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Reducing Risks in Energy Innovation Projects: Complexity Theory Perspective

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Abstract: The aim of this paper is to contribute to existing work on project risk management, and energy innovation projects, using the lens of complexity theory. By regarding energy innovation projects as complex adaptive systems, and linking complexity theory elements to the possibilities for reducing risks of energy innovation projects, the authors conducted empirical research on a representative sample of 100 subjects. The authors used a questionnaire that was formed on the basis of a previously designed research model, which unifies several different management fields, and a large number of phenomena previously studied independently. Therefore, it has a holistic approach to the topic. The results of this research suggest that considering the elements of complexity theory had a positive impact on reducing risks in energy innovation projects, in all analyzed aspects including specific, operational, and especially regarding social and behavioral aspects. This paper strives to support and encourage better results in energy innovation projects by reducing their risks, and hopes to bring additional value by introducing a new risk philosophy, based on complexity theory. Lessons learnt regarding each issue of this research are points of concern for project managers.

Keywords: complexity theory; energy project; innovation project; risk reduction

1. Introduction

1.1. The High-Risk Potential of Energy Innovation Projects

Energy innovation has always had a significant role in the development of human society. It represents an indispensable factor for establishing competitiveness for environment sustainability and sustainable development and is implemented through energy innovation projects (EIP).

EIP characteristics require special attention because of the following reasons:

- Megaprojects: Despite huge financial investments in megaprojects, historical data indicate very poor performance [1].
- Innovative feature of EIPs: When it comes to innovation projects, goals often remain unclear and are vaguely defined; processes tend to be experimental and exploratory, while the risks run high [2]. A high failure rate, and the need to stimulate creativity [3], sets innovation projects apart from other types of projects as well as constant learning.
- Multidisciplinary project teams are common characteristics of both megaprojects and innovative projects.
- EIPs try to reconcile contrary concepts of sustainable development and project management [4] (which are represented in Table 1).

- Many stakeholders, often with conflicting interests [5].
- Difficult decision making as consequence of the previous two characteristics.
- Numerous threats from the environment, which are hard to predict [5].

Table 1. Contrary concepts of sustainable development and project management [4].

Sustainable Development	Project Management
Long-term and short-term oriented	Short-term oriented (i.e., during project life cycle)
In the interest of this generation and future generations	In the interest of sponsor/stakeholders
Life-cycle oriented	Deliverable/result oriented
People, planet, and profit	Scope, time, and budget
Increasing complexity	Reduced complexity

The high-risk potential of EIPs (presented in Figure 1) is reflected in EIP characteristics by balancing the 'energy trilemma' elements, i.e., three core elements of energy sustainability: Energy security, energy equity, and environmental sustainability. These are defined by The World Energy Council [6]. Therefore, we can conclude that EIPs are very 'risky' and highly challenging ventures that are closely-connected to energy sustainability.

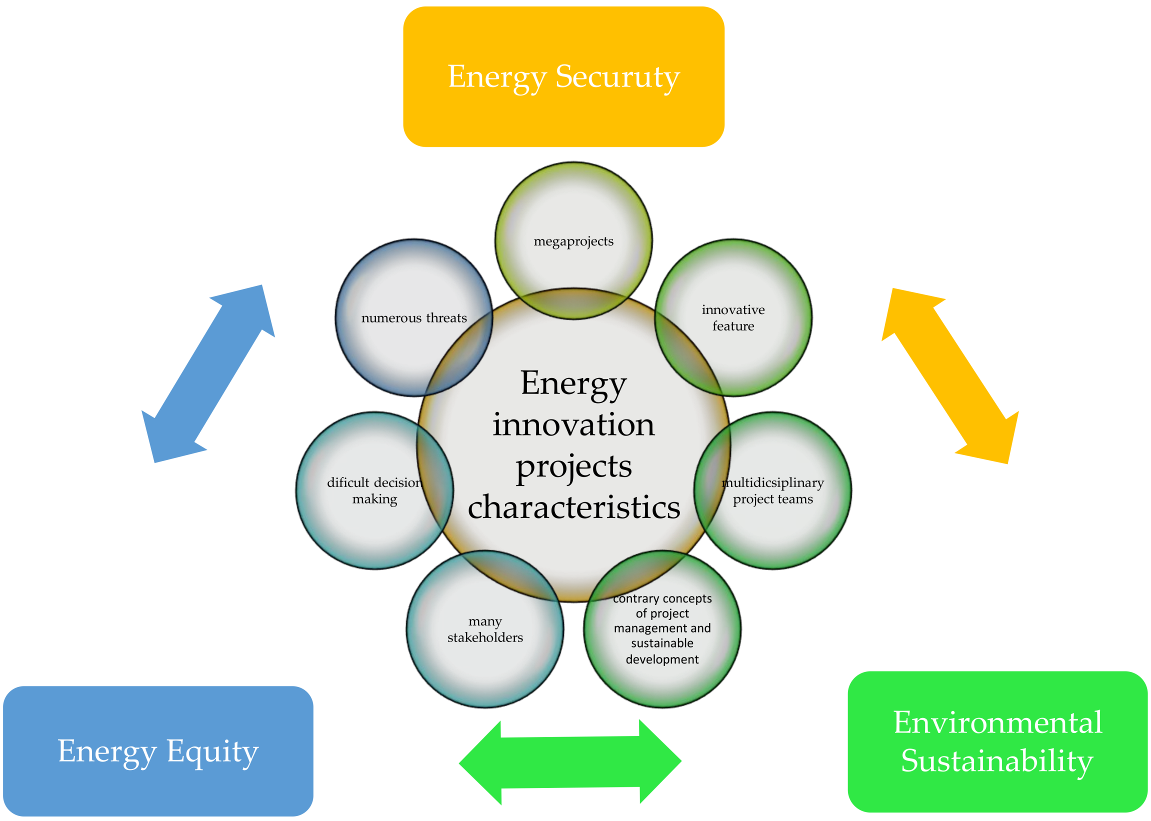

Figure 1. The high-risk potential of energy innovation projects (EIPs): EIP characteristics within balancing the 'energy trilemma' elements.

Advanced risk management and utilization of project knowledge represent the key aspects of sustainability projects [7]. The factor that greatly influences the success of an energy innovation project is the ability of a project manager to the manage risks within it. Although the success of a project is relative, project risk management is of essential importance for ensuring project success [8]. Even though the risk is a crucial issue for innovations, it has not been examined explicitly [3]—and therefore, demands additional attention.

1.2. Energy Innovation Projects as Complex Adaptive Systems (CAS)

Complexity science has found application in project management [9] and innovation [10], but in the energy domain it still belongs to the emerging area of interest [11]. Since EIPs are significant for sustainable development, which we believe is one of the imperatives for the future of human society, one of the aims of this paper is to encourage that interest.

Keeping in mind that there are analogies between projects and complex adaptive systems (CAS) [12], innovation and CAS [13], and energy systems and CAS [11], the idea of this paper is to encompass all these similarities in energy innovation projects as a whole. The analogy between EIPs and CAS is reflected in several important points (adapted according to Reference [14]):

- Both consist of a vast number of different elements that interact with each other, and must constantly adapt to changing environmental conditions. There is a complex implementation of many project activities [5], and there are many actors of energy systems that interact through networks, e.g., physical and social structures [11].
- Uncertainty in the long run is the common characteristic of both EIPs and CAS. Unlike risks, there is no way to calculate uncertainty (or 'the unknown unknowns'), because we cannot imagine it [15]. Although managing uncertainty sounds a bit 'oxymoronic' [16], the same author believes that experimental learning can reduce uncertainty.
- Since innovation does not represent a linear process [17], the innovation feature of energy projects, by its very nature, contains elements of non-linearity or nonlinear behavior (for example, technical systems when operated close to saturation). Creativity is often brought in connection with a chaotic, experimental, unpredictable atmosphere, and poorly structured process [18], therefore engaging more people in the creative processes does not necessarily mean achieving better energy performances.
- In far-from-equilibrium conditions, positive (reinforcing) feedback loops convert small inputs into gigantic changes [19], which is also known as the butterfly effect which is present in innovation processes and energy systems. Positive (reinforcing) feedback loops are also present in social structures For example, bad interpersonal relations can cause the failure to achieve desired results; consequently, the lack of desired results can cause bad interpersonal relations and so on (domino effect).
- Self-organization means that there is no agent in the system with absolute control, and there is cooperation of mutually dependent agents (individuals). Self-organization is spontaneous order [19], which represents an optimal balance [20] between too much control and too much freedom.
- Emergence phenomenon goes together with systems approach as "the whole is greater than the sum of its parts" (Aristotle). Some manifestations of emergence in EIPs are:
    - Synergy (or the T.E.A.M. acronym—"together everyone achieves more" [21]): People join their forces (ideas, knowledge, skills, technology, resources) and bring something new. This is a positive example of emergence, and it encourages innovation.
    - Emergent risks: There are new risks which emerge from existing risks over time (such as global warming [22]).
    - Emergent behavior: System behavior is independent of the behavior of its individual agents (for instance, a new project culture emerges from the group of people involved in a project).
- EIPs demand a systems approach (CAS are also systems). Kapsali [23] concluded that the methods of systems thinking provide the necessary flexibility for managing innovativeness, complexity, and uncertainty.

1.3. Research Goals

The empirical research described in this paper aimed to reduce risks of EIPs. Reducing risk, as the main idea/focus in the paper, is based only on negative risks (threats).

The research was performed under the premise that EIPs can be regarded as CAS (as previously explained). Its goal is to examine whether the inclusion of elements of complexity theory reduces risks in EIPs.

There are two levels of risk in projects: Individual, and overall [24]. In this paper, individual project risk represents the possibility that unwanted and uncertain events or conditions endanger the achievement of at least one project objective, while the overall project risk represents "the effect of uncertainty on the project as a whole" [24].

The research was conducted with the aim of linking complexity theory elements to the possibilities for reducing risks of EIPs. The complexity theory elements in this paper will be regarded as the:

- Sources of risks in EIPs;
- Background for better understanding of risks; and
- Opportunities for risk reduction.

This paper aspires to overcome the challenges in EIPs by reducing their high-risk potential, as well as to enrich the existing knowledge in this area through additional value arising from the new risk philosophy, which is based on complexity theory perspectives.

2. Literature Review

2.1. Reducing Risks in Energy Innovation Projects

In order to find space to reduce risks in EIPs, when reviewing the literature, the authors have noticed certain entries worth considering in this regard, which will later serve as formation elements of the dependent variable.

The flexibility of the EIP structure relates to the freedom generated by the structure of a project allowing agents to act when facing unexpected events [25], so it is crucial for avoiding risks. The same authors discuss two varieties of flexibility: (1) Configurational flexibility (the measure by which the activities in different parts of a project can be implemented independently as well as for the local effects of unexpected events), and (2) sequential flexibility (the measure by which future events are not limited/dependent on past decisions and undertaken obligations; contrary to the concept of 'path-dependency', it represents the flexibility of response to unexpected events). The risk manager needs flexibility in order to be able to make the necessary adjustments, according to the said situation.

Kapsali [26] proposed 'equifinality' as a construct of system thinking most suitable for application in project management. Similar to the contingency approach to management, 'equifinality' implies that there are many ways/paths towards achieving a goal, and that flexibility is necessary when selecting a path (flexible structure of the project). According to this concept, different initial conditions may generate the same results [26]. The high failure rate in innovations requires utilization of parallel paths in order to create prerequisites for the emergence of an effective solution [3].

Adjusting the EIP to changes in the environment is important for overcoming numerous threats during a long project duration. This can involve a change in strategy, practice, resources, market, technology, etc. The dynamic environment of today's projects can break conventional planning and project control [27]. Shenhar and Dvir [28] believe that the failure to adjust to a dynamic business environment is the reason why many projects have turned out to be unsuccessful, and, with that in mind, proposed the so-called adaptive approach to project management.

People are one of the main sources of uncertainty and risk in any project and, at the same time, one of the most important resources for reducing risk [29]. There is a high level of interaction among different members of an EIP team, so interpersonal relations deserve special attention. Geraldi et al. [30] concluded that the traditional discipline of project management does not fully recognize the social structuring of projects. The social aspects of risk are often neglected, and focus is transferred to technical problems, but bad interpersonal relations as well as the fact that there is a high level of interaction among numerous members of an energy innovation project team, lead to risk. Non-technical risks are not to be underestimated as project failure often comes from the human factor.

A large number of stakeholders create the project environment and influence the changes in the environment. Stakeholders represent their (often conflicted) interests, which means that meeting the demands of one side can often imply not fulfilling the requirements of the other side (for instance, Mihic et al. [5] believed that one of the properties of projects implemented in the energy sector is numerous stakeholders with conflicting interests). To solve different issues in the energy planning process, it is suitable to use multi criteria decision analysis (MCDA) methods [31].

It is common for stakeholders' demands to be inconsistent, or badly formulated. Neglecting any of the participating sides generates the risk of failure. In complex projects, with a multitude of stakeholders, the project manager needs to know who the most influential stakeholders are [32]. Project stakeholders with very different world views contribute to the complexity due to differences and diversity in the social-political cultural environment [33]. On the basis of their research, among other things, Karlsen [34] advised project managers to pay more attention to stakeholders. It is important to pay attention and satisfy stakeholder demands, as they will be the ones evaluating the success of your project (each from their own perspective).

A single method is often unable to cover all aspects of risk in EIPs, keeping in mind their complex implementation. Depending on the context, it is desirable to use several methods to solve different risk problems as well as a combination of several methods that overcome the shortcomings of the individual methods. For example, Wyrozębski and Wyrozębska [35] proposed the combination of the Monte Carlo and project planning techniques, while Stosic et al. [36] proposed the combination of risk breakdown structure (RBS) and work breakdown structure (WBS), the so-called risk breakdown matrix (RBM). Project managers face 'complex problem solving' [37], and simple solutions fail because they are not holistic or creative enough [38]. After surveying senior project managers who managed high risks and complex projects, Remington and Pollack [39] concluded that there was no universal recipe for success as 'one size does not fit all'. In uncertainty analysis and risk management, there is no universal right solution between good options and simple options [40]. Depending on the problems they face, project managers can opt for different methods or various combinations of methods that they believe will contribute to achieving the set goals.

After examining risk in complex projects, Thamhain [29] concluded that the early identification of contingencies was the key prerequisite for managing risk. He confirmed that undetected risks in the early stage tended to build up over time, becoming intricately linked (entangled). They also had a tendency to spread to the entire project, and significantly influence its entire outcome like a domino effect (e.g., the potential risks of innovation cooperation need to be predicted before contract signing).

In this segment, several important theses in the context of reducing risks of EIPs were identified: The flexibility of the EIP structure, adjustment to the environment, focus on interpersonal relations, dedication to stakeholders, application of different methods and different combinations of methods, and early identification of contingencies. They will be used for formation a dependent variable in this research, related to reducing risks in EIPs.

2.2. Application of Complexity Theory Elements in Energy Innovation Projects

While have been searching the literature, the authors have recognized application of various complexity theory elements that contribute to reducing risks in EIPs. Later, they grouped them into the three categories (i.e., aspects): (1) Specific aspects, (2) social and behavioral aspects, and (3) operational aspects. The identified categories will be used for formation auxiliary hypotheses, which participate to the main hypothesis. Therefore, in the following steps, the authors describe arguments in the literature which emphasize that considering complexity theory elements leads to reducing risks in EIPs.

2.2.1. Specific Aspects of Energy Innovation Projects

It is useful to consider specific aspects of EIPs from the complexity theory lens as they are observed in a way that can connect them closer to risks. Therefore, the idea presented in this part of the literature review is the application of complexity theory concepts to consider their impact on risks, while everything mentioned is based on the foundation of finding connections with specific aspects of EIPs.

Both excessive control and excessive freedom increase the risk of failure in the case of EIPs. In the first case, creativity can be 'stifled' while, in the other case, there is a very real probability that the creative efforts will not bring about the desired results, so it is necessary to find an optimal 'balance between order and chaos' [20], which can be achieved through self-organization. This means the creation of an adequate atmosphere that encourages the creativity of energy innovation process agents and, at the same time, turns their focus towards results.

Establishing an analogy with organizational complexity, Baccarini [41] explained technological complexity through the following parameters: The number of different technological elements and the degree of their operational interdependence. Additionally, Frenken [42] observed the complexity of technological innovation in two manners:

- "[C]omplexity can refer to the complex interaction structures of components in a technological system"; and
- "[C]omplexity can refer to structures of interactions between agents in innovation networks."

In his study of managing risks in complex projects, Thamhain [29] confirmed his initial claim that the impact of unforeseen events on project success increased with the technological complexity of a project. Despite the fact that a vast number of EIPs today involve high technological complexity, this should not be paralyzing. On the contrary, it should generate a positive posture towards risks (accepting the risk). Therefore, by considering this element of complexity theory means to assume a positive attitude towards high risks in the technical and technological field, bearing in mind that optimism is important for innovation as a discipline: The lack of optimism is the greatest risk for setting off failure. Finally, Tidd and Bessant [43] stressed that complexity could be a strategic advantage in the sense that we offer something people find hard to adopt and imitate (which can be accomplished using complex technology, rare resources, etc.).

Aside from the complexity of project structure, Williams [44] added another component of project complexity—uncertainty. EIPs are not properly structured, Turner and Cochrane [45] defined the uncertainty of a project depending on how well goals and methods were defined. Innovation is often unattainable and cannot be described before it is achieved [2]. Consequently, experience and knowledge harvested from previous projects, and especially learning during the implementation of an EIP, can be very helpful in overcoming the flaws of project management in the conditions of uncertainty.

Since uncertainty precedes risk and represents its important element, overcoming uncertainty will decrease risks. The contemporary creative–reflective model, born from the evolution of project management over time in its attempt to respond to the escalating increase in both the complexity of the project environment and the complexity of the projects themselves [46], requires project managers to constantly learn and develop competencies. Knowledge about risk management as well as context of analysis towards the selection of appropriate risk management technique [47] is important to effectively deal with the complexity of projects.

Complex, evolutionary systems require learning, innovation, and experimentation [10] for surviving. EIPs can be observed as CAS (please see Section 1.2), but also can be regarded as complex evolving systems. Saynisch [48] called the shifts between the stages of a project lifecycle evolutionary jumps, which strive towards radical innovation and a higher level of order. Evolutionary learning ensures their appearance, and the continued existence of EIPs as CAS during the project.

It is important to fight uncertainty in innovation projects by learning, not by planning. With this in mind, Paju [16] proposed a practical experiment, and suggested that it enabled efficient learning about an idea and reduced risks. The project manager needs to learn how to use sophisticated methods and risk-assessment software. Additionally, there is a focus on interaction among people in an EIP team as well as on learning from the environment. According to Kerzner and Belack [49], learning requires frequent risk monitoring, while lessons learnt have to be distributed to the project team as soon as a contingency occurs (not after the project has been completed).

Time complexity (complexity of the time we live) hinders planning in EIPs and relates to unexpected and strong environmental influences (for example, changes in energy policy). The longer an EIP lasts, the harder it is to predict its outcome. Hass [12] writes that there is rich history of long-duration projects that have failed because of the fact that 'change happens'. Neglecting the complexity of the time we live can lead to failure in the field of commercialization of energy innovation, innovation cooperation, technology, etc. The so-called gatekeeper may play an important role in precise timing and monitoring changes during the EIP.

Based on these findings, the following complexity theory elements were identified, which can be applied in the context of risk reduction, and go hand in hand with specifics of EIPs: Self-organization, technological complexity, evolutionary learning verses uncertainty, and time complexity.

2.2.2. Social and Behavioral Aspects of Energy Innovation Projects

Complexity occurs when different people (in terms of interests, loyalties, cultures, etc.) interact with a certain project or program [50]. Azim et al. [51] highlighted the impact of people on project complexity, and therefore the importance of soft skills. Since linear rules are not valid in social systems, complexity theory concepts are often being mentioned in social sciences. In the following lines, these concepts will be considered in the context of finding opportunities to reduce the risks of EIPs.

Early warning signs (EWS) research in complex projects conducted by Williams et al. [52] pointed to the importance of intuition ('gut feeling' factors) in identifying EWS, in addition to real assessments. Visual illusions prove that people can see more than a simple sum of sensations received by their eyes. Risks can be detected even when there is no objective proof of their existence, and these subjective impressions are not to be neglected. The project manager needs to have a developed intuition. Leybourne and Sadler-Smith [53] stressed that the ability to make decisions based on intuition and the ability to improvise was crucial for managers when they lacked relevant information or time for decision-making.

Except for the complexity of the systems themselves, it is also important to pay attention to the manner of how we organize our thinking regarding these systems [54]. Cognitive complexity implies an individual's ability to mentally organize and process information with the aim to identify and understand mutual relations and influences in natural and social systems [55]. The use of complex technology, lack of previous experience, complexity of the very problem EIP team members are facing in combination with different factors represent a sound base for cognitive complexity that 'hinders'. It has a negative effect on the motivation of team members and, in this way, threatens to endanger the project. Therefore, the additional motivation of EIP team members is important.

Cultural complexity is an important type of complexity that affects team members in EIPs if they come from different countries. In addition to differences at the national level, cultural complexity is the result of professional/industrial differences as well as at the company/organizational level [56]. As people of various societies see and evaluate risks in complex projects very differently [57], the issue of risk perception requires particular attention as the so-called cultural blindness prevents teams from using the advantages brought about by gathering people from different cultures on the same project [57,58]. Furthermore, different cultures have different values, which can cause disharmony when setting and achieving project goals. In conclusion, cultural differences can present sources of risk, but diversity can also be an advantage to a project team if solid cooperation is established among team members.

Communication complexity is caused by the number of communication links (participants in a project), or people directly involved in a project, the system for sending and receiving data, activities distributed over time and space, the documentation which regulates communications issues, ways of interpretation data, cultural differences in the team [59,60], as well as by language barriers and different professional/expert terminologies.

Multinational members of EIP teams belong to different cultures; therefore, there can be ambiguity in communication and in the interpretation of mutual actions including body language. Moreover, different professions working together on EIPs speak 'different' languages. The quality of communication affects project success as many risks can be detected in due course and prevented if communication is good.

Social complexity involves frequent interactions among many different individuals, and in many different contexts [61]. According to the three-dimensional model of project management knowledge presented by Thomas and Mengel [9], the increase in uncertainty leads project managers to put more value on spiritual intelligence and leadership competencies. Denison et al. [62] believe that behavioral complexity (with cognitive complexity) is an imperative for efficient leaders. In conditions of uncertainty, the leadership role of a project manager, which requires them to understand social complexity, is important for implementing innovative ideas and taking a positive stance towards risks (this role can also be taken by the so-called change champion). Wüstenhagen et al. [63] highlighted the issue of social acceptance of renewable energy innovation (from three dimensions of acceptance: Socio-political, community, and market) in a developing country context.

Furthermore, Thomas and Mengel [9] state that there are increasing complexity demands from project managers to additionally develop emotional intelligence and managerial competencies. In addition to technical knowledge, emotional intelligence is of crucial importance for a project manager [64]. This has previously been confirmed by the EWS list resulting from a study conducted by Williams et al. [52] as it helps us to eliminate risks generated by the human factor. Individual differences in broadness (diversity) of emotional experiences and the tendency of noticing subtle differences in terms of different emotions about what Kang and Shaver [65] are writing are important for emotional complexity. Overcoming difficulties of emotional complexity is a prerequisite for understanding the human factor risk in any project.

Reviewing the literature, the following social and behavioral aspects of EIPs were allocated: Intuition, cognitive complexity, cultural complexity, communication complexity, social complexity, and emotional complexity. Based on these elements, it can be theoretically assumed that their consideration has a positive influence on reducing risks in EIPs.

2.2.3. Operational Aspects of Energy Innovation Projects

Along with social (and specific) aspects, it is preferable to consider operational aspects of EIPs. Analogously with the previous aspects, they will also be discussed in the sense of complexity theory.

Kerzner and Belack [49] spoke about the fact that risks cannot be regarded separately in a complex project; they influence each other, and new risks emerge during the implementation of a project. From the perspective of emergence, the whole is not merely the sum of its parts, and the focus is on the interaction of those parts and, separately, on the interaction between the whole and its parts [66]. The process of risk management requires a systems approach and integrated analyzes, which is the analysis of the mutual influences of risks in a project and identifying new risks over time (emerging from the 'old' risks).

Fuzzy logic and complexity theory both deal with fields that have uncertainty as an inherent characteristic. In contrast to conventional logic, based on precise, clear, and established rules, fuzzy logic is, as the word itself describes it, foggy, unclear, or murky. In fact, it is based on the concept of partial truth. As a large dose of uncertainty clouds project implementation planning, Pohekar and Ramachandran [67] advised the application of fuzzy MCDM methods in energy planning. Fuzzy logic provides useful tools for treating the unknown in complex energy systems [68].

Due to the subjective assessment of the duration of the project phase, to reduce risk of exceeding the time limit of the project, complexity theory recommends the use of fuzzy numbers in the project planning phase [69]. Research conducted by Shang and Hossen [70] proved that fuzzy logic models could be used for improving risk assessment and risk decision-making, especially as a supplement to the existing probability models in cases where there is a lack of adequate information or knowledge. This means that the use of fuzzy logic is important for subjective risk assessments performed in said circumstances.

In the case of complex projects, there are difficulties related to learning from other projects in the usual way (since complex projects tend to 'behave oddly'). Williams [71] proposed systems modelling as a way to record projects, i.e., the system dynamics (SD) technique for mapping. The modelling has a key role in detecting causal structures and feedback loops (which are hard to explain or identify by simply recording events, decisions, and activities). SD represents a useful tool for displaying a complete picture of a certain system [23], as behavior caused by complex interactions among different parts of a project most likely could not be predicted by analyzing individual parts of a project [72]. Most importantly, SD theory applies to almost any risk management problem since SD focuses on modelling systems, identifying key feedback loops, and examining ways to reduce risks [73]. SD models have found applications in energy risky projects [74], megaprojects [75] as well as much wider—the most well-known example is the World3 model [76].

An energy innovation project may also be seen as a temporary organization, so its organizational complexity can be discussed. Baccarini [41] regards the organizational complexity of a project through vertical differentiation (the depth of organizational hierarchy), and horizontal differentiation (the number of organizational units and division of tasks), and cites interdependence as yet another attribute of organizational complexity in a project. Reducing the complexity of tasks and work processes is most likely to reduce risks [29]. In addition, it is necessary to introduce flat organizational structures that minimize the number of hierarchical levels.

In this part of the literary review, the following phenomena and concepts stand out, which are close to complexity theory and used in the context of operational aspects of EIPs: The emergence phenomenon and systems approach, fuzzy logic (uncertainty, ambiguity, subjectivity), positive feedback loops and systems approach (SD technique), and organizational complexity. The assumption is that taking into account these concepts has an influence on reducing the risks of EIPs.

3. Definition of Research Framework

The goal of this research was to examine whether considering the elements of complexity theory reduces risk in EIPs as described in Section 1.3. After researching the available literature, the authors detected three aspects of EIPs that are important for this topic: Specific, social and behavioral, and operational aspects. In accordance with this, we formulated the main hypothesis and auxiliary hypotheses.

The main hypothesis: *Taking into account the complexity theory elements leads to reducing risks in EIPs.*

The main hypothesis is to be confirmed by using the following auxiliary hypotheses:

Hypothesis 1 (H1). *Taking into account the complexity theory elements in the field of specific aspects of EIPs represents a significant factor in reducing risks in EIPs.*

Hypothesis 2 (H2). *Taking into account the complexity theory elements in the field of social and behavioral aspects of EIPs represents a significant factor in reducing risks in EIPs.*

Hypothesis 3 (H3). *Taking into account complexity theory elements in the field of operational aspects of EIPs represents a significant factor in reducing risks in EIPs.*

A research model with associated hypotheses is presented in Figure 2, which provides the framework and context of this research. As can be seen in the figure, the dependent variable in the model is reducing risks in EIPs, while the independent variables are related to taking into account the complexity theory elements, which are grouped into three aspects of EIPs: Specific aspects, social and behavioral aspects, and operational aspects. The variables considered in the paper are specific for energy innovation field because they have been revealed during the literature review, and because they are important for holistic approach to the topic. Consequently, the authors designed research model in order to mitigate discrepancy among operational aspects, social and behavioral aspects, and specific aspects of EIPs.

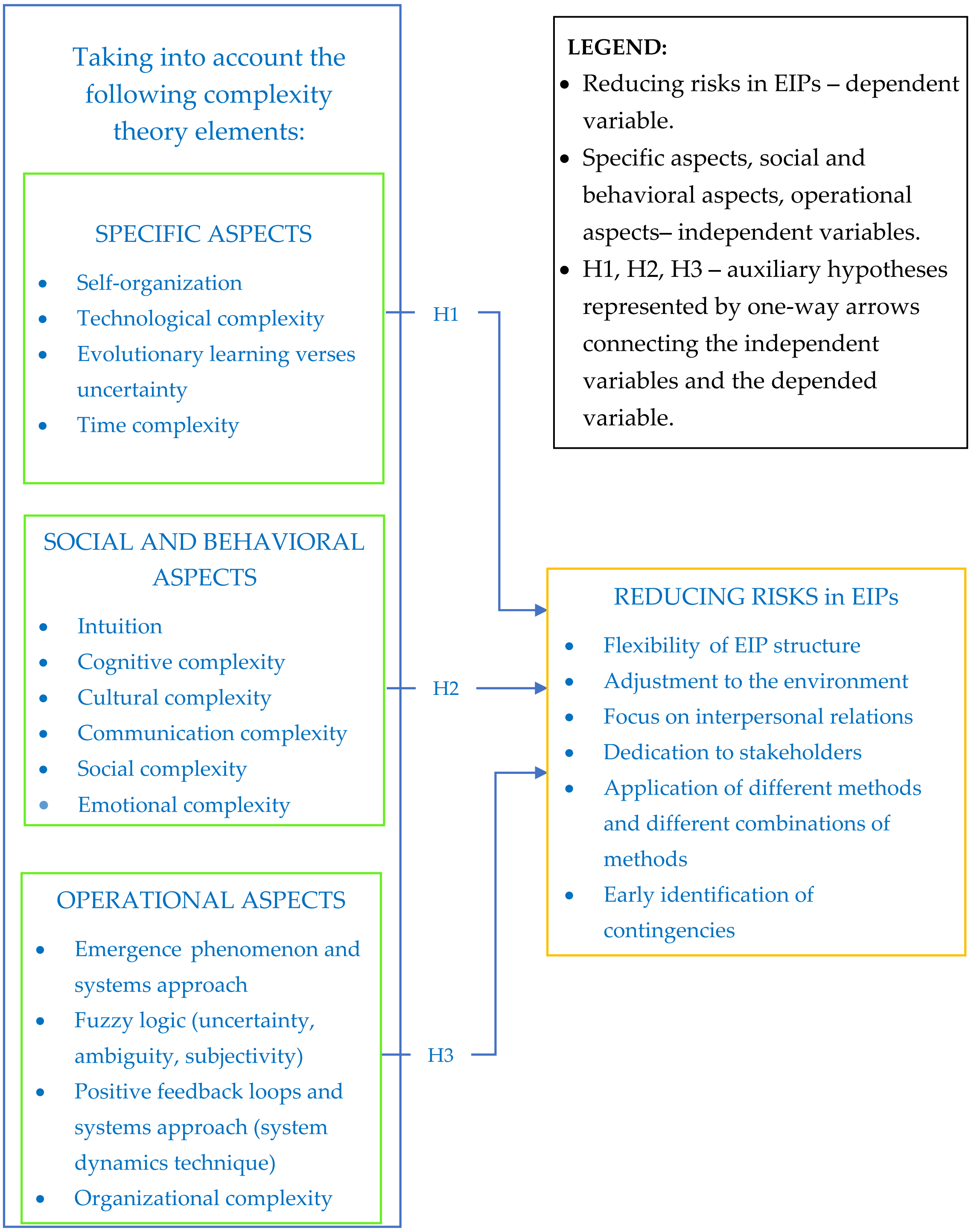

Figure 2. Research model with associated hypotheses.

4. Research Method

4.1. Description and Validation of Questionnaire

The authors created a questionnaire, with the aim of confirming the main and auxiliary hypotheses. The questions were based on the theoretical literature overview, fragmented studies and theoretical papers of other authors from this field as well as based on previous papers from the authors (for example, References [5,14,69]). Next, the authors conducted structured interviews with six project managers from four companies, whom the subject is well known. They have experience in EIPs related to petroleum products, revitalization of energy and industrial facilities, innovative visualization of data in energy research, and development of renewable sources of energy. The questions were modified with the aim to generate the most precise answers, because the initial form of some questions could be understood ambiguously for people working in different fields. A few questions were unnecessary too long. All such questions were slightly modified for the sake of clarity. The essence of the questions was not changed. The questionnaire regarded the influence (or importance) of three independent variables on a single dependent variable; i.e., the authors analyzed four variables in total. In addition, independent variables were the complexity theory elements while the dependent variable was related to reducing risks in EIPs.

The questionnaire contained several parts: General part, reducing risks, specific aspects, social and behavioral aspects, and operational aspects of EIPs. The first one was designed for the needs of descriptive statistics, i.e., sample description (please see Section 4.3). The last four parts contained 20 questions, where the authors used a Likert scale. The subjects were offered a scale ranging from 1 to 5 that enabled them to grade the influence, importance, or agreement with a previous statement (for more details please see Appendix A—Questionnaire).

The answers were acquired in October and November 2017. The majority of questionnaires (73%) were completed in South-East European countries, while the remaining questionnaires (27%) were acquired from geographically dislocated experts.

In order to validate questionnaire, confirmatory factor analysis (CFA) is done by using IBM SPSS Amos 25. Figure 3 shows path diagram of the research model.

The latent variables are: Specific aspects, social and behavioral aspects, operational aspects, and reducing risks in EIPs. The cut-off values indicate the goodness of fit indices, according to References [77–79]:

- The local minimum is reached with the next results:
  - Chi-square = 171.922
  - Degrees of freedom = 154
  - Probability level = 0.153
- CMIN/DF (Minimum discrepancy, divided by its degrees of freedom) = 1.116
- RMSEA (Root mean square error of approximation) = 0.034
- RMR (Root mean square residual) = 0.044
- SRMR (Standardized RMR) = 0.0778
- IFI (Incremental fit index) = 0.934
- TLI (Tucker–Lewis index) = 0.906
- CFI (Comparative fit index) = 0.924

The results show that the model was fitted successfully, and that the measurement instrument (the questionnaire) is valid.

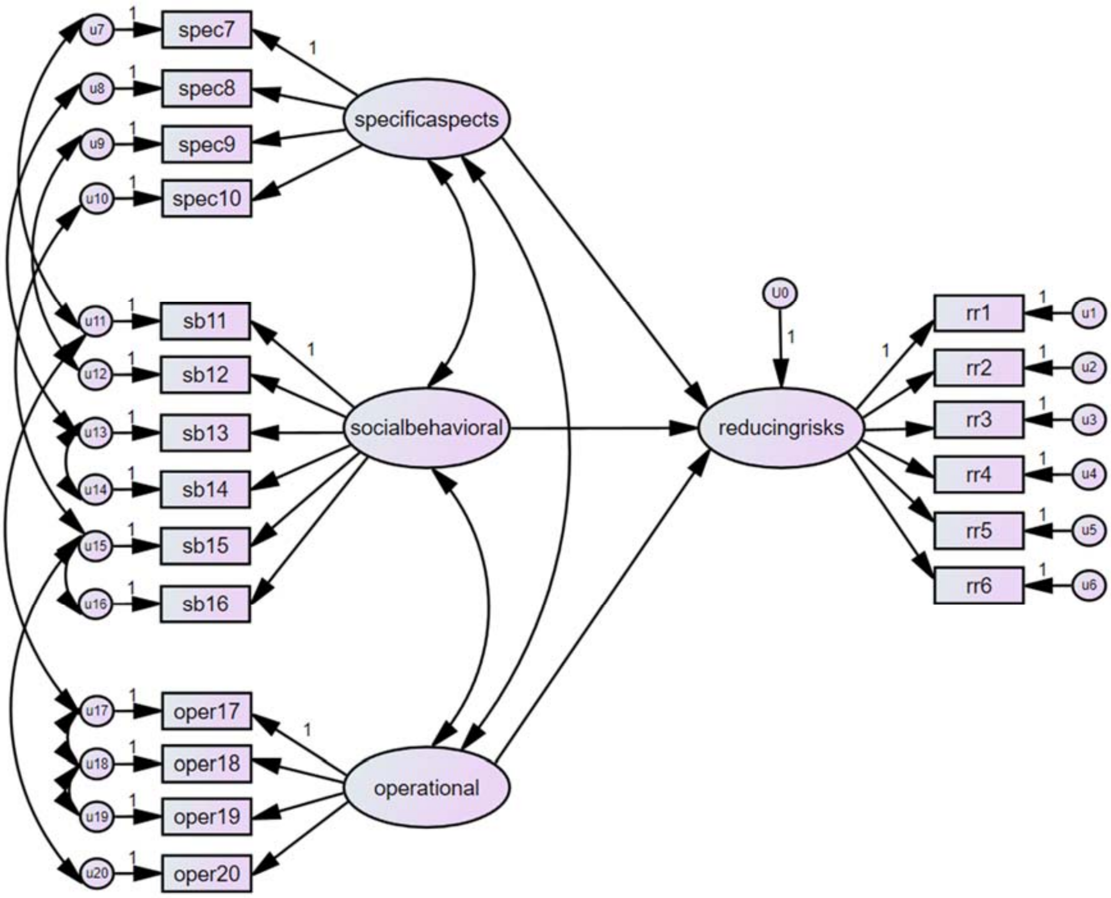

Figure 3. Path diagram of the research model.

4.2. Formation of the Independent Variables and the Dependent Variable

In accordance with the previously mentioned literature overview, the authors identified three independent variables related to EIPs.

The specific aspects variable was derived from several complexity theory elements (please check Figure 2), i.e., by aggregation of the following sub-variables: Self-organization, technological complexity, evolutionary learning verses uncertainty, and time complexity. In an analogy to the procedure of the formation of this variable, all the other variables were formed in the research model. The second and the third independent variable, social and behavioral aspects and operational aspects were generated in the same way, by aggregating appropriate complexity theory elements (please check Figure 2).

Aggregated variables (specific aspects, social and behavioral aspects, operational aspects, reducing risks in EIPs) were derived of responses collected from respondents (Likert scale from 1 to 5) by using the option Transform—Compute Variable in the software package IBM SPSS Statistics. The averages were calculated for each group of questions. Therefore, the aggregated variables obtained that way are scalar and show decimal numbers (they are not integers from 1 to 5).

The dependent variable was formulated in the same way as the independent variables. The elements of dependent variable, reducing risks in EIPs, are also shown in Figure 2.

4.3. Sample Description

In this research, authors distributed approximately 500 copies of the questionnaire, 20% of which were completed and submitted. There were 104 submitted questionnaires. The answers of four respondents were obviously incorrect (two of them did not complete majority of the questions in the printed version of the questionnaire, and the other two gave several obviously incorrect and false answers on the open form questions—descriptive part of the questionnaire, so their answers to the whole questionnaire had to be considered unacceptable). Therefore, there were 100 relevant answers. A description of the respondents is presented in Table 2. The data were processed in IBM SPSS Statistics 20.

Table 2. Description of the respondents.

Description of Respondents	
Average work experience	16.39 years: = 5 years: 2% 6–10 years: 30% 11–20 years: 41% 21–35 years: 24% > 35 years: 3%
Qualifications	Bachelor or equivalent degree—32% Master of Science or equivalent degree—41% Doctoral degree—27%
Education in the field of project management	Formal education and/or professional certificates (IPMA, PMI, PRINCE, etc.)—74% Informal education (training, educational seminars, experience accumulated through practice)—26%
Current position	Portfolio manager—9% Program manager—13% Project manager—33% Assistant project manager—14% Other managerial positions—6% Expert positions—11% None *—14%
Average number of projects that the respondents have participated in	31.47
Average number of EIPs that the respondents have participated in	9.05
Total number of respondents	100

* The respondents who did not have a position on energy innovation project at the moment of completing the questionnaire. These respondents are mostly employees who belong to the functional units (permanent sectors) in their organizations and will be engaged at temporary units when the project starts. They contribute to the research based on their previous relevant experience.

5. Analysis of Data and Results

5.1. Data Reliability

In order to examine the prerequisites for regression analysis, the authors first performed the Durbin–Watson test. The DW equaled 1.946 (a value nearing 2); therefore, based on Savin and White [80], it was possible to conclude that there was no autocorrelation between the variables, so the assumption about the independence of variables was valid. Internal consistency was expressed by Cronbach's alpha coefficient, which was equal to 0.728 for the entire model, and was above the acceptable value of 0.7 [81]. Testing the normality of the aggregated variables was successful (Kolmogorov-Smirnov test, Shapiro-Wilk test, histogram, Normal Q-Q Plot). The conclusion was that the data were reliable for further analysis.

5.2. Pearson Correlation and Partial Correlation

In order to confirm the hypotheses, the authors isolated three key independent variables related to EIPs: Specific aspects, social and behavioral aspects, and operational aspects, then analyzed their influence on the dependent variable, reducing risks in EIPs. For the purposes of determining the interdependence of variables, factor analysis was used: Pearson's correlations between the dependent and the independent variables (please see Table 3).

Table 3. Correlations between the dependent and the independent variables.

	Specific Aspects	Social and Behavioral Aspects	Operational Aspects	Reducing Risks in EIPs
Specific aspects	1			
Social andbehavioral aspects	0.142	1		
Operational aspects	0.367 **	0.388 **	1	
Reducing risks in EIPs	0.404 **	0.581 **	0.543 **	1

** Correlation is significant at the 0.01 level (2-tailed).

Since in all three cases, $\rho < 0.01$ (check the bottom of Table 3), this indicates that the auxiliary hypotheses are most probably correct, which in turn suggests that the main hypothesis can be confirmed.

In all three cases, there was a positive correlation between the variables (correlation coefficient above 0.3), which indicates that when one variable changes, the other variable changes in a positive direction [81]. As presented in Table 3, these values were 0.404 (the influence of specific aspects on reducing risks in EIPs), 0.581 (influence of social and behavioral aspects on reducing risks in EIPs), and 0.543 (influence of operational aspects on reducing risks in EIPs), respectively. In this research model, the biggest influence on the dependent variable was executed by social and behavioral aspects. All values in Table 3 were larger than 0.3, except for the value 0.142, which represents the interdependence of two independent variables, and is not directly related to the dependent variable.

To strengthen the suggestion of confirmation of the main hypothesis, the authors made partial correlations. As there are three independent aggregated variables and one dependent aggregated variable, the authors made six partial correlations in order to measure strength and direction of relationship between each independent variable and dependent one, while in the same time controlling the effect of other variables to their relationship separately for each one. Before providing partial correlation, the authors checked the necessary assumptions for partial correlations and concluded that no assumptions have been infringed. There was a moderate to strong positive partial correlations in five cases and in one case correlation is a little below of significance threshold (please see Table 4). However, in that case zero-order correlation shows statistically significant correlation of the control variable to each of the observed variable. Therefore, the authors believe that this result could be tolerated for this research.

Table 4. Partial Correlations.

Control Variables	Relationship between Two Variables		Correlation
Social and behavioral aspects	Specific aspects	Reducing risks in EIPs	0.400 **
Operational aspects	Specific aspects	Reducing risks in EIPs	0.267
Specific aspects	Social and behavioral aspects	Reducing risks in EIPs	0.578 **
Operational aspects	Social and behavioral aspects	Reducing risks in EIPs	0.477 **
Specific aspects	Operational aspects	Reducing risks in EIPs	0.461 **
Social and behavioral aspects	Operational aspects	Reducing risks in EIPs	0.416 **

** Correlation is significant at the 0.01 level (2-tailed).

5.3. Linear Regression

Along with testing the normality of the aggregated variables the linear regression is done in SPSS with testing the following regression assumptions:

- Tests for linearity: Since ANOVA deviation from linearity sig. is higher than 0.05 in all cases (for all independent variables in relation to the dependent one: 0.949, 0.185, 0.725), the authors conclude that there is linear relationship, so the linear regression can be applied to the data.
- Outliers: Casewise diagnostics in SPSS is used to ensure that there are no significant outliers.
- Autocorrelation: Durbin-Watson test equals 1.946, so there is no autocorrelation between the variables (please check Section 5.1).
- Normality: The errors are normally distributed (Figure 4).
- Homoscedasticity, i.e., homogeneity of variance: The error variance is shown to be fairly constant.

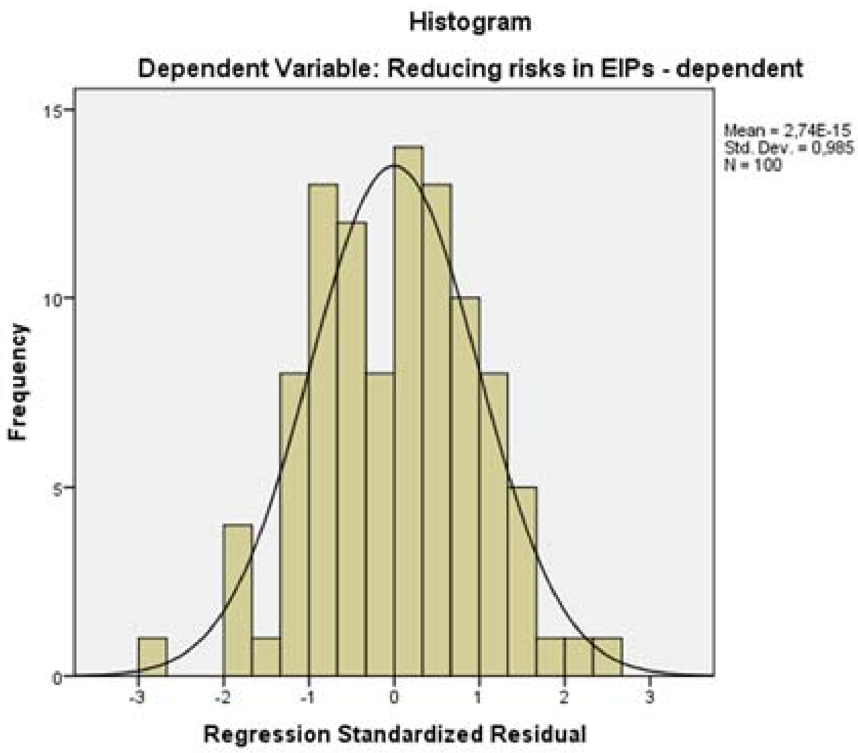

Figure 4. Regression Standardized Residual.

Respondents were asked to choose among categories for each question. However, categorical variables are not adequate for the purpose of conducting a multiple regression analysis. For that reason, the responses were summed up in a scale and represented interval variables. Since all research variables were scalar, this necessary condition for multiple linear regression implementation [82] was fulfilled. According to the research conducted by Todorovic et al. [83], Koo et al. [84], and Müller [85], the sample size of 100 respondents was adequate for the implementation of regression. After examining co-linearity by using the parameters of variance inflation factor (VIF) and tolerance (Table 5), the VIF equaled less than 10 while tolerance remained above 0.2. Therefore, according to Pallant [81], there was no multicollinearity between the variables.

Moreover, since the model's R^2 equaled 0.505, while the Adjusted R^2 = 0.489, we can conclude that the model showed a risk reduction in the EIPs in 48.9% of the cases. The biggest beta coefficient equaled 0.436 (Table 5); therefore, social and behavioral aspects had the greatest influence (importance) when predicting the dependent variable, followed by operational aspects and, somewhat less, specific aspects.

In addition, influences of the individual complexity theory elements on reducing risks in EIPs are presented in Table 6. In most cases $\rho < 0.01$, correlations were positive, i.e., greater or estimated to the value of 0.3 (these conditions were not fulfilled in the case of the following elements: technological complexity, evolutionary learning verses uncertainty, and intuition).

Table 5. Regression analysis.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-Order	Partial	Part	Tolerance	VIF
(Constant)	**0.837**	0.351		2.386	0.019					
Specific aspects	0.239	0.078	0.237	3.072	0.003	0.404	0.299	0.221	0.865	1.156
Social and behavioral aspects	0.383	0.068	0.436	5.591	0.000	0.581	0.496	0.402	0.849	1.177
Operational aspects	0.238	0.069	0.287	3.454	0.001	0.543	0.332	0.248	0.750	1.334

Dependent Variable: Reducing risks in energy innovation projects. R^2 = 0.505 and Adjusted R^2 = 0.489.

Table 6. Influence of the individual complexity theory elements on reducing risks in EIPs.

Individual Complexity Theory Elements	Influence on Reducing Risks in EIPs
Self-organization	0.262 **
Technological complexity	0.045
Evolutionary learning verses uncertainty	0.132
Time complexity	0.320 **
Intuition	0.189
Cognitive complexity	0.489 **
Cultural complexity	0.347 **
Communication complexity	0.486 **
Social complexity	0.276 **
Emotional complexity	0.321**
Emergence phenomenon and systems approach	0.355 **
Fuzzy logic (uncertainty, ambiguity, subjectivity)	0.440 **
Positive feedback loops and systems approach (system dynamics (SD) technique)	0.299 **
Organizational complexity	0.219 **

** Correlation is significant at the 0.01 level (2-tailed).

6. Discussion

This paper discussed and analyzed the common denominators of several different disciplines, so it focuses on a micro niche. It connects the field of the research (energy innovation projects) with complexity theory in an innovative way: The complexity theory gives framework for the research and tool for making research model and measurement instrument (questionnaire).

The research model has a multidisciplinary character, because it is designed to consider specifics of EIPs, while it is suitable to overcome the dichotomy between operational aspects on the one side, and social and behavioral aspects on the other side, namely between 'hard' and 'soft' in project management [86], and all that from the complexity theory viewpoint. In addition, all research variables in the model were layered, caused by aggregating several individual components as this paper unified different management fields as well as a large number of phenomena previously studied independently, which is why we can confirm that it had a holistic approach to the topic.

Before conducting all analysis presented in this paper (Pearson correlation, partial correlation, linear regression, analysis of the individual parameters) the authors tested necessary assumptions, data reliability, and validated measurement instrument (the questionnaire). The aim of the research was fulfilled, i.e., linking the complexity theory elements to the possibilities for reducing risks in EIPs was shown to be significantly correlated in all conducted analysis. This indicates the conclusion that taking into account the complexity theory elements in all analyzed aspects (specific, social and behavioral, and operational) leads to reducing risks in EIPs.

Social and behavioral aspects were the most important for reducing risks in EIPs. The represented research results in this paper went together with contemporary studies in the domain of energy innovation. For instance, neglecting the social factors of the energy project was the reason as to why many energy projects tended to fail, despite using sophisticated technologies [31]. Furthermore, Fri and Savitz [87] highlighted the role of the social sciences in energy innovation related to managing climate changes.

This research supports the efforts of existing studies that have emphasized the importance of adequate risk management and the dissemination of project knowledge corpus in sustainability projects (for example, Reference [7]), but under the framework of complexity theory and in one particular segment, energy innovation.

Positive results were also obtained from the analysis of the individual parameters (influences of the individual complexity theory elements on reducing risks in EIPs), except in the three mentioned cases. The feedback we received from the respondents indicated that:

- Technological complexity is still traditionally associated with high risks.
- In the case of uncertainty in energy innovations, in addition to project learning, there is a need to constantly learn from the environment as well as "in-house" learning (for more details please see Figure 5).
- Most respondents believed that the reliance on intuition is not desirable in risk management processes.

For each issue in the research model, there are recommendations for project managers (general and from all discussed aspects) that are presented in Figure 5.

Project management and sustainable development have contrary concepts [4]. This paper helps to harmonize them by taking into account complexity theory elements as a tool and framework to reduce negative risks in EIPs, which in turn supports both project management and sustainable development.

Reducing risk as the main idea and focus in the paper is based only on negative risks (threats). This is one of constraints in the paper, since positive risks have not been analyzed. Opportunities that arises from risks were treated only occasionally.

It is also worth to say that, when considering long-term aspects, the subject of this paper can be understood in much broader context related to sustainable development of human society. Observation of human society in long periods helps to comprehend that complexity and energy are entangled in the so-called energy-complexity spiral [88]. Risks are interweaved with them, too. It is clear that risks increase when complexity and energy consumption increase. However, it is questionable whether risks necessary decrease when complexity and energy consumption decline. Time shift between complexity and energy consumption could have feedback effect on reducing risks (both positive and negative), but it cannot be claimed without a dedicated research.

Having in mind the above, thorough examination of positive risks and related opportunities, as well as of the relationship among energy, complexity, and risks in long periods of time remain for future researches. The authors believe that this paper gives a sound basis for them.

Figure 5. Recommendations for project managers.

7. Conclusions

Some of the most important conclusions derived from this paper are:

- Statistical significance of the main indices suggests that taking into account complexity theory elements leads to reducing risks in EIPs. It gives reasonable ground to justified belief that complexity theory can find application in challenging field of overcoming the high-risk potential of EIPs.
- Social and behavioral aspects, in general human/non-technical risk factors, are becoming increasingly important for the success of EIPs, which calls for further research in this direction.
- Complexity theory offers a solid theoretical background for the better understanding of risk factors in EIPs. Therefore, education of the project manager in this regard is important for the success of EIPs. It also implies the use of methods that support dealing with complexity in the field of risk management in an appropriate manner.
- Risk philosophy based on complexity theory is useful in finding opportunities for risk reduction. In addition, this paper suggests that complexity does not necessarily increase the EIP risks, on the contrary, complexity insights can be useful for decreasing the high-risk potential of EIPs.
- Integrated consideration of different risk factors, not separately, is one of the crucial ideas from this paper.
- Reducing risks in EIPs from the complexity theory viewpoint is more efficient in the case of the prevention of unwanted events, in comparison to reducing the effects of unwanted events that have already occurred.
- Lessons learnt from complexity theory (presented in the form of recommendations for project managers) show how to take into account all discussed elements of complexity theory, thus reducing risks in EIPs. In turn, this is supposed to generate better results in EIP management and in the field of energy innovation in general.

Future studies by the authors, in the spirit of 'Project Management Second Order (PM-2)' [89], and based on the multidisciplinary character of this research, will be conducted in different relevant segments with the idea of the generalization of obtained results with the goal to increase the project risk management knowledge corpus.

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Appendix A. Questionnaire

Respondents were asked to rate (on the scale from 1 to 5) the influence (1-without influence; 2-low influence; 3-moderate influence; 4-high influence; 5-extremely high influence), importance (1-without importance; 2-little importance; 3-medium importance; 4-great importance; 5-crucial importance), or agreement (1-strongly disagree; 2-disagree; 3-neutral; 4-agree; 5-strongly agree) with a previous statement.

The questions are grouped into the following sections:

- Reducing risks in EIPs:

    1. Rate the importance of flexibility of EIP structure for reducing risks in EIPs.
    2. Rate the importance of the adjusting of EIPs to changes in the environment for reducing risks in EIPs.

3. Rate the influence of focus on interpersonal relationships in EIP teams on risk reduction in EIPs.
4. Rate the influence of dedication to stakeholder relations on risk reduction in EIPs.
5. Rate the importance of using different methods and different combinations of methods for solving different risk problems in EIPs in order to reduce the probability and impact of such risks.
6. Rate the influence of the early identification of risk events on the suppression of risk factors in EIPs.

- Specific aspects:

7. Rate the agreement with the statement that self-organization between too much control and too much freedom in EIPs decreases the risk of EIP failure.
8. Rate the influence of avoidance of negative attitudes towards risks related with usage of complex technology on reducing risks in EIPs.
9. Rate the importance of the experiential knowledge, gained in previous projects and during the implementation of EIP, for the management of EIP under uncertainty, i.e., the importance of evolutionary learning for reducing risks in EIP that come from uncertainty.
10. Rate the importance of consideration of complexity of the time we live on reducing risks in EIPs.

- Social and behavioral aspects:

11. Rate the importance of intuition in identifying risk factors in EIPs (and hence its reduction).
12. Rate the importance of adequate dealing with cognitive complexity (e.g., by raising the motivation of EIP team members) for risk reduction in EIPs.
13. Rate the influence of considering the aspects of cultural complexity on decreasing human factor risks in EIP teams.
14. Rate the agreement with the statement that increasing the quality of communication by overcoming communication complexity in EIP teams is a significant factor in reducing risks in EIPs.
15. Rate the importance of the leadership role of the project manager and their understanding of social complexity in conditions of uncertainty for risk reduction in EIPs.
16. Rate the importance of successfully dealing with the emotional complexity of the project manager for eliminating human risk factors in EIPs.

- Operational aspects:

17. Rate the importance of the analysis of mutual influences of risks in EIP and identifying new risks over time (emerging from the 'old' risks) for EIP risk reduction.
18. Rate the importance of fuzzy logic application for subjective risk assessments, i.e., for the reduction of subjective risk factors in EIPs, under the conditions of handling with insufficient data and incomplete knowledge.
19. Rate the importance of using the system dynamics technique for solving problems of causal embeddedness easier, and for more efficient solution of risk events in EIPs, and, therefore, the importance of using the system dynamics technique for reducing risks in EIPs.
20. Rate the influence of decreasing organizational complexity (simplifying tasks, work processes, and organizational layers in a project) on risk reduction in EIPs.

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