National University of Science and Technology POLITEHNICA Bucharest

Doctoral School of Industrial Engineering and Robotics

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DOCTORAL THESIS – SUMMARY

Analysis and evaluation method for economic organisations in the context of their evolution towards Industry 4.0

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CHAPTER 1. INTRODUCTION

1.1. Research context

The current dynamics of economic and technological phenomena, globalization, and the pandemic have created challenges regarding the continuous adaptation of organizations to rapidly unfolding events and changing paradigms. Contemporary market demands are closely tied to the rapid changes in technologies, the way products are purchased, the provision of services, and ultimately, globalization. These aspects exert significant pressure on business models and personnel policies, constantly questioning their effectiveness. Assessing efficiency requires the use of diagnostic models or frameworks that provide valuable and relevant information about the organization. From the accumulation of experiences and their analysis, as well as the elements that generate them, specific patterns and models can be identified. The use of these models is not a new practice; however, they are becoming increasingly necessary in the aforementioned context, being adapted to the current moment. Utilizing such models facilitates diagnosing an organization. The emergence of Industry 4.0 has necessitated the creation of tools for their evaluation. The vast majority of models and evaluation tools developed for Industry 4.0 enterprises are designed to determine maturity, readiness for the transition to Industry 4.0, or the level of digitization of the organization. There is an interest in studying the organizational impact of business transformation, preparing people within organizations, and the relationships established within such organizations. This paper proposes a dedicated analysis and evaluation model that, in the context of Industry 4.0, can provide an organizational perspective for these enterprises.
Regenerate

1.2. Importance and scientific relevance of the topic

The transition to Industry 4.0 has brought about the need to assess the status of enterprises in terms of technological maturity, the level of organizational readiness for the transition to Industry 4.0, and implicitly, change management. The need for understanding and analysis has led to the creation of several tools for evaluating enterprises in the context of Industry 4.0, but up to now, there hasn't been a dedicated organizational diagnostic model or tool. We can evaluate the readiness for transitioning to Industry 4.0, the level of maturity, the degree of technological advancement, and digitization. However, we lack a unified organizational approach and cannot analyze the relationships established between the elements of the model.

The hypothesis that technology is a neutral factor that only brings benefits to all parties involved cannot be supported in all cases. This paper aims, among other things, to find answers and solutions to this situation by creating a method for organizational evaluation and analysis in the context of 4.0. This involves finding a way to create a suitable organizational model, an analysis tool that takes these aspects into account, and validating it by using it on as many diverse organizations as possible.

Obtaining a valid model, a valid tool, essentially obtaining the method, allows us to propose a specific analysis and evaluation tool for 4.0 enterprises. To achieve this, we need to identify an analysis and evaluation tool for a company's performance, starting from the general characteristics of an organization. To describe the functionality of this tool, the paper presents

the initial testing of the tool on several companies: 11 real companies, one of which represents a group of companies containing two of the other 10, and the virtual model of a 4.0-type company.

To do this, the starting point is the study of existing organizational models, the elements they contain, and the relationships established between elements. These research efforts aimed to reveal the existence of relationships between elements as determinants. This determination of elements follows a cycle, referred to as the determination cycle. At the same time, we also studied the nature of certain factors - defined by us - of complementarity specific to the characteristics of the elements of the organizational model. These complementarity factors can describe an organization by quantifying the balance/health state of a company. The diagnosis of a company's health state will result from the balance between complementarity factors that describe that organization, which we will describe in detail in the following chapters of this paper. The obtained results consist of:

- Obtaining an organizational model that considers the transition of the industry to 4.0.
- Obtaining a model for analysis and evaluation for any type of organization - validated by using it on a number of enterprises and other types of organizations.
- Proposing an analysis and evaluation tool for 4.0 enterprises.

1.3. Research objectves

The main objective of the doctoral thesis is to conceive and develop a performance analysis tool for organizations in the context of their evolution towards the 4.0 revolution. To achieve the main objective, several specific objectives have emerged. These objectives form the basis of the structure of this thesis:

Objective 1: Researching the most commonly used organizational diagnostic models.
Objective 2: Identifying the most frequently encountered elements underlying a diagnostic model and the relationships established between these elements.
Objective 3: Establishing the organizational model

3.1 - Establishing the elements of the proposed model and the relationships between them.
3.2 - Identifying the characteristics of the elements of the proposed organizational model.
3.3 - Establishing the factors that describe these characteristics.

Objective 4: Designing an analysis and evaluation tool based on the established diagnostic model.
Objective 5: Developing the analysis tool based on the created model.
Objective 6: Testing and evaluating the specific tool for the 4.0 enterprise.

1.4. Thesis structure

The doctoral thesis is structured into 6 chapters. The first two chapters present the concepts underlying the diagnostic model and the proposed analysis tool.

In Chapter 1, the research context, importance, and scientific relevance of the topic are presented. The research objectives and the structure of the thesis are also outlined.

Chapter 2 defines the concepts used in organizational diagnosis. Representative models used in diagnosis are presented, including:

- Lewin's Force Field Model
- Leavitt's Model
- Likert's System Analysis

- Weisbord's Model
- Nadler-Tushman Congruence Model
- McKinsey Model
- Gailbraith Model
- Tichy Model
- Nelson & Burns Model
- Harrison's Diagnostic Model
- Burke-Litwin Model of Performance and Change
- Falleta Model

These models are analyzed, identifying common elements and the types of relationships established between the elements of each model. Industry 4.0 is defined in this chapter, presenting its characteristics and evaluation methods. Conclusions regarding organizational diagnosis in Industry 4.0 are also discussed here.

Chapter 3 presents the directions, main objective, and methodology for developing the proposed model in this work.

In Chapter 4, the diagnostic model is presented, and the tool for analyzing organizations based on this model is introduced. The constitutive elements of the model, model characteristics, and complementarity factors describing the characteristics are presented here. The principle of determination, a defining relationship for the elements of the proposed model, is discussed. The analysis tool resulting from the model is presented, utilizing the Likert scale.

Chapter 5 of the work contains the testing and validation of the proposed analysis tool. General considerations, 11 case studies with observations and conclusions for each analysis, as well as proposed solutions for organizations to increase their efficiency, are discussed.

Chapter 6 contains the final conclusions of the work, the author's personal contributions, and the perspectives and future research directions derived from this work. The research results have been disseminated in 5 scientific papers/articles, defining the author's activity in this doctoral work, highlighting the interest in organizations and enterprises, and illustrating the level of involvement.

CHAPTER 2.

CURRENT STATE OF RESEARCH ON ORGANIZATIONAL DIAGNOSIS AND ITS UTILIZATION IN INDSTRY 4.0

2.1. Definition of concepts used in organisational diagnosis

"**The organization** is a mechanism through which an individual's effort is replaced by the expertise or knowledge of several or more individuals. The counterpart of specialization is always organization – an organization can have specialists who, individually, are technically incomplete and to a large extent, useless, but collaborating with other specialists, they produce complete and useful results." [2] The organization arises out of necessity when individuals, due to individual limitations, come together for a common purpose. More precisely, the organization is "a socially conscious entity, relatively coordinated, with relatively identifiable boundaries, operating on a relatively continuous basis to achieve a consciously shared set of objectives (a set of goals) by its members." [3]

The management of a business [4] represents the process of organizing, coordinating, and controlling resources to achieve an organization's objectives. This involves - according to Henry Fayol (1916) [5] - goal setting, organizing, leading, coordinating, evaluating, and controlling. Although over time these functions have been reevaluated or revised by the literature, the function of evaluation and control has remained constant. Management, as an action, art, or manner of leading an organization, directing, planning development, and control, applies to all areas of a company's activity. [6]

As an expression of this function, organizational diagnosis represents, for the management of a company, the process of understanding the current state of the organization and its environment, analyzing existing problems and opportunities, and developing performance improvement strategies. This process involves examining the structure, processes, systems, and culture of the organization, as well as the external environment, to identify areas that require improvement. Organizational diagnosis is typically used continuously, as part of a continuous improvement process. Depending on the size and complexity of the organization, this process may occur annually or biennially, or even more frequently if needed.

Organizational diagnosis is an evaluation of an organization's health. It provides an assessment of the current state and the path to improving this state. The first comprehensive definition of organizational diagnosis was provided by Edgar H. Schein in his book "Organizational Culture and Leadership" [7]. He defined organizational diagnosis as "the process of analyzing an organization's structure and culture to identify improvement opportunities and to assess the current state of the organization to provide a roadmap for improvement." In other words, organizational diagnosis is an important and necessary process in business management. It is based on the use of a model and an analysis tool that can provide a coherent and comprehensive picture of the analyzed organization.

2.2. Main analytical models used in organisational diagnosis

Many of the models used are based on the Open System Theory (OST) from the general systems theory defined by Von Bertalanffy [9] (a complex of interacting systems). Katz and Kahn [10] apply the concept of Open System Theory (OST), analyzing the relationship between organizations and the environment in which they operate. This emphasis reflects the organization's ability to adapt to changes in environmental conditions (with or without the need for information processing). [11] The premise of this theory is that organizations are social systems that depend on the environment in which they operate. [10] The system/organization incorporates elements from the external environment, transforms them, and cycles them back to the environment, as seen in Figure 2.1 below.

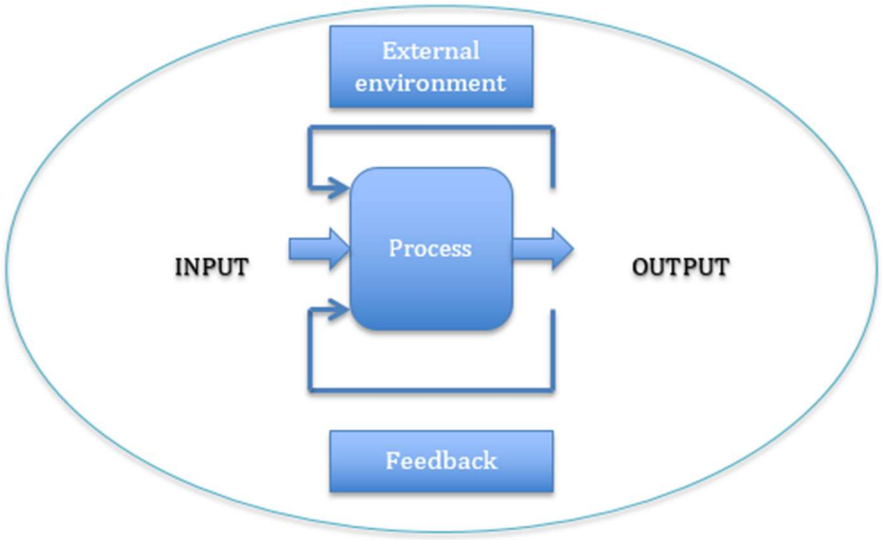


Fig. 2.1 Open system model of Katz & Kahn [10]

Creating an analysis model involves, based on the Open System Theory, identifying constituent elements and their interactions. They represent the integration of content and process, practice, and theory. Analyzing the model leads to identifying dysfunctions within the system. Addressing these dysfunctions leads to organizational development. For a better understanding of organizational models and modeling, the following analysis models, representing the most commonly used models in the specialized literature, have been identified and studied. These are:

1. Lewin's Model (Lewin's Force Field Analysis) - 1951
2. Leavitt's Model (Leavitt's Model) - 1965
3. Likert's System Analysis (Likert's System Analysis) - 1967
4. Weisbord's Model (Weisbord's Six-Box Model) - 1976
5. Nadler and Tushman's Congruence Model (Nadler and Tushman's Congruence Model for Organization Analysis) - 1977
6. McKinsey's Model (McKinsey 7S Framework) - 1980
7. Galbraith's Model (Galbraith's STAR Model) - 1982
8. Tichy's TPC Model (Tichy's Technical Political Cultural Framework – TPC) - 1983
9. Nelson and Burns' Model (Nelson and Burns' High-Performance Programming) - 1984

10. Harrison's Model (Harrison's Diagnosing Individual and Group Behavior Model) - 1987
11. Burke-Litwin Model (Burke- Litwin Model of Organizational Performance & Change) - 1992
12. Falleta's OIM Model (Falletta's Organizational Intelligence Model) - 2008

2.3. Analysis of studied models

It is evident that the models exhibit both common and distinct features, with some being reinterpretations and updates of previous models, all of them being grounded in open system theory. The models generally identify a set of essential elements and define the types of relationships established between them (inputs/outputs, supporting relationships, connections, influences, etc.). Analyzing the models presented in the previous subchapters allows for classifications, the identification of common elements, and patterns. A presentation of the characteristics of each model, the constituent elements, as well as the relationships established between them, can be found in Table 2.3 below.

Table no. 2.3. Centralising organisational models, characteristics, elements and relationships

Nr. Crt.	Model name	Caracteristics	Model elements	Types of relationships established between elements
1	Lewin	Holding forces and driving forces that are constantly rebalancing	Driving and restraining forces	Echilibrium
2	Leavitt	Four interconnected elements in an interdependent relationship	Structura, sarcini, tehnologie și oameni	Interdependence
3	Likert	Proposes four types of organisations: exploitative-authoritarian, benevolent-authoritarian, consultative and participatory	Motivation, communication, interaction, decision - making, goal setting, control, and performance	Different relationships between leadership and subordinates depending on the type of organisation
4	Weisbord Six Box	6 elements that tend to be in a balanced relationship	Purpose, structure, relationships, rewards, leadership, coping mechanisms	Echilibrium
5	Nadler & Tushman	Pivotal elements of the model: the organisation's tasks, people, structure, culture and organisational environment determine the degree of effectiveness of the organisation through the degree of congruence between the elements.	Organizational tasks, people, structure, culture and organizational environment. Inputs, strategy and outputs are also identified.	Congruent

6	7's McKinsey	A functional organisation is based on 7 mutually supporting elements	Hard Elements: Strategy, Structure, Systems and Soft Elements: Values, Skills, Style, Personal.	Support - alignment
7	Galbraith	The 5 elements of the system must be compatible with each other otherwise organisational dysfunction occurs	Specific tasks, structure, membership, reward system and information processing	Compatibility
8	Tichy	It overlaps three dimensions: technical, political and cultural. The alignment of these three dimensions determines the effectiveness of the organisation.	Three layers: Technological, political and cultural	Alignment
9.	Nelson & Burns	Proposes 4 models of organisations at evolutionary levels of development	Unspecified	Different relationships between leader and organisation's members depending on the type of organisation
10.	Harrison	Model based on three levels: individual, group and organisational	Complex	Relationship of influence
11.	Burke Litwin	Complex model showing that intervention on organisational elements leads to transactional changes and then to transformational changes	Complex system with 12 elements	Transactional / Transformational relationships
12.	Falletta OIM	Complex system with 11 factors and variables	Complex	Determination

Organizational diagnosis models, as can be observed, generally have a specific number of internal elements between which relationships are established. Analyzing these elements provides the opportunity to obtain a diagnosis for the studied organization. Some models distinguish between elements through definition (soft/hard - in the case of McKinsey) or through positioning (e.g., leadership is at the center of the Weisbord model). The relationships identified between the elements of various models can be interdependence, alignment, connection, congruence, or may not be explicit (Weisbord). In constructing a diagnostic model, it can be observed that identifying the significant elements for the model and the relationships between them determines their positioning in the model's scheme and leads to obtaining a graphical representation of the model. Another factor that can lead to the graphical representation of the model under construction is the type of relationships established between its elements. Table 2.4 provides a classification of the identified relationships between the elements of the models.

Table no. 2.4 Classification of the types of relationships established between the elements of the models studied

Nr. Crt.	Relationship chategory	Relationship type	Model
1	Relationships between elements seeking to find a common denominator and enabling the organization to act efficiently:	Balance Interdependence Congruence Support Alignment Compatibility	Lewin Weisbord Leavitt Nadler-Tushman McKinsey 7S TPC Tichy Gailbraith
2	Relationships between elements that embrace permanent change and actively contribute to it:	Driving forces vs. restraining forces Transactional/transformative relationships Different relationships between leaders and subordinates based on the type of organization Influence relationships	Lewin Burke Litwin Likert, Nelson&Burns Harrison
3	Relationships that directly cause other elements to change	Determination	Falleta OIM

As observed in the table above, three categories of forces/relationships between elements have been identified in the analyzed organizational models, whether explicit or implicit. In the first case (Category 1), the forces/relationships established between elements seek to find a common denominator, whether termed alignment, support, balance, or compatibility. The lack of alignment, balance, etc., provides information about the element(s) that need to be changed. The necessary information is obtained using various analysis tools based on questionnaires or performance indicators. If the desired alignment has not been established, a change within the organization is necessary. In the second case (Category 2), the forces within the system continually contribute to change management. It is not about an inherent internal dynamic that contributes to ultimately balancing/aligning the elements, as in the first case. Instead, it represents a constant evolution from one state to another, progressing towards a superior state. In the third category (Category 3), we speak of a dynamic of determination, in which one element determines another. Another observation from the analysis of the models is that only some explicitly integrate the external environment. The same applies to technology, which is a consideration for some of these models.

2.3.1. Relationship with the external environment

Although the analyzed models are based on Open Systems Theory (except for the Nadler-Tushman model, which is based on complexity theory), only a few explicitly represent their relationship with the external environment. The Open Systems Theory presents the external environment in the model as a resource generator (input) as well as a beneficiary of the organization's internal processes (output). In this context, many models no longer find it necessary to represent the external environment, focusing solely on the elements and

relationships within the organization. However, a few models still consider it necessary to include the mentioned external environment in the representation, as previously stated, as an input/output factor (Nadler & Tushman Congruence Model, TPC-Tichy Model, Faletta-OIM Model).

A couple of models attempt to present in more detail the interaction of the external environment with the organization from a qualitative perspective. For example, Weisbord's Six-Box Model represents the external environment as a factor that sets constraints and demands in interaction with the organization. The environment is also a factor that can provide any other unforeseen elements for the organization. Harrison provides a more detailed representation within the model of how the external environment provides the organization with material and human resources. The Burke-Litwin Model considers the external environment a transforming factor that is in relation to all other constituent transforming factors of the model.

2.3.2. Relationship with technology

Only four out of the twelve models presented consider it necessary for technology to be included in the representation. The Leavitt Model and the Weisbord Model view technology as an important element (with a weight of 25% and 16.6%, respectively, relative to the number of elements in the model). The Harrison Model details the presence of technology at both the organizational and group levels. The Falleta OIM Model presents technology as a constituent element of organizational and executive capabilities.

One of the technological components that no enterprise can overlook is the digital component. The current economic environment is digitalized. The architecture essentially includes the following components:

- Enterprise Resource Planning (ERP).
- Customer Relationship Management (CRM).
- Applications for promotion, marketing.
- Utility applications (maintenance, design, etc.).
- Integration platforms for applications used by enterprises.

Depending on the specific nature of the enterprise, providers of Enterprise Resource Planning (ERP) applications customize the applications to be as close as possible to the enterprise's needs. This shows that technology has become a flexible element within an organization, just like the other elements designated as representative for organizational models. Traditional hierarchical structures necessary for classic production will be replaced by self-organizing cyber-physical systems (CPS).

In the context of Industry 4.0 development, we consider it necessary to take into account the two important relationships that allow for a clearer assessment of the organization. The external environment influences the business model and can significantly modify the company's structure and implicitly its organizational model. Rapid environmental changes require adaptations from organizations. Technology, viewed in a broader sense, including digitization, is an important influencing factor in shaping the organization. Its impact on the organization occurs at all levels, altering the status of the relationships between its elements. These two factors act more extensively, profoundly, and rapidly than in the past, indicating that the entire economy is moving towards Industry 4.0. In light of these observations, it is evident that a new model, similar in principle, can only help by providing a new perspective on an analyzed organization, finding new solutions to the same efficiency-related problems of the organization.

2.4. Industry 4.0. Characteristics

Industry 4.0 transforms the entire product production cycle, from design to delivery, increasing production speed by 30%, efficiency by 25% (according to the Boston Consulting Group), and elevating product customization to unprecedented levels.

Recruitment within Industry 4.0 enterprises is undergoing changes. According to an article from BCG [41], "To succeed with Industry 4.0, companies should consider new recruitment approaches that focus on capabilities rather than qualifications determined by degrees and roles. As employees will work on a wider range of tasks unrelated to their basic education, recruiters will need to look beyond official certifications to identify workers with the relevant skills for specific roles." This will change the role and importance of HR within the company. It is clear that without an analysis of the external environment and technology in relation to the organization, without organizational diagnosis, the evolution of the enterprise on the path to Industry 4.0 cannot have a clear direction and may encounter challenges.

2.5. Methods for assessing the readiness of organisations for Industry 4.0

The transition of enterprises to Industry 4.0 has brought about the need to assess the status of companies in terms of technological maturity, the level of organizational readiness for transitioning to 4.0, and consequently, change management. Table 2.5 below reproduces the models and tools for assessing readiness or maturity related to Industry 4.0 identified by A. Schumacher, S. Erol, W. Sihn [42] in the article 'Maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises.

Table 2.5. Industry 4.0 readiness/maturity assessment models and tools identified by A. Schumacher (2016)

Model name	Institution /Source	Evaluation approach
IMPULS – Industry 4.0 Readiness (2015)	VDMA, RWTH Aachen, Aachen, IW Consult	Assessment in 6 dimensions including 18 elements indicating readiness at 5 levels; the barriers that arise when moving to the next stage are defined, as well as advice on how to overcome them.
Empowered and Implementation Strategy for Industry 4.0 (2016)	Lanza et al.	The evaluation of Industry 4.0 maturity is seen as a quick check and part of a process model for implementation; analyses of gaps and dedicated tools for overcoming the barriers are included, without details about the elements and the provided process development.
Industry 4.0 / Digital Operations Self Assessment (2016)	Pricewaterhouse Coopers	Online self-assessment in 6 dimensions; focused on digital maturity at 4 levels; application as a consultancy tool with evaluation fee, required in 3 out of the 6 dimensions; no details about the elements and the offered process development.
The Connected Enterprise Maturity Model (2014)	Rockwell Automation (2014)	Maturity model as part of the five-stage approach to achieve Industry 4.0; evaluation focused on technology in 4 dimensions; no details about the elements and the offered process development (whitepaper)
I 4.0 Reifegradmodell (2015)	FH – Oberösterreich (2015)	Maturity assessment in 3 dimensions including 13 elements for its indication; maturity is evaluated on 10 levels; no details about the elements and the offered development process (unfinished development process).

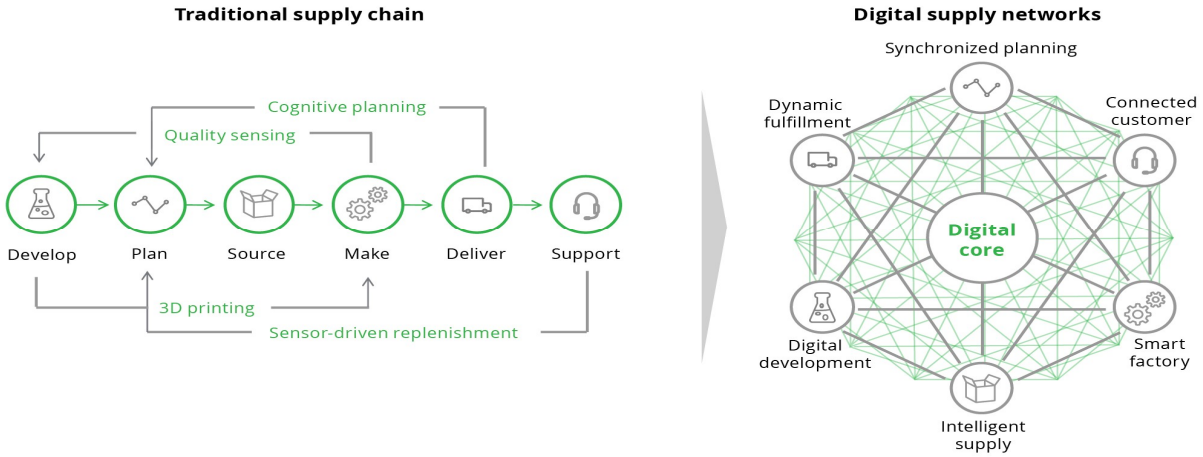
Several studies show technology as the most important dimension used in models that indicate an organization's readiness for Industry 4.0 [43] [44].

It can be observed that the need for analysis has led to the creation of evaluation tools for enterprises in the context of Industry 4.0. However, to date, there hasn't been a dedicated organizational diagnosis model or instrument created. As shown, it's possible to evaluate the level of preparedness for transitioning to Industry 4.0, the degree of maturity, and the level of technology adoption and digitalization. There isn't a unified organizational approach yet. The relationships established between the elements of an organization have not been identified and studied. In practice, interest in organizational modeling diminished with the advent of Industry 4.0. In the conditions where Industry 4.0 represents a paradigm shift [52], [53], organizational diagnosis needs a change in perspective as well. It needs a reintroduction of technology and digitalization into organizational modeling in a different way. The hypothesis that technology is a neutral factor that only brings benefits to all involved actors doesn't seem to hold true in all situations. There are tensions in the transformation to Industry 4.0 that need to be resolved [54], often these resolutions are made based on Industry 3.0 principles, indicating that an organizational model serving as the basis for the analysis and evaluation of Industry 4.0 can start from traditional organizational modeling. Technology needs to be qualitatively and quantitatively viewed differently in this equation."

2.6. Aspects of organisational diagnosis in Industry 4.0.

The continuous development of robots within the industry leads to a major change in employees' activities. Industry 4.0 was conceived, among other things, as a solution to the shortage of employees in developed countries with an aging population. Those remaining in the enterprise will be motivated to engage in a continuous learning process that allows them to retain their jobs and utilize high-tech equipment [55]. The disruptive nature of the industry dictates that these processes take place at a rapid pace. Understanding this dynamic is necessary to enable the adoption of necessary measures. Some have been identified [56], while others will be identified and adopted based on the experiences accumulated by organizations.

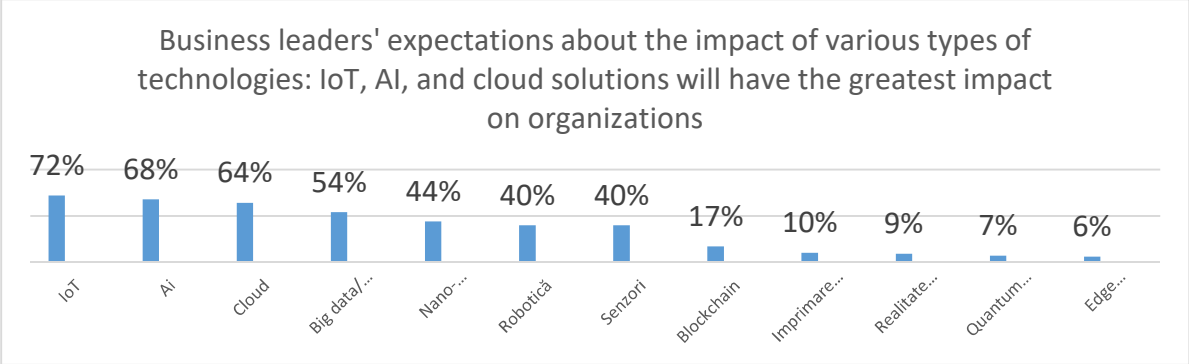
Industry 4.0 has a transformative impact at the social level. These transformations necessitate the joint involvement of the business environment, educators, and governments in a proactive process of developing programs that allow for achieving the desired economic and social results. All these substantive processes lead to significant changes at the organizational level. There are changes in strategy, leadership [58], internal processes, organizational culture [59], as well as the learning process [61]. The implementation process of Industry 4.0 required tools in its initial phases to evaluate a company's digitalization potential, adoption level, and maturity degree. The question of its impact on the organization [62] and the industry ecosystems, supplier-customer relationships, regulations, experts, influencers [63] was then raised. Figure 2.16. shows, according to a Deloitte study, the transformation of the traditional supply chain as a result of digitisation. [Deloitte insights; delloite.com/insights]



Source: Delloite

Fig. 2.16. Transforming supply chains as a result of digitisation - Deloitte, Dec 2017 [69].

At the level of supply chains, integration and collaboration appear to be the key to implementing Industry 4.0 [64]. Another important aspect that has started to be studied in the implementation of Industry 4.0 is the impact on the organization's members, resulting from the transformations [65] and organizational culture [66] [67] [68]. 'Adapting employees' skills for the fourth industrial revolution remains a challenge for organizations worldwide,' as mentioned in a Deloitte study regarding readiness for Industry 4.0 [69]. The study reflects the opinions of over 2,000 business leaders. (Fig. 2.17.)



Source: Deloitte Industry 4.0 Readiness Survey, ed 2020

Fig. 2.17. Industry 4.0 readiness according to Deloitte survey 2020 [69]

In the same study, it is mentioned that only '10% of the leaders who participated in the study say they have a comprehensive, holistic strategy regarding Industry 4.0, and nearly half of them have an ad-hoc approach.' This pragmatic approach by leaders, based on 'seeing and doing,' can create problems and tensions within an organization [70], prompting the search for solutions. The need for new perspectives in understanding Industry 4.0 in a broader organizational context is becoming increasingly evident. The obtained results represent customized products or services with better efficiency. The production relationships between suppliers, manufacturers, and customers on one hand, and those between humans and machines on the other hand, are different from traditional ones.

There is a wide range of technologies introduced in the operational area and integrated into all structures of an organization.

- Edge computing [74] [75]
- Digital twin robots [76]
- Cyber-physical systems
- IoT
- Hybrid cloud systems [77]
- Big data, big analytics
- Mobile devices
- Augmented reality [78] [79] [80]
- 4G and 5G

The list is not exhaustive, but it can give us an idea of the technologies used in Industry 4.0 that are capable of making the decisive step towards the transformation to Industry 4.0. The deep integration of technology within the organization leads us to view technology as a development environment for every element of an organization, not just as another constituent element. Initially, companies began the digitization process with small-scale projects tailored to various departments or sectors. Later, these evolved to a level where integration with other units could be ensured. There is no one-size-fits-all solution for digital interconnection at the company level. Some companies implement digital processes in their organizations from the outset. There is also the option of creating an independent platform that governs the organization's operations. A combination of the two solution options is a digital center of excellence, around which specific digital capabilities are created [81].

Organizations are beginning to be viewed as a techno-social system [82]. In practice, technology is no longer an element that needs to be analyzed separately within an organization; it must be taken into account in the analysis of each relevant element within it. Studies show that high-tech firms have significantly changed the organizational design of companies at all levels [83]. There is a correlation between the level of technology integration in a company and the organizational model. The need to evaluate the level of digitization in all organizational domains is emerging."

2.7. Conclusions

As seen, the specialized literature has focused primarily on the following issues:

- The benefits and technological impact that Industry 4.0 can bring [85][86][87].
- Evaluating a company's level of digitalization [88] [89]
- Enterprise maturity for transitioning to 4.0 [90][90][91]
- Changes and the impact on human resources during the transition [92] [93]
- Influence on strategy and business models [94] [95] The speed at which the transition to Industry 4.0 was desired did not allow for the development of new organizational diagnosis tools, considering we have a few new characteristics:
- The strongly disruptive nature of technology
- Radical changes in the client-service/product supplier relationship
- Diversified digitalization of communication at the organizational level and in relation to customers
- Extensive customization brought closer to the customer [96] [97]
- Flattening of the hierarchical pyramid within the organization
- Continuous learning and permanent requalification of employees [98]

The maturation of Industry 4.0 will raise new topics for analysis, along with the experiences gained and the problems encountered. There is a need for an expanded perspective

that includes all the changes that occur in all elements of an organization and in all the relationships established between them. Expanding the perspective can be achieved by answering the following questions:

1. How does Industry 4.0 influence the organizational model of the enterprise?
2. Can a diagnostic model suitable for diagnosing a 4.0 enterprise be created?
3. Is such an evaluation of a 4.0 enterprise necessary?
4. What could be the adaptations of an organizational model for a 4.0 enterprise?
5. What could be the differences between a classic organizational model and one that describes a 4.0 enterprise?
6. Does Industry 4.0 change the classical organizational paradigm?

The organizational model of the enterprise is influenced by the characteristics that define the industry. A 4.0 enterprise is a particular case of an organization, which means it can be attributed an organizational model. It must take into account the characteristics of Industry 4.0.

The disruptive nature [99] implies introducing the external environment into the model as a representative element that interacts with all the other elements of the model. The multiplication of communication channels between the client and the organization shortens the distance between them, leading to a closer connection between them. Customization requires the technology used to be constantly adapted to the needs of customers, leading to continuous change in processes and procedures. This necessitates the introduction of processes into the descriptive model as a defining element. The flattening of the hierarchical pyramid in Industry 4.0 must also be represented by the organization's structure within the model.

All these characteristics of Industry 4.0 need an evaluation within the context of an organizational model for a better understanding of such an organization. A model for organizational diagnosis needs a better description of the system's relationship with the external environment (see § 2.3.1.) and with technology (see § 2.3.2.). These adaptations can represent the differences between a classic model and one suitable for Industry 4.0. We sought to obtain answers to these questions through the analyses and studies presented in this work."

CHAPTER 3. DIRECTIONS, MAIN OBJECTIVE AND METHODOLOGY OF RESEARCH AND DEVELOPMENT OF THE ANALYSIS AND EVALUATION METHOD IN THE CONTEXT OF THE EVOLUTION TOWARDS INDUSTRY 4.0

3.1. Research objectives

3.2. Design of the performance assessment and analysis methodology

To achieve the main objective and the proposed objectives 1-6, theoretical research means found in this work with references in the bibliography have been utilized. For objective 7, specific means of mixed quantitative and qualitative research were used, including our own questionnaires and materials from public information sources. To collect information, questionnaires, interviews, and observation of organizations were used, either directly or from information sources. The questionnaire used in the analysis of companies was designed based on the conceptual model and its elements (Table 3.3.). The data were completed in a questionnaire form.

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Table 3.3. Model model questionnaire

1.	Management is directly responsible for failure or success.
2.	A significant portion of the success or failure is due to external forces that the manager manages.
3.	The vertical structure is differentiated in terms of management layers.
4.	The horizontal structure of the company, in terms of occupational, administrative, and task groups, is differentiated.
5.	Job descriptions in the company are strict and well defined.
6.	Positions in the company are flexible and adaptable.
7.	Orders come from the center.
8.	Orders come from multiple management centers.
9.	The structure is functional (divided into functional departments).
10.	The structure is divisional.
11.	The corporate strategy is growth-oriented.

12.	The corporate strategy is renewal-oriented.
13.	The competitive strategy is to be better (through price, quality, speed, etc.).
14.	The competitive strategy is to be different from other competitors.
15.	Internal changes are happening (personnel, equipment, implementations).
16.	External changes are happening (changes in the industry, technology replacement, different clients).
17.	Recruitment primarily focuses on internal candidates within the organization.
18.	Recruitment primarily focuses on external candidates outside the company.
19.	Training is formal (utilizing written materials, tutorials, one-to-many courses).
20.	Training is informal (one-to-one courses, direct workplace interaction).
21.	We rely on the people within the organization to achieve results.
22.	The proposed results drive the members of the organization to perform.
23.	Relationships within the organization are formal.
24.	Relationships within the organization are informal.
25.	The organization's results are appreciated by its members.
26.	The organization's results are appreciated by its clients.

The research aimed to analyze various organizations to determine whether the proposed model is applicable to any type of organization. Some questionnaires were repeated after significant periods to observe:

- The organization's evolution
- Whether similar measures were taken as proposed through the analyses
- Whether the analysis based on the proposed model has a predictive nature
- What other characteristics/factors can be added for a more in-depth analysis
- The effectiveness of the questionnaire

The situation where information about a company is provided by several employees from different departments was also evaluated. For a better understanding, the newly created tool was used in parallel with another diagnostic tool for a specific company, allowing an evaluation of the new tool. The research showed that using the model is more effective the larger the organization, although the model is valid for organizations with few members as well.
It was observed that, when questionnaires were completed by different individuals within the same organization, despite varying opinions, the conclusions drawn were nearly the same.
The research set out to:

- Identify an organizational model that allows analysis of any type of organization.
- Identify behavioral patterns of the analyzed organizations to establish a working methodology.
- Find characteristics of the model elements, the complementarity factors of which can be measured.
- Identify possible helpful analysis formulas.
- Demonstrate that a diagnosis can not only provide a snapshot of the moment but can also predict its evolution broadly.
- Demonstrate the existence of a cycle of determinations within an organization.
- Demonstrate that balance within each element leads to overall organizational equilibrium.
- Demonstrate that the existence of imbalance within an organization leads to modifications of its elements sooner or later.
- Find an organizational analysis model adapted to Industry 4.0.
- Analyze the problems that may arise in 4.0 enterprises.

For interpreting the questionnaire data, the following calculations were performed:

3.2.1. Calculation of trends sums

3.2.1.1. Complementarity Factor Values for a Characteristic.
Values were assigned for centripetal factors A and centrifugal factors B as follows:

- 1 point for a very poorly defined characteristic. Development of that characteristic is necessary.
- 2 points for a poorly defined characteristic. Development of this characteristic is recommended.
- 3 points for a moderately defined characteristic.
- 4 points for a strongly defined characteristic.
- 5 points for a very strongly defined characteristic. Review of this characteristic is recommended. If necessary, measures can be taken to reduce this characteristic.

3.2.1.2. Complementarity Factor Values for an Element represent either the results collected directly from completed questionnaires (for Leadership and Results) or an average of these (for the others).

$$Ae = \sum Ai/i \ ; \ Be = \sum Bi/i$$

where i is the number of features corresponding to an item. $i \leq 6$.

3.2.1.3. The Trend Δ of a feature. Represents the difference between the complementary centripetal factor (A) and the complementary centrifugal factor (B) corresponding to a feature.

$$\Delta = A\text{-}B$$

If $\Delta > 0$ we have a **centripetal trend**, dacă $\Delta < 0$ we have a **centrifugal trend.**

3.2.1.4. The trend Δe of an element is the difference of the values of the two complementarity factors corresponding to the element

$$\Delta e = Ae\text{-}Be$$

If $\Delta \mathbf{e} > 0$ we have a **centripetal trend**, dacă $\Delta < 0$ we have a **centrifugal trend.**

3.2.1.5. The relative tendency of an organisation is the difference between the sums of an organisation's centripetal and centrifugal complementarity factors.

$$\Delta ro = \sum Aei - \sum Bei$$

The calculation of trends gives us the possibility to identify the major differences between the complementarity factors, i.e. elements and organisation. Once identified, corrections can be introduced for each characteristic, element by increasing or decreasing the value of the complementarity factors.

3.2.2. Calculation of absolute trend sums

3.2.2.1. The absolute trend Δabs of a feature. Represents the modulus of the difference between the complementary centripetal factor (A) and the complementary centrifugal factor (B) corresponding to a feature.

$$\Delta abs = |A\text{-}B|$$

$$\Delta abs = |\Delta|$$

3.2.2.2. The absolute trend Δeabs of an element is the sum of all the trends of an element's features relative to the number of features.

$$\Delta eabs = \sum \Delta e/i$$

where $i=1\text{-}6$ is the number of characteristics corresponding to an item.

3.2.2.3. The absolute trend Δoabs of the organisation is the sum of the absolute trends of all elements of an organisation.
$\Delta oabs = \sum \Delta eabs$

Calculating the sums of the absolute trends shows us the maximum differences that exist between the complementarity factors. Always $\sum \Delta abs \geq \sum \Delta$.

3.2.3. Simple centripetal-centrifugal diagram of the elements.

Based on the calculated values of the complementarity factors for each of the elements, a simple centripetal-centrifugal diagram can be drawn. An example can be seen in Figure 3.1.

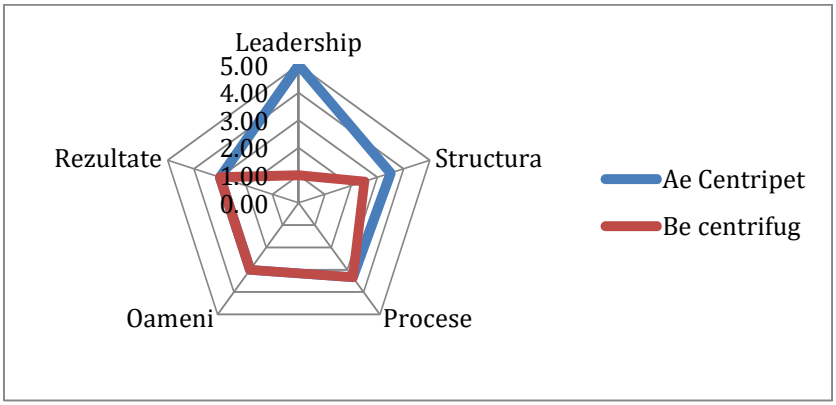

Fig 3.1 Example of a simple centripetal-centrifugal diagram

The diagram shows us the values of the complementarity factors of the elements of the organisation as well as the major differences between the complementarity factors of its elements.

3.2.4. Calculation of turbulence and stability indices

3.2.4.1. The relative turbulence index of an element is the value of the sum of all the trends of the characteristics of an element relative to the mean of the sum of all the values of the corresponding complementarity factors of the element.

$$Itre = \sum \Delta i / \sum [(Ai+Bi)/2]$$

3.2.4.2. The relative turbulence index of the organisation is the sum of all the trends of the characteristics of an organisation relative to the average of the sum of all the values of the complementarity factors of the organisation.

$$Itro = \sum \Delta e / \sum [(Ae+Be)/2]$$

3.2.4.3. The absolute turbulence index of an element is the sum of all the trends of the absolute characteristics corresponding to an element compared to the average of the sum of all the values of the complementarity factors corresponding to the element.

$$Itabse = \sum \Delta iabs / \sum [(Ai+Bi)/2]$$

3.2.4.4. The absolute Turbulence Index of the organisation is the sum of all absolute trends of the characteristics of an organisation relative to the average of the sum of all values of the complementarity factors of the organisation.

$$Itabso = \sum |\Delta e| / \sum [(Ae+Be)/2]$$

3.2.4.5. The Organisation Stability Index shows how stable the organisation is. The values are between 0 and 1, where zero is the minimum degree of stability and 1 is the maximum degree of stability. The stability index will also be expressed as a percentage.

$$Is = 1 - |Itr / It|$$

3.2.5 Calculation of dispersion factors

The dispersion factor is the influence of the turbulence index on an element. It is the product of the value of the complementarity factor and the value of the turbulence index of an element.

$$FdeA = Ite * Ae; \qquad FdeB = Ite * Be$$

3.2.6. Centrifuge-centrifuge dispersion diagram

Based on the calculated values of the dispersion factors for each of the elements, a simple centripetal-centrifugal diagram can be drawn. An example can be seen in Figure 3.2.

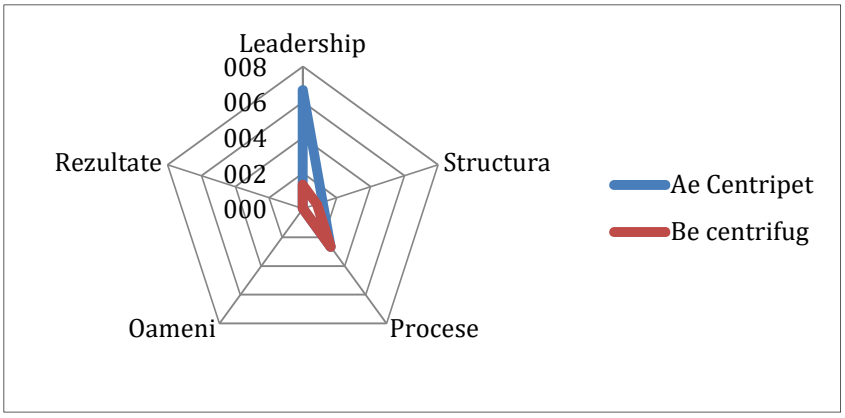

Fig 3.2. Example of a centripetal-centrifugal dispersion diagram

The diagram shows us which elements contribute significantly to the destabilisation of the organisation, as well as the differences between the dispersion factors of the elements of an organisation.

All the values calculated above have been passed as in the example in the following table.

Table 3.6. Table of calculated values corresponding to the questionnaire

Caracteristics	A	B	Δ	|Δ|	Ae	Be	Δe	|Δe|
1,00	5,00	4,00	1,00	1,00	5,00	4,00	1,00	1
2.1.1	5,00	4,00	1,00	1,00	4,67	3,67	1,00	1,00
2.1.2	5,00	3,00	2,00	2,00				
2.1.3	4,00	3,00	1,00	1,00				
2.2	5,00	4,00	1,00	1,00				
2.3.1	5,00	4,00	1,00	1,00				
2.3.2.	4,00	4,00	0,00	0,00				
3.1.1	5,00	2,00	3,00	3,00	3,67	3,33	0,33	0,33
3.1.2	2,00	5,00	-3,00	3,00				
3.1.3	4,00	3,00	1,00	1,00				
4.1	4,00	4,00	0,00	0,00	4,00	3,50	0,50	0,50
4.2	4,00	3,00	1,00	1,00				
5,00	3,00	3,00	0,00	0,00	3,00	3,00	0,00	0
Organization	**∑A**	**∑B**	**∑Δ**	**∑Δabs**	**∑Ae**	**∑Be**	**Δro=∑Δe**	**Δabso**
	55,00	46,00	9,00	15,00	20,33	17,50	2,83	2,83
	∑Ai	**∑Bi**	**∑A+∑B**	**∑|A-B|**	**Itre**	**Itabse**	**Fd A**	**Fd B**
Leadership	5,00	4,00	9,00	1,00	0,22	0,22	1,11	0,89
Structure	28,00	22,00	50,00	6,00	0,24	0,24	1,12	0,88
Proceses	11,00	10,00	21,00	7,00	0,10	0,67	2,44	2,22
People	8,00	7,00	15,00	1,00	0,13	0,13	0,53	0,47
Results	3,00	3,00	6,00	0,00	0,00	0,00	0,00	0,00

∑(A+B)/2	**Itabso**	**Itro**	**Is**	**Is (%)**
50,50	0,30	0,18	0,40	40,00

The table contains all the indicators calculated in § 3.2.1- 3.2.4 needed in the analysis of the organisation.

3.3. Conclusions on the proposed methodology

The scores obtained from completing the questionnaires allow us to evaluate each element of the organization as having a centripetal, centrifugal tendency, or being in balance. As presented in Chapter 4, the centripetal tendency leads to the blocking of the element, while the centrifugal tendency leads to its dissolution. By summing the values of the elements, we obtain the tendency of the entire system. A high value of a tendency indicates that the likelihood of changes within that element is very high. The same judgment applies to high values of the tendency for the entire organization. A high tendency of an element, based on the determination (presented in Chapter 4), allows us to anticipate changes in the next determined element. All this information allows us to anticipate important events that will take place within the

organization, resulting from the natural tendency of the organization towards balance. The transition from a tendency to a state of equilibrium generates a change within that specific element and the organization, creating turbulence. The turbulence index shows us how high the risk of destabilizing the organization is, allowing us to phase the necessary changes in the system so that it can withstand these changes at the level of both the element and the organization. The stability index practically shows us how stable the organization is. If the value is low, we can predict that there will be major problems in the organization leading to major changes within it. If the value of the stability index is high, we can make changes within the organization without major risks. For a refinement of the trend evaluations, the dispersion index was calculated to have a clearer picture of the trends at the element level. The intervals of trends, turbulence indices were calculated based on the minimum and maximum possible values of the scores from the questionnaire. Through these means, analyses and evaluations could be made for the case studies presented in Chapter 5. All of this led to the creation of the analysis and evaluation tool for Industry 4.0 enterprises.

CHAPTER 4. THE DESIGN OF THE PROPOSED PERFORMANCE ASSESSMENT AND ANALYSIS TOOL

The development of the diagnostic model was based on the analysis of the previously presented models, by establishing its constituent elements and the relationships between them. The proposed model should be able to analyse any type of organisation, including a 4.0 enterprise whose specificities have been taken into account.

4.1. Establishing the building blocks of the model

As seen from the presentation of the other models in the literature (see Chapter 2.2), their component elements are different. Each author has established the necessary elements to describe and analyse the organisation and the relationships between them. In order to determine what the defining elements of the proposed model might be, we have taken as a starting point the elements used by the other organisational diagnosis models, which are listed in Table 2.3. in Chapter 2.3. The elements have been grouped and centralised in the table below (Table 4.1.), summarising the number of identifications in each model. For simplicity, similar items or items from common families have been grouped together.

Table 4.1. Centralisation of the elements identified in the organisational models studied

Elements	Lewin	Leavitt	Likert	Weisbord	Nadler	McKinsey	Gailbraith	Tichy	Nelson&Burns	Harrison	Burke Litwin	Falletta OIM	Total
Structure	-	1	-	1	1	1	1	-	-	1	1	1	8
Culture/organisational environment/values	-	-	-	-	1	1	-	1	-	1	1	1	6
Tasks/purpose	-	1	-	1	1	-	1	-	1	-	1	-	6
Skills/abilities/performance	-	-	1	-	-	1	-	-	1	1	1	1	6
Leadership/decisions	-	-	1	1	-	-	-	-	1	-	1	1	5
Motivation/rewards	-	-	1	1	-	-	1	-	-	-	1	1	5
Communication	-	-	1	-	-	-	-	-	1	1	1	-	4
Interaction/relationships	-	-	1	1	-	-	-	1		1	-	-	4
Strategy/mission	-	-	-	-	1	1	-	-	-	-	1	1	4
People/staff	-	1	-	-	1	1	1	-	-	-	-	-	4
Management processes/procedures/practices/control	-	-	1	-	-	-	1	-	-	-	1	1	4
Technology/assistive mechanisms	-	1	-	1	-	-	-	1	-	-	-	1	4
Inputs/resources	-	-	-	-	1	-	-	-	-	-	1	1	3
Outputs/outcomes	-	-	-	-	1	-	-	-	-	-	1	1	3
Strengths	1	-	-	-	-	-	-	-	-	-	-	-	1
Growth&development	-	-	-	-	-	-	-	-	-	-	-	1	1

The results obtained allow us to observe which are the most used elements considered as representative in the existing organisational models.

4.2. Establishing relationships between model building blocks

The proposed model (Fig. 4.4) is based on two premises:

1. There is a cycle of determinations that can be established between the elements of the organization. The cycle of determinations was identified based on the fact that the organization can be described by analyzing its elements: structure and design, management, strategy, processes, organizational culture, and relationships between members of the organization. A better understanding of the organization can be achieved through a representation of its elements and the determinations between them. For a simplified representation, we considered the structure and design of the organization as a single element - as some authors also present them. Similarly, we considered this for organizational culture and the relationships between members of the organization. By establishing the determinations between elements - who determines and who is determined - we can create an image of the organization that can be represented as in Figure 4.3.

Fig. 4.3 Cycle of determinations of the elements of an organisation

2. The elements of the organization are subject to complementary centripetal and, respectively, centrifugal forces. The proposed analysis tool is based on the complementarity of factors that define an organization, aiming to help us evaluate the company's state and provide insights into what the enterprise should do in the future. To be able to perform this evaluation, suitable indicators need to be identified to describe the organization, which we will refer to as complementarity factors. These factors provide quantitative information about the characteristics considered representative for an organization. To determine the organization's state, an analysis of the corresponding centripetal and centrifugal complementary factors is conducted, corresponding to the established characteristics for the elements of the proposed diagnosis model. These factors are referred to as complementarity factors. Technology, which is integrated into each element of the model, is also influenced by the aforementioned centripetal and centrifugal forces.

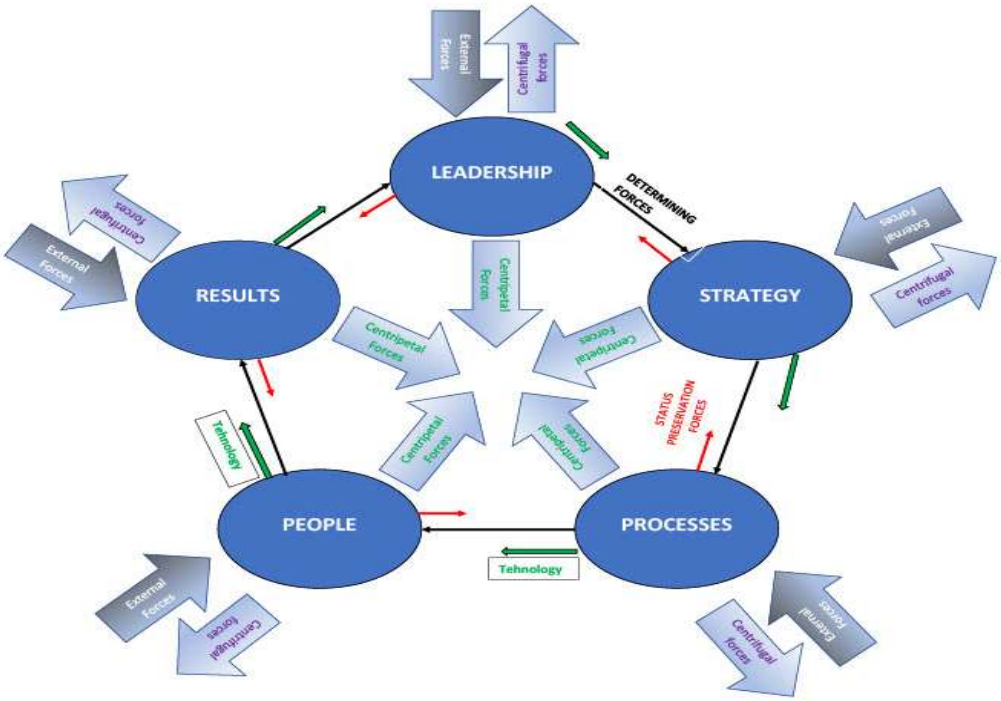

Fig. 4.4. Relationships between model elements

4.3. Features of the model elements. Complementarity factors

We have identified for each element of the model one or more characteristics. We have chosen the characteristics most commonly found in management and organisation theory textbooks, especially those written by Stephan P. Robbins. [104] [105] Each characteristic, is under the influence of two complementary factors: centrifugal and centripetal. For all selected characteristics, sets of complementary factors were identified.

4.3.1. Leadership – Characteristics and complementarity factors

The identified characteristic of the Leadership element is represented by managerial competence. It is constrained by both the organizational environment and the organizational culture. According to S.P. Robbins (2012), there are two perspectives in management theory:

- The omnipotent view of management: wherein managers are directly responsible for the success or failure of an organization.
- The symbolic view of management: wherein a significant portion of an organization's success or failure is influenced by external forces controlled by managers.

The complementary factors are omnipotent and symbolic. Through its evolution, Technology has created a dynamic interdependent relationship with Leadership. Information technologies have introduced new ways of working and are value creators, allowing physical distance between individuals in the organization. Differences in time and space are reasons behind the formation of virtual teams [107]. Consequently, new types of organizations and new

types of leadership emerge, such as E-leadership. However, E-leadership implies the same style and content as traditional leadership [108].

4.3.2. Structure – Caracteristics and complementarity factors

Leadership determines the structure, design, and strategy for an organization. These aspects have been consolidated into the same Structure element. For these three, a series of characteristics have been identified. According to S.P. Robbins, the organizational structure defines task allocation, reporting relationships, formal coordination mechanisms, and the interaction patterns to be followed. The organizational structure consists of three components:

1. Complexity
2. Formalization
3. Centralization

Spatial dispersion is not relevant to our model given that communication and transportation can be easily facilitated in contemporary times. Furthermore, the spatial differentiation highlighted by Robbins can be viewed as horizontal differentiation. In this scenario, both **vertical and horizontal differentiation** can be considered complementary factors that determine organizational complexity.

Formalization pertains to the extent to which jobs and procedures within the organization are standardized. In highly formalized job roles, individuals have minimal discretion over what, when, and how things are done. Formalization can also take the less tangible form of predictable thinking models and problem-solving approaches within the organization. From this perspective, we can identify two complementary factors describing formalization: **clearly defined and continuously adaptable.** "Centralization is the most difficult to define of the three components. Most organizational theorists agree that the term refers to the degree to which the decision-making process is concentrated in a single point in the organization." - P. Robbins. For describing centralization, we have two complementary factors: **concentrated and dispersed**.

A characteristic of design is structure. In the 11th edition of "Management" by S.P. Robbins and M. Coulter [111], three traditional design models for enterprises are described:

- **Simple Structure**: An organizational structure with weak departmentalization, where authority is centralized in a single person. Typical of organizations with a small number of individuals.
- **Functional Structure**: Represents an organizational design that groups specialties together based on similarity or relatedness. This structure can be seen as functional departmentalization applied to the entire organization.
- **Divisional Structure**: An organizational structure consisting of separate business units or departments. In this type of structure, each department has limited autonomy, and there is a manager responsible for its performance.

The simple structure, being a particular case for very small organizations, was not considered. In the literature, we also encounter the matrix structure, a combination of the divisional and functional structures. Considering that as an enterprise grows, any simple structure becomes either functional or divisional, we have chosen 2 complementary factors to describe the enterprise's design: **functional and divisional.**

For strategy, two characteristics were identified. According to S.P. Robbins in "Management," 11th edition, there are three types of strategies [idem]: corporate, competitive, and functional. Corporate strategy is defined by top managers, competitive strategy is defined

by middle management, and functional strategy belongs to lower-level managers. To identify complementary factors, we considered the first two types:

- Corporate strategy is the one that determines where the business is or will be headed. There are three main types of corporate strategy: growth, stability, and renewal (S.P. Robbins). Growth involves increasing the number of products, stores in a chain, provided services, etc. Stability means the organization continues to do what it has been doing. Renewal involves cost reduction and restructuring of organizational operations. The strategy that promotes stability essentially preserves what exists; therefore, it does not show any tendency. Hence, we selected the two complementary factors as growth and renewal.

- Competitive strategy determines how the company will compete with its competitors. The more complex the company is, the more complex its competitive strategy will be, differentiated for each product of the company. The complementary factors defining the competitive strategy will be better and different. Strategy remains an important subject for new business models (e-business, e-commerce) [112], and original methods are sought [113].

4.3.3. Proceses – Caracteristics and complementarity factors

Three characteristics have been identified for the Processes element:
- *Change Process:* Changes within a company can be internal or external. Internal changes refer to a new organizational strategy, changes in workforce composition, new equipment, or changes in employee attitudes. External changes involve shifts in consumer needs and desires, new government laws, emerging technologies, or economic changes. The two complementary factors for the change characteristic are **internal change and external change**. For example, if the changes within the company are due to changes in personnel or equipment, it's internal change. If the change is driven by a shift in the industry or clientele or a change from one technology to another, it's external change.
- *Employee Recruitment:* It's self-evident that recruiting for a vacant position within an organization can only be done from two areas: from within the company or from outside it. The two complementary factors for the recruitment characteristic are **internal recruitment and external recruitment.**
- *Employee Training*: Employee training can be conducted informally or formally [118]. Informal learning occurs continuously, skill development happens based on workplace feedback. Formal learning is planned, systematic, and requires structured training and programs involving instruction and practice. The complementary factors defining the training characteristic are **formal learning and informal learning**.

4.3.4. People – Caracteristics and complementarity factors

Two characteristics have been identified for the People element: organisational culture and relationships between members. Organisational culture has a significant influence on an organisation's performance. In "A handbook of Human resource management practice" 10th edition by Michael Armstrong [idem], we find summarized the most common classifications by Roger Harrison, Charles Handy, Edgar Schein. Most often 4 dimensions are presented. Harrison classified what he called "organization ideologies" [119]. These were:

- *power*-oriented - competitive, responsive more to personality than expertise.
- *people*-oriented - consensual, with control management being rejected.
- *task*-oriented - competency-focused, dynamic.

- *role*-oriented - legality-focused, legalistic, bureaucratic.

Handy bases his typology on Harrison's classification although Handy prefers the word culture to ideology [120].

- *Power culture* - is one in which the central source of power exercises control. There are few rules or procedures. The atmosphere is competitive, power-oriented and political.
- *Role culture* - is one in which every activity is controlled by procedures and rules, the role or job description is more important than the person employed.
- *task culture* - is one in which the goal is to get the right people together to do the job. The culture is adaptable and teamwork is important.
- *Person culture* - is where the individual is the focus. The organisation exists purely to serve and assist the people in it.

The two complementary factors are **what exists/exists** and **what is wanted/desired**.

The relationships between the members of an organisation are of particular importance within the organisation. They are influenced by several factors such as the way they communicate, their numbers, the culture of the organisation, its values and so on. Relationships between employees can be formal, established by rules, procedures, rules, protocols, the degree of complexity of which is directly related to the size of the organisation, or they can be informal, outside the rules and procedures, having a more personal character. The two factors that describe the relationships between employees are: **formal and informal relationships**.

4.3.5. Results – Caracteristics and complementarity factors

We consider that the factors of complementarity of results are internal, when they directly concern the organization and its members, determining its preservation on the basis of the existing management, and external, when they concern the beneficiaries outside the organization (customers, shareholders, society, etc.), determining changes at the organizational level.

4.4. Development of the analysis tool based on the established model

Establishing the elements, their characteristics and complementarity factors led to the creation of a table containing them (Table 4.3). The questionnaire for completing the table was also created. The questionnaire with the help of which the analysis is made was created based on the Likert scale. Specifically, a score from 1-5 was given to each statement in the questionnaire. Five points are given for situations where the statement is completely true and down to one point for situations where the statement is partially true. The questionnaire has 26 boxes to fill in and is presented below (Table 4.4). The scores obtained from the questionnaire have been recorded on a sheet.

Table 4.3 Centraliser of elements, characteristics and complementarity factors

Elements of the organisation		Caracteristics	*A*- Complementary centripet factor	*B*- complementary centrifuge factor
1. LEADERSHIP	**1. Management**	1.Managerial Competence	Omnipotent	Symbolic/ Democratic
2. STRUCTURE	**2.1. Structure**	2.1.1 Complexity	Vertical differentiation	Horizontal differentiation
		2.1.2 Formalisation	Strongly structured	Permanently adaptable
		2.1.3 Centralisation	Concentrated	Dispersed
	2.2. Design	2.2 Structurarily	Functional	Divisional
	2.3. Strategies	2.3.1 Corporate	Growth	Renewal
		2.3.2 Competitive	Better	Different
3. PROCESES	**3.1. Proceses**	3.1.1 Proces change	Internal	External
		3.1.2 Recrutment	Internal	External
		3.1.3 Learning	Formal	Informal
4. PEOPLE	**4.1. Culture**	4.1.1. Culture	Exist	Wanted
	4.2. Relationships	4.2.1. Relationships	Formal	Informal
5. RESULTS	**5. Results**	5.1.1. Results	Internal	External

The validation of the proposed organisational model is done experimentally, by using the tool in the evaluation of different organisations and collecting feedback from members of those organisations. The resulting tool can be adapted to Enterprise 4.0.

CHAPTER 5. EXPERIMENTAL TESTING AND VALIDATION OF THE PROPOSED PERFORMANCE ASSESSMENT AND ANALYSIS TOOL

5.1. General considerations

The aim of this research is to demonstrate the usefulness of the proposed analysis and assessment tool which, through its validation, will validate the proposed organisational diagnosis model for Enterprise 4.0. Once the validity of the tool is confirmed through case studies, an analysis and evaluation tool dedicated to Enterprise 4.0 can be proposed based on the method obtained, which can be used for the analysis and evaluation of Enterprise 4.0.

5.2. Case studies

Table 5.1 below provides data on the questionnaires completed throughout the research period.

Table 5.1 Centraliser of completed questionnaires

	Company	Field of activity	Country	No. of empl	Date of quest.	Answers
1	BO S.A.	Agriculture	France	66	01.10.2016	HR Director
2	BO S.A.	Agriculture	France	66	12.07.2017	HR Director
3	IQHR S.R.L.	HR	Romania	20	10.10.2017	GM
4	FE ROMÂNIA	Distribuție echipamente	Romania	28	29.04.2018	Manager
5	MM S.R.L.	Distributie echipamente	Romania	7	15.05.2019	GM
6	BO S.A.	Genetică animală	France	66	21.07.2019	HR Director
7	EL S.A.	Producere energ. Electrică	Romania	1720	01.08.2020	Consultant
8	CT S.A.	Furnizare agent termic	Romania	3700	01.09.2021	GM
9	EL S.A.	Producere energ. electrică	Romania	1720	01.09.2021	VP
10	UAT	Servicii publice - UAT	Romania	256	10.12.2021	Consultant
11	CA INT. S.R.L.	Producție și comerț alimentar	Romania	2500	05.03.2022	HR Director
12	CA INT. S.R.L.	Producție și comerț alimentar	Romania	2500	06.03.2022	Manager
13	CA INT. S.R.L.	Producție și comerț alimentar	Romania	2500	02.04.2022	Consultant
14	CA INT. S.R.L.	Producție și comerț alimentar	Romania	2500	04.04.2022	GMA

15	CA INT. S.R.L.	Producție și comerț alimentar	Romania	2500	10.04.2022	Manager
16	CA INT. S.R.L.	Producție și comerț alimentar	Romania	2500	12.04.2022	Manager
17	AV S.R.L.	Abator	Romania	1000	10.05.2022	GM
18	Media trustului CA	Producție și comerț alimentar	Romania	2500	11.05.2022	media
19	CT S.A.	Furnizare agent termic	Romania	3700	01.06.2022	Manager
20	Întreprindere 4.0	simulare	Romania	100+	01.06.2023	

5.2.1. Case study 1 BO S.A.

The study was done for a company in France, a subsidiary of a multinational company that has subsidiaries in the United States, Europe, China, Russia, India and South Africa. The company was performing well, as expected. The information was provided in an interview with the regional HR director responsible for France, Italy, Germany and Poland and South Africa. Based on the information listed in the tables below we have assessed and summarized the company's situation in October 2016 and July 2017 and July 2019 respectively.

The results of the first completed questionnaire from 01.10.2016 are shown in the table below:

Table 5.4 Results of the first questioner BO S.A.

Caracteristics	**A**	**B**	**Δ**	**|Δ|**	**Ae**	**Be**	**Δe**	**|Δe|**
1,00	5,00	1,00	4,00	4,00	5,00	1,00	4,00	4
2.1.1	1,00	2,00	-1,00	1,00	3,17	2,50	0,67	0,67
2.1.2	1,00	4,00	-3,00	3,00				
2.1.3	5,00	2,00	3,00	3,00				
2.2	5,00	1,00	4,00	4,00				
2.3.1	2,00	1,00	1,00	1,00				
2.3.2.	5,00	5,00	0,00	0,00				
3.1.1	1,00	1,00	0,00	0,00	1,33	2,33	-1,00	1,00
3.1.2	2,00	5,00	-3,00	3,00				
3.1.3	1,00	1,00	0,00	0,00				
4.1	3,00	2,00	1,00	1,00	4,00	3,50	0,50	0,50
4.2	5,00	5,00	0,00	0,00				
5,00	3,00	3,00	0,00	0,00	3,00	3,00	0,00	0
Organization	**∑A**	**∑B**	**∑Δ**	**∑Δabs**	**∑Ae**	**∑Be**	**Δro=∑Δe**	**Δabso**
	39,00	33,00	6,00	20,00	16,50	12,33	4,17	6,17
	∑Ai	**∑Bi**	**∑A+∑B**	**∑|A-B|**	**Itre**	**Itabse**	**Fd A**	**Fd B**
Leadership	5,00	1,00	6,00	4,00	1,33	1,33	6,67	1,33
Structure	19,00	15,00	34,00	12,00	0,24	0,71	2,24	1,76
Proceses	4,00	7,00	11,00	3,00	-0,55	0,55	0,73	1,27

People	8,00	7,00	15,00	1,00	0,13	0,13	0,53	0,47
Results	3,00	3,00	6,00	0,00	0,00	0,00	0,00	0,00

∑(A+B)/2	Itabso	Itro	Is	Is (%)
36,00	0,56	0,17	0,70	70,00

The calculation of the complementary factors of the elements of the organisation results in the simple centrifuge - centrifuge diagram as shown in Figure 5.1.

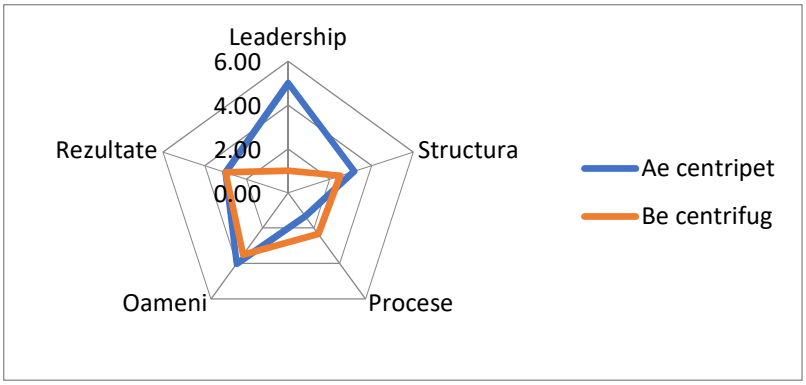

Fig. 5.1 Simple centrifuge-centrifuge diagram case study 1 - Bo

The calculation of the dispersion factors of the elements of the organisation results in the centrifugal-centripetal dispersion diagram as shown in Figure 5.2.

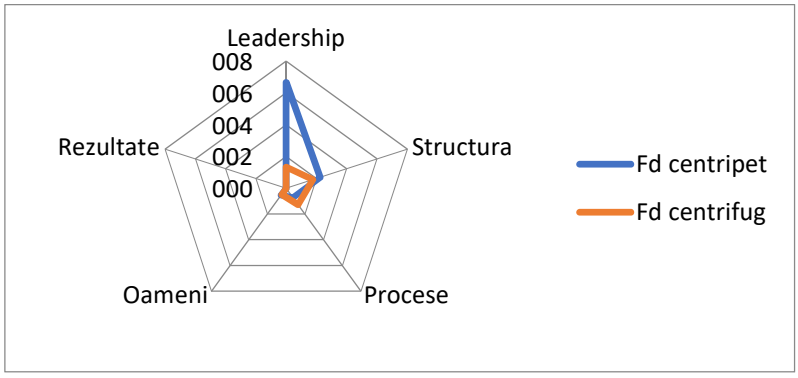

Fig. 5.2 Centrifugal-centrifugal dispersion diagram case study 1 - Bo

5.2.1.1. Case analysis

5.2.1.1.a. Analysis of complementarity factors:

The following characteristics are very poorly defined with very low complementarity factors (1 point):

- democratic management
- vertical differentiation

- strong formalisation
- divisional design
- renewal strategy
- internal process change
- external process change
- formal learning
- informal learning

The following characteristics are poorly defined with low complementarity factors (2 points):

- horizontal differentiation
- dispersion
- corporate growth strategy
- internal recruitment
- desired organisational culture

All of the very poorly defined or poorly defined characteristics identified have potential for development.

5.2.1.1.b. Trends analysis

The organisation has very strong tendencies for the following characteristics:
- Element: Leadership; Characteristic: Management - centripetal tendency
- Element: Structure; Characteristic: Design - centripetal tendency

The organization has strong tendencies for the following characteristics:
- Element: Structure; Characteristic: Formalization - centripetal tendency
- Element: Structure; Feature: Centralization - centripetal tendency
- Element: Processes; Characteristic: Recruitment - centrifugal tendency

The organization has no average centripetal or centrifugal tendencies.
The Leadership element of the organisation has a strong centripetal tendency.
The relative tendency of the organisation is 4.17 i.e. it is a strong centripetal tendency. The absolute trend of the organization is 6.17 i.e. it is a weak centripetal trend.

5.2.1.1.c. Turbulence index and stability index analysis

- Relative turbulence indices

Leadership - Itr = 1.33. The potential for change in this element is very high. The changes that can occur can be rapid and large in magnitude. They may also lead to changes in the Structure element, whose turbulence index value for Structure is Itr = 0.24, which already indicates a weak tendency to change. The relative turbulence index Processes has a value showing a medium tendency for the element to change. The value of the Relative Turbulence Index for the People element shows that its tendency is to maintain the current status which leads us to predict that the change in processes may create resistance problems from staff. The results tend to remain unchanged. The relative turbulence index of the organisation, Itro =0.17 indicates that the organisation tends to maintain its current status.

- Absolute Turbulence Indices

The high values of the absolute turbulence indexes of the Leadership, Structure and Process elements (greater than 0.5) indicate that changes need to be made in these organisational elements to decrease the absolute turbulence indexes. The value of the absolute turbulence index of the organisation is also too high, Itrabs=0.56. The value of this index reinforces the above statements about the imminence of changes within the organisation, specifically in the Leadership element.

Percentage wise, the value of the Index of Stability of the organisation is 70%, a value that cannot lead us to say that the organisation is stable.

5.2.1.2. Conclusions of the analysis

The organisation is run in an authoritarian way, with an underdeveloped structure. Procedures are arbitrary, waiting to be validated by the Director-General. The organisation is underdeveloped, no significant procedural changes are expected, there is no interest in developing the organisation, preserving the existing culture of the organisation. However, we believe that the overly authoritarian management will have to increase the vertical structure of the organisation, redefine the job descriptions of the employees and put more emphasis on the learning and training process of the employees. The high relative and absolute turbulence indices identified for leadership, structure and processes lead us to expect that staffing problems will arise in the long term.

5.2.1.3. Proposals

- Introducing an additional level of management to take over some of the tasks of the Director-General.
- Clearer differentiation of administrative and task groups.
- Check job descriptions within the company.
- Delegating part of the management act by strengthening the positions of the HR, sales and operational directors.
- Reassess the company's organisation chart
- Establishing with the HR Director policies for the promotion of existing staff within the company.
- Establish learning and training programmes for staff.
- Discuss bonus schemes for employees to motivate them.

5.2.14. Case study – Entreprise 4.0

Industry 4.0 is in a process of definition and identification. It cannot be said that there is an explicit organisational profile, at least at this stage. We have not been able to identify any companies willing to help in this modelling, as the actual and declared number of 4.0 companies is in any case relatively small. The request sent to such companies to participate in this questionnaire went unanswered. In these circumstances it was very difficult to move forward with the proposed research. However, given that Industry 4.0 is still in its infancy, we can discuss a theoretical model to which to refer later.

Given that our model is a model valid for any type of organisation, we can also do the analysis of a theoretical model. Under these circumstances, based on the organisational model created, we simulated the profile of a 4.0 company, completing the questionnaire used in the analysis of the other companies so far. The results, as in the other companies, have been analysed, drawing the two diagrams: the simple centrifuge-centripole and the scatter diagram. The possible profile of Enterprise 4.0 was created in such a way as to highlight its features. Here is the result:

Table 5.26

Elements of the organisation		Caracteristics	*A*- Complementary centripet factor	*B*- complementary centrifuge factor	*A-B*
1. LEADERSHIP	**1. Management**	1.Managerial Competence	Omnipotent	Symbolic/ Democratic	
			1	5	-4
2. STRUCTURE	**2.1. Structure**	2.1.1 Complexity	Vertical differentiation	Horizontal differentiation	
			1	5	-4
		2.1.2 Formalisation	Strongly structured	Permanently adaptable	
			1	5	-4
		2.1.3 Centralisation	Concentrated	Dispersed	
			5	5	0
	2.2. Design	2.2 Structurarily	Functional	Divisional	
			5	5	0
	2.3. Strategies	2.3.1 Corporate	Growth	Renewal	
			5	5	0
		2.3.2 Competitive	Better	Different	
			1	5	-4
3. PROCESES	**3.1. Proceses**	3.1.1 Proces change	Internal	External	
			1	5	-4
		3.1.2 Recrutment	Internal	External	
			5	5	0
		3.1.3 Learning	Formal	Informal	
			5	1	4
4. PEOPLE	**4.1. Culture**	4.1.1. Culture	Exist	Wanted	
			1	5	-4
	4.2. Relationships	4.2.1. Relationships	Formal	Informal	
			5	1	4
5. RESULTS	**5. Results**	5.1.1. Results	Internal	External	
			5	5	0

Below, Table 5.27 shows the calculated simulation results for Enterprise 4.0.

Table 5.27 Estimated results for an 4.0 enterprise

Caracteristics	A	B	Δ	|Δ|	Ae	Be	Δe	|Δe|
1,00	1,00	5,00	-4,00	4,00	1,00	5,00	-4,00	4
2.1.1	1,00	5,00	-4,00	4,00	3,00	5,00	-2,00	2,00
2.1.2	1,00	5,00	-4,00	4,00				
2.1.3	5,00	5,00	0,00	0,00				
2.2	5,00	5,00	0,00	0,00				
2.3.1	5,00	5,00	0,00	0,00				
2.3.2.	1,00	5,00	-4,00	4,00				
3.1.1	1,00	5,00	-4,00	4,00	3,67	3,67	0,00	0,00
3.1.2	5,00	5,00	0,00	0,00				
3.1.3	5,00	1,00	4,00	4,00				
4.1	1,00	5,00	-4,00	4,00	3,00	3,00	0,00	0,00
4.2	5,00	1,00	4,00	4,00				
5,00	5,00	5,00	0,00	0,00	5,00	5,00	0,00	0
Organization	**∑A**	**∑B**	**∑Δ**	**∑Δabs**	**∑Ae**	**∑Be**	**Δro=∑Δe**	**Δabso**
	41,00	57,00	-16,00	32,00	15,67	21,67	-6,00	6,00
	∑Ai	**∑Bi**	**∑A+∑B**	**∑|A-B|**	**Itre**	**Itabse**	**Fd A**	**Fd B**
Leadership	1,00	5,00	6,00	4,00	-1,33	1,33	1,33	6,67
Structure	18,00	30,00	48,00	12,00	-0,50	0,50	1,50	2,50
Proceses	11,00	11,00	22,00	8,00	0,00	0,73	2,67	2,67
People	6,00	6,00	12,00	8,00	0,00	1,33	4,00	4,00
Results	5,00	5,00	10,00	0,00	0,00	0,00	0,00	0,00

∑(A+B)/2	Itabso	Itro	Is	Is (%)
49,00	0,65	-0,33	0,50	50,00

The calculation of the complementary factors contained in Table 5.27 of the elements of the organization results in the simple centrifuge - centrifuge diagram as shown in Figure 5.29.

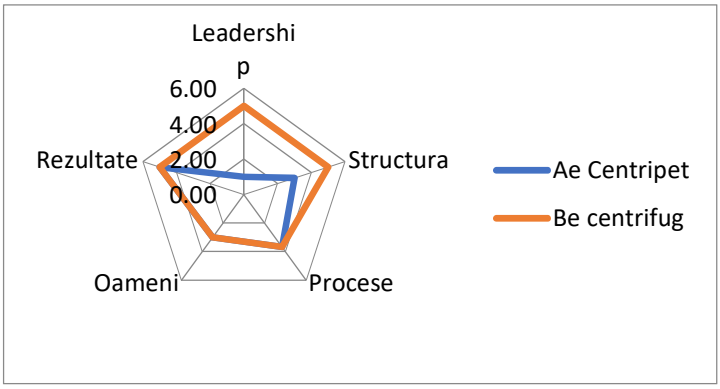

Fig.5.31. Centrifugal centripetal diagram. 4.0 Case study Company

The calculation of the dispersion factors of the elements of the organisation results in the centrifuge-centripetal dispersion diagram as shown in Figure 5.30.

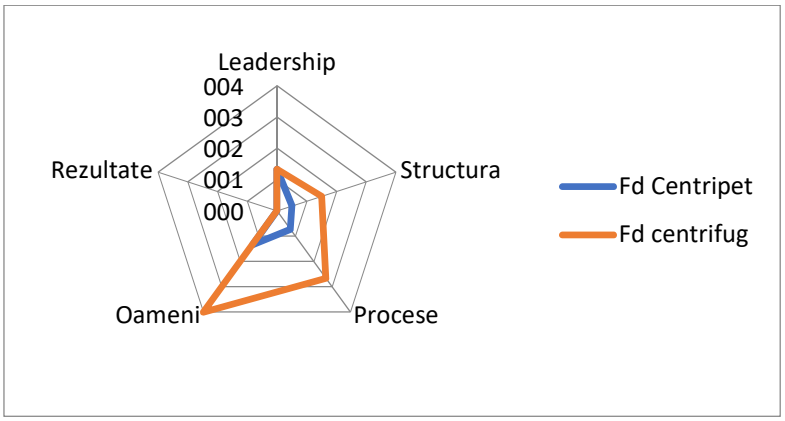

Fig. 5.30 Centrifuge-centripetal dispersion diagram. Case study Enterprise 4.0

5.2.14.1. Case analysis

5.2.14.1.a. Analysis of complementarity factors:

The following features are very poorly defined with very low complementarity factors (1 point):

- omnipotent management
- vertical differentiation
- strong formalisation
- better competitive strategy
- internal process change
- informal learning
- existing organisational culture

5.2.14.1.b. Trends Analysis

The organisation has very strong tendencies for the following characteristics:

- Element: Leadership; Characteristic: Management - centrifugal tendency
- Element: Structure; Characteristic: Complexity - centrifugal tendency
- Element: Structure; Characteristic: Formalization - centrifugal tendency
- Element: Structure; Characteristic: Competitive strategy - centrifugal tendency
- Element: Processes; Feature: Process change - centripetal tendency
- Element: Processes; Feature: Learning - centripetal tendency
- Element: Processes; Feature: Employee relations - centrifugal trend.

The relative tendency of the organisation is -16 i.e. it is an imbalance tendency. The organisation has a dissolution tendency. Action needs to be taken. The absolute trend of the organisation is 6 i.e. it is a strong centripetal trend. This indicates that action needs to be taken.

5.2.14.1.c. Turbulence index and stability index analysis

- Relative turbulence indices

Leadership - Itr = 1.33. There is a strong tendency for the item to change. Relative Turbulence Index Structure has a value (0.5) indicating a medium tendency for the item to change. The values of the Relative Turbulence Index of zero for the elements Processes, People and Results show that their tendency is to maintain the current status which leads us to predict that their change may create serious resistance problems on the part of the staff. The relative turbulence index of the organisation, Itro =-0.33 indicates that the organisation tends to maintain its current status.

- Absolute Turbulence Indices

The maximum values of the absolute turbulence indices of the Leadership and People elements (1.33) tell us that changes need to be made in these organisational elements as soon as possible. The Structure and Process elements also have high values indicating the need for change in these elements. The Absolute Heat of the Organization (0.65) tells us the same thing. Percentage wise, the Organisation Stability Index value is 50%, which leads to changes in the organisation. The interpretation is as follows: significant changes have to be made in the organisation's processes, its members are opposed, the results determine the maintenance of the status, which generates a high degree of instability for the company making change management difficult.

5.2.14.2. Conclusions of the analysis

There is a strong centrifugal tendency in the organisation which can lead to its dissolution. The leader needs to be much more engaged in the management process. Without support from specialists through constant communication, the leader cannot make the best decisions for the organisation. On closer examination, we see that very strong centrifugal tendencies are also emerging in the structure. There is a need to develop a middle level of management that is represented by technology specialists to bridge the gap between the top level of management and the rest of the employees. There is also a need to increase the formalisation of the organisation by setting precise tasks in the organisational monitoring processes of technological integration within the structures and interaction with the external business environment. The better competitive strategy can be implemented by introducing regular training sessions for employees, while at the same time aiming to increase their creativity. A process improvement department can solve internal process improvement problems. Continuous process automation leads to prioritisation of formal training, standardisation. Simulation and upgrading offered by software causes the informal way of learning to take on less and less importance. With more and more work being done "from home" - a way that has often been adopted as a solution during the pandemic - computer and internet-assisted interactions between people, the use of email, teleconferencing, are leading to a reduction in informal relationships, and the stimulus of direct contact between people tends to disappear. This risks diminishing creativity at organisational level, entering into a recurrence that can create problems for the organisation. Competitors may also use the same technological solutions and achieve similar results. In this case, differentiation will play a more important role. A significantly affected element is the creative element, weakened both by reduced training and informal relationships.

5.2.14.3. Proposed measures

- Establish an effective way of information and communication between senior management and technology specialists.
- Introduce technology and HR specialists into senior management positions
- Preparing specialists for management positions
- Establishing effective methods of collaboration between management and HR
- Placing a strong emphasis on the ongoing recruitment of people both inside and outside the organisation
- Employee training to maintain a balance between formal and informal
- Cultivating a creative environment in the organisation with the support of HR that reinforces the competitive strategy aimed at differentiation from the competition.
- Finding solutions that monitor and facilitate the development of informal relationships between members of the organisation.

5.2.14.4. Observations

The analysis was based on a simulation of a 4.0 enterprise in which certain complementary factors were emphasised and others were blurred, in order to highlight certain trends in the organisation. In this way, organisational issues that may arise in this type of enterprise were identified.

5.3. Enterprise 4.0 analysis and assessment tool

As we have seen, this organisational analysis tool has been designed so that it can make assessments for any type of organisation, whatever its nature. It can be extended. New features can be added and appropriate complementarity factors identified. As shown in chap. 2.4, a 4.0 enterprise has a number of specificities, which can be summarised in one word: technology. As presented in chap. 2.3.2, the other models may or may not introduce Technology as an element. We believe that another approach is to include Technology as a characteristic for each element of the model and to define, for each element, the two complementary factors.

5.3.1. Technological characteristics and complementarity factors

In order to obtain an analysis and evaluation tool specific to Enterprise 4.0, we introduced a technological characteristic for each element of the model and identified the corresponding complementarity factors.

5.3.1.1. Element: Leadership, Characteristic: Information Access

The way in which the organisation's management is connected to the internal information flow is the central factor of the technological characteristic. We therefore say that **internal information access** is the centripetal factor of this characteristic.
In the current conditions the whole business model is changing, the emergence of e-business [145] [146] [147] and other tools, have shown the importance of digital platforms [148] in the

context of industry 4.0. For the access to necessary information from the external environment we designate as a complementary centrifugal factor, **external information access**.

5.3.1.2. Element: Structure, Feature: Technological Organizational Model.

An organisational study on the Industry 4.0 model concluded that "there can be different organisational models because in some cases these technologies allow for organisational design aimed at developing employee engagement, and in other cases they allow for organisational design aimed at increasing employee control." [149]]. We designate as complementary factor centripetal **driven engagement** for the feature Technological organizational model and as complementary factor centrifugal **autonomous engagement.**

5.3.1.3. Element: Processes, Characteristic: Degree of integration

Vertical and horizontal integration are features of Industry 4.0 [150]. We can designate **vertical integration** as a centripetal complementarity factor. It includes the integration of digital systems at all levels of the organisation. Digital links with suppliers, business partners, distributors and the transfer of data with them determine **horizontal integration** [151]. We therefore refer to horizontal integration as the centrifugal complementarity factor.

5.3.1.4. Element: People, Feature: degree of technological connectivity.

Connectivity is an important factor in business cooperation finding simple solutions to increase efficiency, in obtaining products and services [152]]. [153].].
Augmentation - another feature of Industry 4.0 creates the opportunity for employees to work more easily and efficiently. The way members of an organization communicate with the external environment is very important nowadays [154] [155] [156]. Access to information of any kind gives the possibility to find quick solutions both internally and externally [157]]. We consider that the degree of internal connectivity is the centripetal factor for the characteristic Degree of technological connectivity, and the degree of external connectivity is the complementary centrifugal factor.

5.3.1.5. Item : Results, Feature: Customization

Industry 4.0 has made the value chain more responsive, allowing industrial manufacturers to reach customers in a more direct way, adjusting their business model accordingly, digitizing the customer relationship [158] [159] and customizing the product [160]. At the same time, perfectly adapting the workplace to the specificities of the workforce leads to optimised results [161]. All this is possible thanks to digitisation and automation by default of technology. Digital twin technology can mimic and replicate real workspaces, situations and processes in the enterprise, which gives greater flexibility and gives the possibility to reduce the number of workers in the real production space giving the possibility of remote monitoring of processes [162] and giving the possibility of workplace customisation. We consider product customization as a complementary centrifugal factor of the Customization feature and workplace customization as its centripetal factor.

5.3.1.6. New assessment and analysis tool for Enterprise 4.0

This makes the analysis tool dedicated to Industry 4.0. Below in Table 5.28 is the new resulting questionnaire.

Table 5.28. New questionnaire developed dedicated to Enterprise 4.0

	4.0.1.		
Nr. crt.	**Statements describing the company**	**Ind.**	**Punctaj**
1.	Management is directly responsible for failure or success.	1.1. A	**1**
2.	Much of its success or failure is due to external forces that the manager manages.	1.1. B	**5**
3.	Management has real-time access to all information about the organization.	1.2. A	**5**
4.	Management is connected to the most advanced external platforms related to the organization's activities.	1.2. B	**5**
5.	The vertical structure is differentiated in terms of management layers.	2.1.1 A	**1**
6.	The company's horizontal structure in terms of occupational, administrative, and task groups is differentiated.	2.1.1 B	**5**
7.	Job descriptions in the company are strict and well outlined.	2.1.2 A	**1**
8.	Positions in the company are flexible and adaptable.	2.1.2 B	**5**
9.	Orders come from the center.	2.1.3 A	**5**
10.	Orders come from multiple management centers.	2.1.3 B	**5**
11.	The structure is functional (divided into functional departments).	2.2 A	**5**
12.	The structure is divisional.	2.2 B	**5**
13.	Corporate strategy is growth-oriented.	2.3.1 A	**5**
14.	Corporate strategy is renewal-oriented.	2.3.1 B	**5**
15.	Competitive strategy aims to be better (in terms of price, quality, speed, etc.).	2.3.2 A	**1**
16.	Competitive strategy aims to be different from other competitors.	2.3.2 B	**5**
17.	Organizational technological design aims to increase control over employees.	2.4.1. A	**1**

18.	Organizational technological design aims to increase employee engagement.	2.4.1. B	**5**
19.	Internal changes take place (personnel, equipment, implementations).	3.1.1 A	**1**
20.	External changes take place (changing the industry, replacing technology, different clients).	3.1.1 B	**5**
21.	Recruitment primarily focuses on those within the organization.	3.1.2 A	**5**
22.	Recruitment primarily focuses on those outside the company.	3.1.2 B	**5**
23.	Training is formal (uses written materials, tutorials, one-to-many courses).	3.1.3 A	**5**
24.	Training is informal (one-to-one courses, direct interaction at the workplace).	3.1.3 B	**1**
25.	The organization is technologically integrated vertically.	3.2.1. A	**5**
26.	The organization is technologically integrated horizontally.	3.2.1. B	**5**
27.	We rely on the people in the organization to deliver results.	4.1 A	**1**
28.	The proposed results drive the members of the organization to perform.	4.1 B	**5**
29.	Relationships between organization members are formal.	4.2 A	**5**
30.	Relationships between organization members are informal.	4.2 B	**1**
31.	The organization's internal communication system is highly developed.	4.3. A	**5**
32.	The organization's external communication system is highly developed.	4.3. B	**5**
33.	The organization's results are appreciated by customers.	5.1. A	**5**
34.	The organization's results are appreciated by its members.	5.1. B	**5**
35.	The products/services offered are customized.	5.2. A	**5**
36.	Jobs are technologically tailored to employees' requirements.	5.2. B	**5**

Tabelul cu rezultatele chestionarului a fost și el refăcut. Mai jos se găsește varianta nouă a tabelului cu rezultate dedicat întreprinderilor 4.0.

Tabelul 5.29. Varianta nouă a tabelului cu rezultate dedicat întreprinderilor 4.0

4.0.1.			FIȘA NR.1		
Elemente of the organisation		**Caracteristics**	***A*- Complementary centripet factor**	***B*- Complementary centrifuge factor**	***A-B***
1. LEADERSHIP	**1.1. Management**	**1.1. Management**	Omnipotent	Symbolic/ Democratic	
			1	**5**	**-4**
	1.2. Tehnology	**1.2. Informational access**	Intern	Extern	
			5	**5**	**0**
2. STRUCTURE	**2.1. Structure**	**2.1.1 Complexity**	Vertical differentiation	Horizontal differentiation	
			1	**5**	**-4**
		2.1.2 Formalisation	Strongly structured	Permanently adaptable	
			1	**5**	**-4**
		2.1.3 Centralisation	Concentrated	Dispersed	
			5	**5**	**0**
	2.2. Design	**2.2.1. Organisational Design**	Functiona	Divisional	
			5	**5**	**0**
	2.3. Strategies	**2.3.1 Corporate**	Growth	Renewal	
			5	**5**	**0**
		2.3.2 Competitive	Better	Different	
			1	**5**	**-4**
	2.4. Tehnology	**2.4. Organisational model**	Determined	Autonomus	
			1	**5**	**-4**
3. PROCESES	**3.1. Proceses**	**3.1.1. Proceses change**	Internal	External	
			1	**5**	**-4**
		3.1.2 Recruitment	Internal	External	
			5	**5**	**0**
		3.1.3 Learning	Formal	Informal	
			5	**1**	**4**
	3.2. Tehnology	**3.2. Integration**	Vertical	Horizontal	
			5	**5**	**0**

4. PEOPLE	**4.1. Culture**	**Organisational culture**	Exist	Wanted	
			1	**5**	**-4**
	4.2. Relationships between employees	**Relationships between employees**	Formal	Informal	
			5	**1**	**4**
	4.3. Tehnology	**Conectivity**	Internal	External	
			5	**5**	**0**
5. RESULTS	**5.1. Results**	**Results**	Internal	External	
			5	**5**	**0**
	5.2. Tehnology	**Customised**	Internal	External	
			5	**5**	**0**

5.4. Conclusions from testing the performance assessment and analysis tool

- In the vast majority of cases, the very weak absolute trend and high stability index was encountered in organizations with long-standing
- Two elements with strong biases in the system lead to poor results.
- Very strong element trends lead to changes in the organisation.
- Change in a very short time of more than 2 elements creates major disruptions in the system.
- The minimum value of a complementary factor indicates that the factor needs to be developed.
- There is a natural tendency for the system to balance. In general, the proposed solutions for balancing the system, or at least part of them, were already considered by the members of the organisation.
- Simultaneous intervention on more than two elements of the organisation creates imbalance.
- Achieving another type of outcome requires a change in the system even if the organisation is in balance.
- The very small value of the Relative Turbulence Factor of an element indicates that the element does not want to change its state.
- If there is no visible change in any element of the system, it is possible that the system is operating according to arbitrary rules other than those identified by the -natural- model of determination and, in this case, the predictive character of the model disappears.

CHAPTER 6. FINAL CONCLUSIONS AND MAIN CONTRIBUTIONS OF THE PAPER

1. From the analysis of the state of play on organisational diagnosis, important conclusions have been drawn, which are presented in Chapter 3.

2. In relation to the current status and directions of research and development on organisational diagnosis, in the context of their evolution towards Industry 4.0, it was determined as the main objective of the research and development activity within the PhD (see § 3.2): Design and development of a performance analysis tool that takes into account the current context of the evolution towards Industry 4.0.

3. The relevant conclusions from the research activity for the PhD in order to achieve its main objective, in relation also to the methodological benchmarks (see § 3.3), are the following:

- The building blocks of the model have been established.
- Based on the study of the constitutive elements of the other organisational models, representative elements for a model that aims to be able to analyse the organisation in the context of the transition to Industry 4.0 have been identified and selected (see § 4.1).
- The relationships that are established between the elements of the model have been identified.

There were 2 premises:

1. There is a determination relationship between the elements of the model. Based on the identification of determinations between elements - who determines whom - a cycle of determination between model elements was established.

2. The model elements are subject to centripetal and centrifugal forces that lead either to their centring, their stiffening, or to their dissolution, their flexibilisation. (v. § 4.2).

- The characteristics of the elements have been established. On the basis of the literature, the characteristics considered representative for the model elements were determined. For each characteristic established, complementarity factors were identified, factors that represent the manifestations of the two centrifugal-centripetal forces. (v. § 4.3).
- An assessment and analysis tool for organisations has been developed. On the basis of the diagnostic model obtained, a tool was created to analyse and evaluate a company. (see § 4.4.) The tool was validated by analysing and evaluating 17 organisations of various types and sizes and comparing it with another analysis tool. (v. § 5.2).
- A variant of the tool adapted for the analysis and evaluation of enterprises 4.0. was developed (see § 5.3), adding one technological characteristic for each element of the model to the original analysis tool

6.1. Final Conclusions

This paper has provided answers to the questions in § 2.1:

1. Enterprise 4.0 as a representative of technological evolution, has influenced organisational diagnosis causing technology to become a main factor in subsequent modelling.

2. If the previous observation is taken into account, it is possible to obtain an organisational model suitable for Industry 4.0 that can lead to a dedicated analysis and evaluation tool.

3. Given that the vast majority of analysis tools dedicated to Enterprise 4.0 are for assessing the maturity or readiness for Industry 4.0, there is also a need for an analysis and assessment tool that identifies the traditional problems of an organisation of this type.

4. The introduction of technology analysis for each constituent element of the organisational model is the most important adaptation for the organisational diagnosis of a 4.0 enterprise.

5. The differences between the analysis of an organisation and a 4.0 enterprise are due to the fact that although a 4.0 enterprise can be analysed like any other organisation, we do not have enough details about the technological component for a more detailed assessment.

6. With the paradigm shift produced by Industry 4.0, the paradigm shift of organisational diagnosis becomes a necessity.

The transition to Industry 4.0 has brought the need to assess the status of companies in terms of technological maturity, organisational readiness for 4.0 and change management. The need for analysis, as shown in this paper, has created several tools to assess enterprises in the context of Industry 4.0. but has not, so far, created an organisational diagnosis model nor a dedicated tool. This was the purpose of the present research, to provide such a model. Although there are ways to assess readiness for Industry 4.0, maturity, level of technology and digitisation but there is no uniform approach from an organisational point of view. The relationships that are established between the elements of the model cannot be analysed. The assumption that technology is a neutral factor that only benefits all actors involved is not able to satisfy the requirements of such an analysis. All these analyses and evaluations could be carried out on the basis of the proposed model and the analysis and evaluation tool.

The proposed diagnostic model provides a different view of organisations that need to identify imbalances and the situation they are in. The model makes it possible - based on the cycle of determining the model elements - to anticipate situations generating future problems. At the same time, the model helps to understand an enterprise 4.0 from an organisational point of view and to optimise it. Both the analysis tool created and the diagrams showing the determinants and determinations can describe the overall situation in an enterprise. It is possible to further refine them to highlight in more detail the existing problems in a company, if needed once the methodology has been established. This is true for both the validated diagnostic tool and the customised one proposed for Enterprise 4.0. This can only be done by analysing several companies with different organisational cultures in order to introduce new application formulas. The implementation of Industry 4.0 will certainly generate major changes in all areas. It can be seen that some of the strategies, processes and some of the operational management of companies are taken over by intelligent machines capable of learning and streamlining production. Using autonomous optimisation algorithms, in terms of operational innovation machines can effectively replace humans. However, exploratory innovation and especially continuous innovation [163] remain the task of managers and other members of the organisation. As seen from the analysis of the Enterprise 4.0 model, it requires the willingness of the general manager to create an innovation-friendly environment, which can be achieved

with the help of others in management positions and those in the HR department. There is a need for continuous training of the members of the organisation to develop professional skills, which managers are beginning to understand [164], and at the same time there is a need to establish a training framework [165]. Only an environment conducive to innovation can stimulate organisational members to be creative, an environment cultivated by management and HR [166]. The diagnostic model together with the analysis and evaluation tool described in this paper are intended to assist managerial decisions in this critical area for long-term performance.

6.2. Personal contributions

To the achievement of the main objective of the doctoral research and development activity, the present PhD thesis brings a number of contributions, the most important of which are the following:

- the creation of a new approach in the diagnosis of organisations by introducing a new diagnosis model
- the creation of an analysis and evaluation tool for all types of organisations
- validation of a new analysis and assessment tool for all types of organisations
- introducing a new analysis and assessment tool for enterprises 4.0 that can be algorithmic

The present PhD thesis, by its problematics, approach and results, develops organisational diagnosis in general as well as analysis and evaluation of Enterprise 4.0 from an organisational point of view by providing a mathematical method of working.

The scientific importance of the present PhD thesis is supported by the contributions made through the publication of the following scientific papers:

1. **Baicu, Andrei Valentin** (2017). Methods of Assessment and Training of a Company Towards the Enterprise 4.0, Proceedings of the 28th DAAAM International Symposium, pp.1065-1073, B.
Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-11-2, ISSN 1726-9679, Vienna, Austria
DOI: 10.2507/28th.daaam.proceedings.148
https://www.daaam.info/Downloads/Pdfs/proceedings/proceedings_2017/148.pdf,
https://1010e86uf-y-https-www-scopus-com.z.e-nformation.ro/record/display.uri?eid=2-s2.0-85040713986&origin=resultslist&sort=plf-f&src=s&sid=ec859fed38bd1e3d69a5d2d47c5f7edb&sot=b&sdt=b&s=TITLE-ABS-KEY%28Methods+of+Assessment+and+Training+of+a+Company+Towards+the+Enterprise+4.0%29&sl=89&sessionSearchId=ec859fed38bd1e3d69a5d2d47c5f7edb

2. Crețu, Claudiu; **Baicu, Andrei**; Livan, Alina; Demeter Mihai, Ludovic; (2021). Future-Proof for Improving Urban Life through Enhanced Public Service Delivery; Articol publicat de Review of International Comparative Management, Volume 22, Issue 2, May 2021 261, JEL: H0, H4, M1. DOI: 10.24818/RMCI.2021.2.261, CNCSIS CODE: 361. link: http://rmci.ase.ro/no22vol2/12.pdf, https://econpapers.repec.org/article/romrmcimn/v_3a22_3ay_3a2021_3ai_3a2_3ap_3a261-273.htm

3. **Baicu, Andrei**; George, Căruțașu; (2022). Proposing a method of organizational diagnosis. Study case. Conferința 38-IBIMA Seville, Spain 23-24 Nov.2021 link: https://ibima.org/accepted-paper/proposing-a-method-of-organizational-diagnosis-study-case/ Indexing | International Business Information Management Association (IBIMA)

4. **Andrei Valentin BAICU**, Costel Emil COTEȚ, Lidia PARPALĂ, Analysis of an enterprise based on a new diagnosis model, Proceedings in Manufacturing Systems, Vol. 16, Iss. 4, (2021), pp. 151-156 link: http://icmas.eu/Volume16_Issue4_2021.htm#pp_93-98

5. **Baicu, Andrei;** Voican Sorin; (2023). Increasing the efficiency of District heating. Case Study.

The practical importance of this PhD thesis lies in the fact that the proposed diagnostic model, the analysis and evaluation tools developed represent a useful support system for teachers, organisations, specialists and companies, as appropriate. The method gives the possibility of permanent adaptation of the tool.

6.3. Prospects for further development

The problem of organisational diagnosis, analysis of enterprises - especially those in transition to Industry 4.0 - requires continuous research and development and analytical work, determination of all the technological characteristics corresponding to the elements of the diagnosis model, questioning as many enterprises as possible for analysis and evaluation. The results obtained can refine the analysis and evaluation tool, making it a very effective working tool when organisational diagnosis is needed for the enterprises concerned, and can provide answers to problems arising in the management of an enterprise and the choice of appropriate technology in direct correspondence with human resources. Another possible and necessary direction of development is the algorithmization of the tool. Digitization of the tool makes it possible to use it on a large scale, and it can become an easy tool for managers and senior staff of organizations. Periodic analysis and evaluation can be made, allowing the evolution of the organisation to be tracked over time. Real logbooks can be produced in which the company's activity can be quantified. Thus, on the basis of the data collected and the tool used, company-specific indicators can be found that can better describe the company's activity. New characteristics and complementarity factors identified from the diagnostics carried out can be added or the model can be readjusted as technological complexity increases. Based on the model and the tools presented in the paper, integrative solutions can be developed that can provide good support for the new Industry 4.0 that has started to develop.

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