

Critical analysis of literature sources and deductive considerations carried out so far allow to formulate the following conclusions:

- Due to the growing dynamics of changes in the environment of irregular and discontinuous nature, there are changes in the conditions of competition.
- The importance of managing flexibility is increasing as a response of enterprises to the uncertainty inherent in the dynamics of change.
- The unpredictability of events implies an increase in enterprise internal complexity.
- Disregarding the issue of complexity in the operation of enterprises adversely affects the actions taken by the enterprise.

Complexity and flexibility management conducted as a process within the company is mirrored in the competitiveness enhancement. The most vital factor is the interaction between these two notions.

It is reflected by the increasing value of this interaction in generating new kinds of strategies, in the alteration implementation, in the planning, control and organizational structures.

Four hypothetical scenarios are presented below. They depict different attitudes of four groups of enterprises towards balancing the effects of complexity and flexibility. They have been supplemented by the determination of the intensity of the studied variables in successively defined areas. The defined areas representing the attitudes of enterprises towards balancing the effects of complexity and flexibility are enumerated in the following order:

- conservative attitude,
- overactive attitude,
- pro-development attitude,
- rational attitude.

The conservative attitude is presented by enterprises whose environment and internal organizational structures, as well as processes, are characterized by low or medium intensity of complexity, with the same, i.e. low or medium degree of enterprise flexibility. Enterprises from this group are usually characterized by overproduction, stagnation and a central system of controlling departments as well as organizational units. Efficiency is defined in such enterprises in terms of performance. The hierarchical network of connections results in preference for silo connections characterized by minimal inter-departmental information flows.

Enterprises with an overactive attitude are characterized by medium to high levels of complexity with low or medium levels of flexibility. As a result of the weaknesses in the management of complexity and flexibility, the company's development prospects may stagnate.

Enterprises with high growth potential adopt a pro-development attitude. A non-linear, non-hierarchical network of connections with high intensity, under the influence of decentralized power, triggers constructive dynamics of connections. Such enterprises have a high or medium level of flexibility, with low or medium complexity. Such a high level of flexibility in a pro-development attitude is gaining importance in a particularly turbulent environment and prejudges a high degree of openness to emerging activities or opportunities. The area of opportunity can be defined by restrictions imposed on flexibility mechanisms (diversification of activities and resources, redundancy of resources, monitoring of the environment, decision making, 'organization in motion'). Enterprises with a pro-development attitude are characterized by a high degree of identification and use of opportunities or a set of simple rules as the main strategic categories of the enterprise. Enterprises with a pro-development attitude, on one hand, take advantage of opportunities (created inside and outside the enterprise), on the other build redundancy of resources that enables the exploitation of opportunities.

In addition to a pro-development attitude, enterprises adopting a rational attitude have a high or medium degree of flexibility. Such a high (also medium) level of flexibility plays a huge role in the turbulent environment and determines the competitiveness of the company. Enterprises with a rational attitude, in contrast to enterprises with a pro-development attitude, are additionally characterized by a high or medium level of internal complexity and the complexity of the environment.

9. Discussion and Conclusions

On the basis of the primary research, and literature studies key cognitive results of the research work which was carried out were achieved.

The role of flexibility and complexity in the management of enterprises increases, however, the knowledge of this issue is highly insufficient. The use of this knowledge in practical functioning of enterprises raises too many objections. On one hand, enterprises recognize that flexibility is the condition of contemporary competitiveness. This was confirmed by 70% of

the companies surveyed, which were characterized by the high or medium intensity of flexibility. On the other hand, in a large group of companies, there is poor management of complexity or its total ignorance, which limits the flexibility on its higher levels and thus interferes with the compatibility of the flexibility and complexity category. The survey found that the barriers to strike a balance between the flexibility and complexity at their higher levels influence destructively the quality of the process management. It was manifested in the increase in the cost of waste (as the costs of correcting mistakes and delays, costs of waiting, costs of additional working overtime, as well as costs of implementing a bigger number of 'temporary' solutions), and in the increased costs of poor customer service and in the increased lead time of orders. Limiting the flexibility at its higher levels results in a situation in which the market risk is increased. Enterprises with poor flexibility management incur higher labor costs and their decision-making processes extend over time.

The paper adopted the feature definitions of flexibility and complexity adequate to the research processes of these complex phenomena. Identification of the complexity within the redefinition of the concept includes not only a structural, but also a dynamic cross-section.

Identification and measurement of the complexity do not need to be limited to the manufacturing companies. The study involved the service sector.

The attitudes which are characteristic for companies with industrial automation, which deal with the problems of complexity and flexibility were examined. Among the companies tested, dominated the companies presenting pro-growth or reasonable features (70%). Such a large number of companies that have a high or medium level of flexibility, confirms its strategic importance. For companies in the industrial automation, which are based on technological innovation, such a large number of companies presenting high and medium level of flexibility has a positive impact on their competitiveness. For the remaining 30% of the companies presenting a conservative or overactive features, there was found the existence of impediments to strike a balance between the complexity of the company and its flexibility. The factors disturbing the synchronisation of flexibility and complexity, exert a destructive impact on the quality of the process management. The evidence of this situation can be the poor measurement of the process management (time, quality, cost, innovation), which results in lower level of competitiveness in this group of companies. With regard to industrial automation full synchronization of medium or high complexity is required, which results from the nature of the sector, with a correspondingly high or medium level of flexibility in the company. Therefore, in this sector there are recommended the pro-development and rational features, due to the high complexity of the environment in which these companies operate. The high complexity of the environment is due to the specific nature of this sector, which is based on technological innovation.

In the study there were developed the Perceptual Maps allowing to analyse the relationships between different dimensions of complexity and flexibility by the use of the Multidimensional Correspondence Analysis (MCA). The adopted method allows, on the basis of partial indicators, to capture the multidimensionality features of complexity and flexibility.

The analysis which was carried out, based on partial indicators, confirmed inter alia the importance of technological factors as key conditions of success in the industrial automation sector. The response of companies tested for uncertainty inscribed in the dynamics of change, is the growing importance of effective tools making a company flexible. The particular importance from the point of view of the analysis of the relationship between the complexity of the business and its flexibility in the industrial automation sector have flexible Information and Communication Technologies. Increasing the flexibility of the company and the elimination of restrictions which have the balancing effects on the complexity and flexibility of enterprises by the use of Information and Communication Technology is the response to the constantly growing list of conditions determining the growth in complexity not only in production systems, but also in the service sectors both in terms of operational, structural and strategic flexibility [18].

The final part of the paper presents that in the statistical terms there is a moderate relationship between flexibility and complexity. The value of the *V-Cramer factor* amounting to 0.49 in the study, can be evaluated positively. It means that the management of the complexity and flexibility category such as the identification, measurement and analysis carried out as a part of the company activities is reflected in the increased competitiveness. Moreover, the key is the effect of the interaction of these two categories. Systematic study of the flexibility and complexity, their measurement and analyses will reduce the devastating impact of the interaction of these two categories. Moderate relationship shows that the level of destruction resulting from the poor complexity and flexibility category management has not yet reached such a level, which would prevent the introduction of corrective actions.

Further research should focus specifically on other sectors. They could cover the sectors of manufacturing or other service sectors. An interesting task would be to verify the scientific hypotheses adopted by using other measurement tools.

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