sustainability

MDPI

Article

Human Factor Preparedness for Decentralized Crisis Management and Communication in Cyber-Physical Systems

Levente Bakos [1,2,*], Dănuț Dumitru Dumitrașcu [1] and Katalin Harangus [3]

[1] Management and Industrial Engineering Department, Lucian Blaga University of Sibiu, 550024 Sibiu, Romania; dan.dumitrascu@ulbsibiu.ro
[2] Mechanical Engineering, Sapientia Hungarian University of Transylvania, 400112 Cluj-Napoca, Romania
[3] Applied Social Sciences, Sapientia Hungarian University of Transylvania, 400112 Cluj-Napoca, Romania; katalin@ms.sapientia.ro
* Correspondence: bakos@ms.sapientia.ro

Received: 18 September 2019; Accepted: 22 November 2019; Published: 26 November 2019

Abstract: Crises are influencing the corporate sustainability. Long-term stakeholder value built in decades can be ruined by a middle scale crisis. In the new world of cyber-physical systems, scholars emphasize the decentralized, human–machine cooperation based disturbance handling. From information technology and communication (ICT) point of view the cyber-physical systems are ready for a sustainable, decentralized crisis management. The aim of the article is to present results of a research that has as objective to study the readiness of the human component of cyber-physical systems for a decentralized crisis management approach in industrial organizations. Two highly regulated industries—automotive and pharmaceutical industry- was selected; in all the studied organizations the continuous human-machine cooperation is a reality. The sample consisted of 151 respondents and a questionnaire-based survey was used. The study revealed the need for guidance and education for the personnel regarding the roles and competences of the different departments regarding the relationship with certain stakeholders. The study also reveals that apart from some explicitly regulated by law areas—fire safety, occupational health and safety, and some issues related to technological failures—the studied organizations are not prepared for unexpected situations. Also, our survey revealed that the members of the organization, others than top managers, are not prepared to handle 'off the job-description' situations.

Keywords: crisis management and communication; human resources; corporate sustainability; Cyber-Physical Systems

1. Introduction

Crises situations are unwanted, unpleasant and, mostly, unforeseen events. Periodically and unexpectedly crises situations happen in all organizations. Obviously, there is continuous concern to be better prepared for unwanted events, but is still impossible to predict the unpredictable. Organizations, especially SMEs, are not ready to create mitigation plans even for the major conceivable hazards. For example, backup plans for low probability and high impact events are overlooked, just for the simple reason of being financially unattractive. Still, continuous risk management processes and long term business strategies built on core concepts such is Total Quality Management (TQM), lean and sustainable manufacturing, stakeholder theory and many others, have as goal to improve the preparedness for the unwanted situations. In spite of the growing preparedness, due to the growing complexity of our interconnected world, unforeseen events happen on regular basis. Organizations

seem to be more vulnerable than ever. Long-term stakeholder value built in decades can be ruined even by a middle scale crisis.

The stake of crisis management is not just the immediate damage minimization, but assuring the short term resilience and the long term sustainability. Crises shall be seen not only as struggle for survival, but as an opportunity to grow and to prove sustainability. A crisis situation, at the same time, is always a sustainability issue for the organization. Sustainability means strategic thinking and leadership [1], but this should be proved during crises in a few hours struggle for the immediate and long term survival.

We'll skip to present the multitude of crisis definitions, but the interested reader, for example, only in [2] can find more than twenty definitions. Here, we will define the organizational crisis as a major, unexpected event, foreseen or unpredicted, that threatens the sustainability of the organization and can have significant consequences for the future of the organization. Regardless if it was predicted, or we have a totally unforeseen event, any mistreated- even minor- disturbance can lead to a crisis situation. In these cases, few minutes after the first signs, the organization may find itself in front of an unknown magnitude situation. Being ill-defined problems, in mathematical sense, the crises must be handled by the available human resources at that very moment. Even in the case of the most developed cyber-physical systems –let's imagine an airplane-, during crises the leading role is assigned to the human operator. Many times the outcome of the crises hinges on the quality of the decisions of the human resources. A wrong crisis management and communication can cause more damages than the crisis itself. Let's imagine a hypothetical situation in which a warehouse fire at a well-known company a small amount of merchandise is destroyed. In the official crises communication, in spite of the many evidences, the manager of company denies the fire. And more, later, a storekeeper declares to the press that the loss is not significant because probably the burned goods were not declared at the customs, and all the products they sell are fakes, they are just copies of original brands. These communication errors definitively can cause more losses to the company than the book value of the goods burned in the fire.

In crises preparation every organization struggles with two, mathematically non-definable, optimization dilemmas. None of it has optimal solution, but both have major influence on the long term sustainability. The first one is related to the level of decentralization during crises and it can be measured with the degree on which the management delegates authority and assigns competencies during crises. A high degree of delegation may improve the reaction time and lead to good local solutions, but may cause one sided subjective results and/or suboptimal solutions at the level of the whole organization. The second dilemma is related to the level of automation. Here we may refer to Sheridan's illustrious ten levels ranking from 'the computer offers no assistance, human do it all' till 'the computer decides everything and acts autonomously, ignoring the human' [3]. Both extremes are dangerous and inappropriate in modern crisis management.

Crisis management and communication had an impressive evolution together with the new achievements in ICT (Information and Communication Technology). A new infrastructure and communication environment emerged turning into complex systems that we never experienced before. Concepts like cloud technology, smart factory, organic computing and Industry 4.0 points to a decentralized disturbance handling [4,5]. There is paradigm shift in systems engineering that should enable future ICT systems to carry out certain tasks on their own [6]. These 'self-systems' can have self-* properties (self-organizing, self-configuring, self-tuning, self-repairing, self-protecting, self-optimizing and so on) [7]. At the present, the most developed new cyber-physical systems (CPS) are able to handle any emerged perturbation or disturbance, using a decentralized, human – machine cooperation based approach. CPS is a technology that allows the connection and communication, such as information exchange, triggering actions, and independent control between humans, machines, and products [8]. From ICT point of view the CPS are ready for a sustainable, decentralized crisis management. Can we state the same with the human component of the CPS, as well? That is the main question of research. While currently it seems easy-going to create computer networks able for

self-organized and decentralized disturbance handling –the Internet itself is decentralized network of computers-, the situation is not as evident for the human-based decentralized crisis management and communication. Are the human resources of today's organizations ready to make independent decisions, to assess a crisis situation and act in accordance? Our research analyses in what an extent the employees in some highly regulated industries are ready to cope by their own with unexpected situations and how the organization as whole is prepared for crises from HR point of view.

2. Background Literature and Hypothesis

'A crisis can be viewed as the perception of an event that threatens important expectancies of stakeholders and can impact the organization's performance. Crises are largely perceptual. If stakeholders believe there is a crisis, the organization is in a crisis unless it can successfully persuade stakeholders it is not.' [9] Many of the background literature, based on Freeman's [10] stakeholder theory, states that business must focus on a broad range of stakeholders by defining and delivering values of the business to them. [11–13]. Sustainable success is related to successfully fulfilling the needs of corporate stakeholders. In this approach the crisis is both a management and a communication issue. The decisions related to right communication are as important as the (financial and/or technological) decisions related to damage control. By right communication we mean, here, a communication to *all* stakeholders. It is hard to tell, which stakeholders are the most important in a certain crisis, but it should be a fatal mistake to consider the shareholders the only stakeholders in these situations. Today, it is obvious that the success of an organization is not solely evaluated by its present economics success. For the long-term viability must be balanced the economic prosperity, social equity and environmental quality. [14]. The most common Triple Bottom Line (TBL) approach of sustainability is getting more and more acknowledged not only at macro level, but at the level of the individual organizations, too [15]. The integration of corporate sustainability into business activities has challenged traditional business models. This has pushed companies to better engage with stakeholders, while creating competitive advantages to customers, the company, and society [16].

Scholars of the stakeholder theory emphasize the complex, inter-dependent relationships among the organization's stakeholders [17]. Many groups have a moral claim on the corporation because the corporation has the potential to harm or benefit them. [18]. Sustainable organizational advantage may be built with tacit assets that derive from developing relationships with key stakeholders: customers, employees, suppliers and communities where businesses. [19] Thus, a crisis situation may be harmful not only to the organization, but also to the organization's stakeholders. Almost all stakeholder categories, - customers, business partners, employees, neighbours, shareholders, creditors and many other categories-, even the competitors, may have a concerns regarding the outcome of the crisis, and may have in interest to support the shortest possible resilience.

Crises have a short duration of several hours or days. The golden rule here is: be quick, be accurate and be consistent. Crises shall be handled few hours after they occur; the practitioners suggest that the first reaction should be within the first hour [20]. Although the short term reactions are extremely important for the final consequences of the crisis, the long term sustainability is the most important challenge of crisis management. By crisis management we understand, both the direct response in the very short term (minutes, hours) to the event, but the management of the medium and long term of the consequences (months, years), as well.

From sustainability point of view the short term management of the crisis is mostly related to public safety. We mean by that the protection of life (employees and anyone else outside of the organization) and all kind of environmental issues. In this approach we are more related to concept of environmental sustainability, rather than corporate sustainability, however the two concepts are not separable. Environmental sustainability is out of the scope of our research; here we'd like to focus on other threats –like financial losses or reputation loss-, which are more related to the corporate sustainability concept. The goal is, by proper crisis management, to ensure the continuity of the

activity and the sustainability of the organization. This is not just about to 'keep the business going' or 'bouncing back from crisis'.

Figure 1 depicts how the long term resilience can be achieved [21]. As we can see, after the first response we can have a deep fall. There are no warranties for the full resilience; the long term impact can be anything between bankruptcy till a better position than the pre-crisis status.

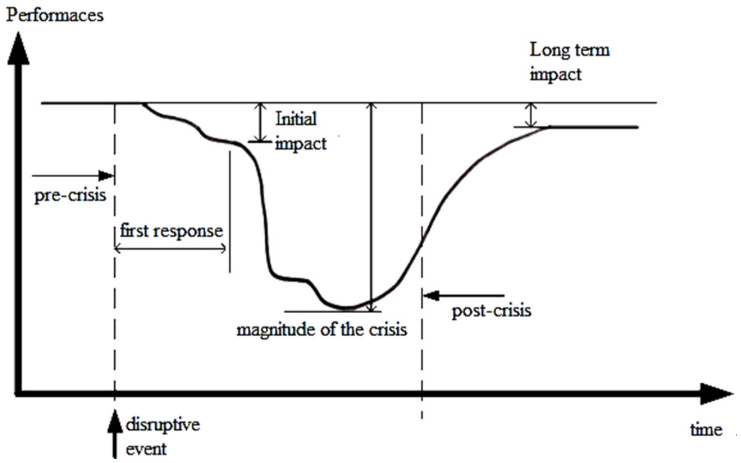

Figure 1. The evolution of the impact of the crises in time (source: [21]).

The target is to create organizational capability to achieve the original objectives, or more, to dynamically reinvent the original business model as the surrounding environment changes [22]. The resilience, the aim to restore normality (or closest achievable state to it) in the shortest time possible is just one major object of crisis management; in broader sense crises has to be seen as opportunities for growth.

Any crisis pushes the organization into a totally new context, in which vulnerabilities are discovered and at the same time new capabilities are identified. By crises the organization gets experience in facing unforeseen events and to cope with threats and challenges. Crises may promote self-reliant growth and sustainable development. Resilient companies endure social and economic difficulties because they anticipate and prepare for change and continuously develop innovation throughout the entire operation, consistent with previous findings [23]. According to Pauchant and Mitroff organizational crisis must be seen 'as normal events triggered by the complexity of the system itself and by faulty decisions as well as by the interrelationship between technological systems and the humans who attempt to manage them' [24]. The chance to have crises at the level of organization is permanently increasing due to the growing complexity of the internal and external environment. System theorist John Casti [25] states that our technology based complex world is increasingly fragile, and he enumerates several reasons for 'yet not experienced' spectacular collapses, which might lead back to the preindustrial ages (for example 'nanoplagues', robot uprisings, crash of the Internet, and many others). We will not go as far, but during our research we documented that the studied organizations are not ready to face new types of crises. In the preliminary phase of our quantitative research we investigated the level of readiness of some organizations by interviewing 8 top managers from automotive industry. We followed some ideas taken from Ian Mitroff, who states that usually ordinary organizations are not prepared for several situations (for example, cyber terrorism, acts of violence and sabotage within the organization, data theft, deviations from ethical behaviour, bad intention, causing an ecological disaster, crisis caused by conflicts of interest, gossip, headhunting or personal theft) [26]. After these interviews, we draw the conclusion that, indeed, the studied organizations are not prepared to this kind of crises. But also we noticed that the managers were not afraid about the lack of awareness about this; they argued it is not possible to be prepared for any kind of crises, but the management of organization definitively will handle all kind of situations, as they previously did. This confidence, it seems, partially is grounded in their well-developed quality

assurance system. They trust on the severe regulations and standards of their industry and also on the ability of the human resources to cope with any situation.

In the emerging context of Industry 4.0., in the era of Internet of Things (IoT) and the so-called Cyber-Physical Systems (CPS), intelligent manufacturing systems are already a reality. Intelligent entities form decentralized organizations, using 'smart things' (smart grids, smart phones, smart materials, smart logistics and so on), are about to create complex networks that provide sustainable resource allocation and a promise to fulfil the highest consumer demands [27,28]. In our interconnected world engineers try to interconnect everything using digital equipment, leaving those issues that can't be automated, like perturbations and failures, to the human operators. [29]. by definition, today's manufacturing systems are techno-centred. The experts involved in industrial engineering, but system engineers and ITC experts too, usually do not have skills and expertise to deal with the human factor. During the design processes the human factor represents a hardly evaluable, unpredictable, blurring element. Yet, there is a hidden assumption, as Patrick Millot and Damien Trentesaux states, that the human operator is an 'omniscient person' that will solve all not anticipated problems, provides good information in due time and makes perfect decisions in real time. The magic human ensures with full reliability the recovery towards normal operating conditions after unforeseen perturbation [30]. The 'magic human' assumption is not just an overestimation of the abilities of the human resources, but it is a proof of the misjudgement of the human resources in techno-centred systems. However the human factor gets the full attention in some issues, such is work safety or ergonomic design, its role is generally under-evaluated during the operation of the technological processes. Usually, it has a supervisor role and it is supposed to interfere only during machine breakdowns and deadlocks. This may lead to a lethargic attitude whenever something unpredicted or off the job-description occurs. In these situations we may a 'dumb human' attitude, a human factor that turns into passive witness or victim of the events. That is why sustainable manufacturing, or the transition to it, requires interdisciplinary research [31]. Industry 4.0, as one of most forward-thinking manufacturing concepts offers many opportunities for the development of sustainable manufacturing, [32], but the developers of such systems must be aware that the incoming cyber- physical systems (CPS) will consists of intelligent cross-linked a self-organized and decentralized entities. Any disturbance handling procedure in CPS will be efficient only if will combine the decentralized disturbance management of ICT systems, with the traditional human centred approaches of crisis management. In these more and more complex systems new control mechanism are needed in order to handle the increasing unpredictability. Paul Walckenaers and Van Brussels states 'when competition favours larger systems, the top levels of competitive systems cannot be effectively controlled in a centralized manner (. . .), but much still needs to be invented and remains to be discovered. Here, the social sciences and humanities may find some challenges to address'. [33] During crises, the constituent elements of a manufacturing system work together to assess to situation, minimize the damages and assure sustainability; regardless if there are technical intelligent subsystems (machines) or human operators. The ICT devices are already designed to perform well under altered connectivity conditions (crises situation by definition means sub-optimal connectivity among the constituent elements) having a decentralized disturbance handling approach. In order to have an efficient crisis handling architecture in CPS the human components might need to use the same decentralized pattern to handle the crisis.

In order to see on what on extent the employees of the studied organizations are prepared for decentralized crisis management and subsequently to cope by themselves with unexpected situations, we framed the following hypothesis:

Hypothesis 1. *In the studied organization the preparation for the crisis situations is limited to those situations that can be solved on the basis of predetermined protocols.*

By this hypothesis we state that in the studied organizations the preparation for crisis situations means only predetermined protocols. We supposed that apart from some explicitly regulated by laws

areas –fire safety, occupational health and safety, and readiness related to some technological failures -, the studied organizations are not prepared for emergencies.

Hypothesis 2. *In the studied organization the non-executive members of the organization do not have the professional maturity to manage a crisis situation.*

By this hypothesis we want to analyse the extent to which the members of the organization, others than top managers, have the will and necessary skills to be involved in solving crisis situations. We assumed that in the studied organizations the employees are not prepared to handle 'off job-description' situations, -cases in which they do not have predefined tasks-, they do not possess the necessary skills to manage the crisis and therefore they will avoid being involved in managing crisis situations.

3. Sample and Methodology

3.1. Research Setting, Data Collection and Survey Instrument Design

The study examines the level of readiness for unforeseen crises situations of the studied organizations, and the envisioned scenarios to handle the unpredicted. There were used mixed investigation methods in order to test the hypothesis. In the preliminary phase a qualitative research took place at an automotive company. The goal of this pilot-project was to have a foundation for designing the survey instruments of the quantitative research and to better understand the complex reality of the crisis handling procedures in one of the most normalized industries. Content analysis, in-depth interviews and participant observation methods were used to identify the specific social and technological context in which real crisis management takes place on regular basis. Systemically collected evidences gave directions where is a room for improvement in their crisis management preparedness. There were interviews with 8 persons, and discussions with other 10 professionals. After over 20 meetings and more than 40 hours of survey the research provided culturally specific information, as values, behaviours, beliefs, and also a detailed image about how the studied company tries to handle the unpredicted situations. Also, a cause-effect diagram, presented in Figure 2, was shaped. It shows the most important causes and the consequences of the analysed topic. According to this figure the most important causes of crises can be grouped in four categories (external, management related, human resources related and technology related causes).

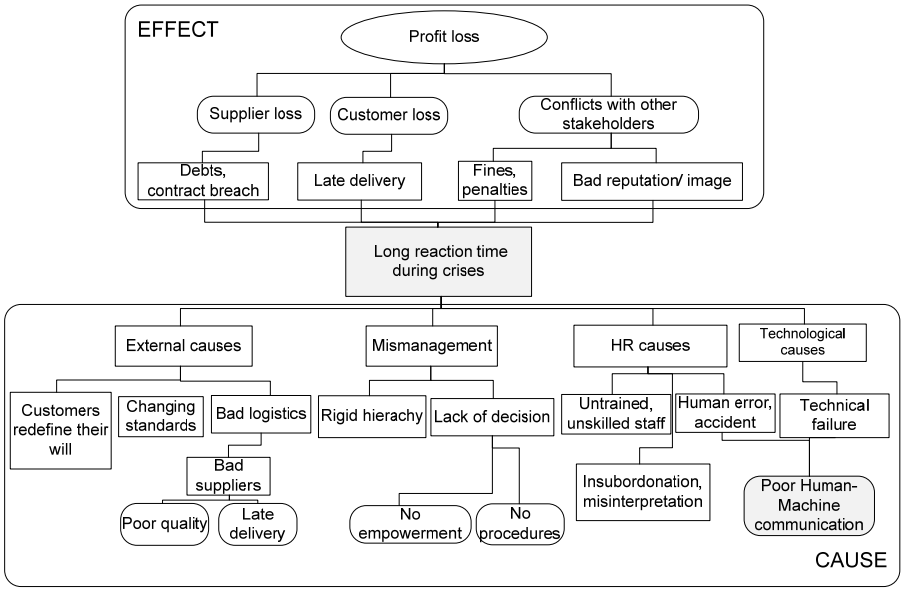

Figure 2. Cause- effect diagram.

Among the identified causes and weaknesses, the causes related the human resources and the poor human – machine communication are subject of interest. The qualitative research phase provided valuable information about 'human' side of crisis preparation, revealing issues that are not readily apparent. The most important outcome of this phase was that it provided valuable information to design the questionnaire used at the quantitative research.

Once the survey instrument was set, the developed questionnaire was tested at few local industrial organizations. During this test phase the final shape of the questionnaire was decided, several details were set up, including timings, how to choose and approach the subjects. In this phase were made the arrangements with the management of the studied organizations about the time, location and number of staff that should participate in the survey.

The studied organizations are successful examples of their field of activity; all companies have increased their turnover and currently have a growing market situation. Due to their size and notoriety each of the analysed companies are important and acquire the attention of many local stakeholders, including mass media, NGOs and the general public. In spite of the fact that the studied organizations can be located in relatively narrow circle in Central and South East of Europe, any major crisis may go beyond local concern, all of the companies are part of international supply chains, most of them are branches of multinational holdings and some of them are listed on the stock exchange. Regarding the field of activity of these companies, there were chosen organizations that represent in the eyes of the community activities with major risks (for social, environmental or other reasons). As common characteristics we may find, that all the studied organizations are medium and large sized companies, their turnover is over 2,000,000 euro/year and they are part of the pharmaceutical and automotive industry.

The survey was carried on two stages. The first was in July–August 2018 (automotive industry) and the second stage in January–March 2019 (pharmaceutical industry). Some of the companies express their will to fill online questionnaires and others chose a survey based on the printed questionnaire. The online version was made using Google Forms. Some organizations accepted to be surveyed only on the basis of confidentiality contracts, and some asked for a split data processing. Regardless of whether the organizations have requested express confidentiality, the collected data have been treated confidentially. Neither the respondents, nor the organizations can be identified by any means. Theoretically, there is a possibility of comparing the data obtained from the two different industrial fields, the data being collected in different time frames. It would be interesting this kind of comparison, each of the industries is extremely well regulated, but at this time the resulting sample does not allow a sufficiently well-founded statistical analysis.

3.2. The Sample

The sample consists of 151 employees from 10 multinational companies. The demographic characteristics of the sample are presented in Table 1. The sampling was done in limited area in Romania (East of Europe), but due to the rigorous regulations of these industries the data provided by the respondents regarding their presumptive behaviour during crises certainly has many similarities to all the branches of the studied companies, located all over the world. The selection of the respondents was made by the top-management of the studied organizations, based on a profile description provided by our research team.

However, the influence of the local culture on the behaviour the respondents can't be neglected. Thus, the sample is not representative, and it reflects only the opinion of the staff involved on the research.

Table 1. Demographic characteristics.

Classification	Variable	Number	%
Gender	Female	43	28%
	Male	108	72%
Education	Less than Bachelor	27	18%
	Bachelor or above	124	82%
Position	Staff	29	19%
	Frontline manager	54	36%
	Middle manager	44	29%
	Senior Manager	24	16%
Enterprise nature	Automotive industry	85	56%
	Pharmaceutical industry	66	44%
Job experience	Less than 5 years	37	25%
	5–10 years	18	49%
	More than 10 years	96	64%
Job nature	Administration	54	36%
	Accounting/Financial	8	5%
	Production	84	56%
	Other or N/A	5	3%

As we can see from the table the majority of the respondents can be considered professionally mature employees, characterized by long professional experience and important responsibilities inside the company. According to the top managers, all selected persons are characterized with integrity, loyalty and self-confidence. The questionnaire was designed mostly for middle-level managers, staff with certain decision-making competencies, but closely monitored by upper management levels of the organization. As a matter of fact, in addition to middle-level managers the questionnaire was completed also by other categories. Firstly, as we can see in Table 1, among the respondents there are also a number of top managers. They participated in the survey in order to understand the content of the questionnaire and to be able to propose appropriate employees for the survey. We also find among the respondents some staff without direct subordinates, in a quite significant proportion of 19%. These respondents are persons with specially assigned duties during the crises. For example advisors on security issues (mostly dealing with fire safety management), quality assurance experts, trainers in HR, people involved in occupational safety and health. These categories of personnel usually do not have subordinates, but they do play an important role in most of the crisis situations. Due to these particularities the respondents largely come from a technical or administrative department. As final note, must be mentioned the fact that the respondents were from industries with many specific standards and regulations, including related to crisis management. This particularity led us to assume that in other industries there is much less degree of preparation for special situations. All the conclusion of this study that show certain deficiencies in communication or weaknesses/ lack of preparedness in the way how the studied companies handle crises, very likely is even more valid for the organizations from other fields. Unquestionably, the conclusions of the paper refer strictly to results obtained on the study of the given sample.

4. Findings and Results

4.1. Descriptive Statistics

In this section there are presented statistical figures of the answers provided by the participants during the survey. In the first question (*q1*) of the questionnaire the participants were asked about their opinion regarding the degree of readiness of their organization in the case of certain emergencies. According to the respondents, as Figure 3 shows, the degree of preparation is the highest in those

emergency situations that are related to well-defined issues (technological breakdowns) or there detailed legal norms (fire emergencies or workplace accidents). In the rest of the situations the degree of preparation is moderate or insufficient, even in some quite predictable situations (lack of raw materials or difficulties with the logistics partner). In the opinion of the majority of the respondents, in a hypothetical totally unpredictable situation, the degree of preparation of their organization is extremely weak. See the responses for the appearance of military forces in their yard, or a noisy, aggressive group of 50 persons speaking a foreign language.

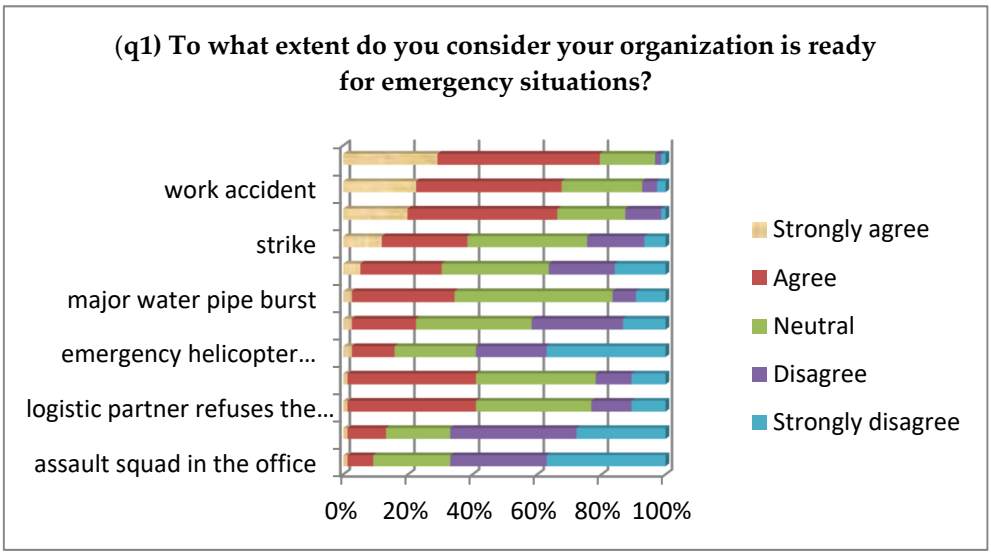

Figure 3. Respondents' answers for (q1).

The second question (q2) investigates the opinion of the respondents about some variables that might have an influence on crisis management efficiency. The respondents considered that effective crisis management is largely influenced by almost all the listed variables (Figure 4). There were two unexpected exceptions: ICT/software and team buildings. For these two variables the dominant answer was 'neutral'. Thus, almost all respondents considered—to some extent—computer applications and team-buildings might have a moderate influence on effective crisis management.

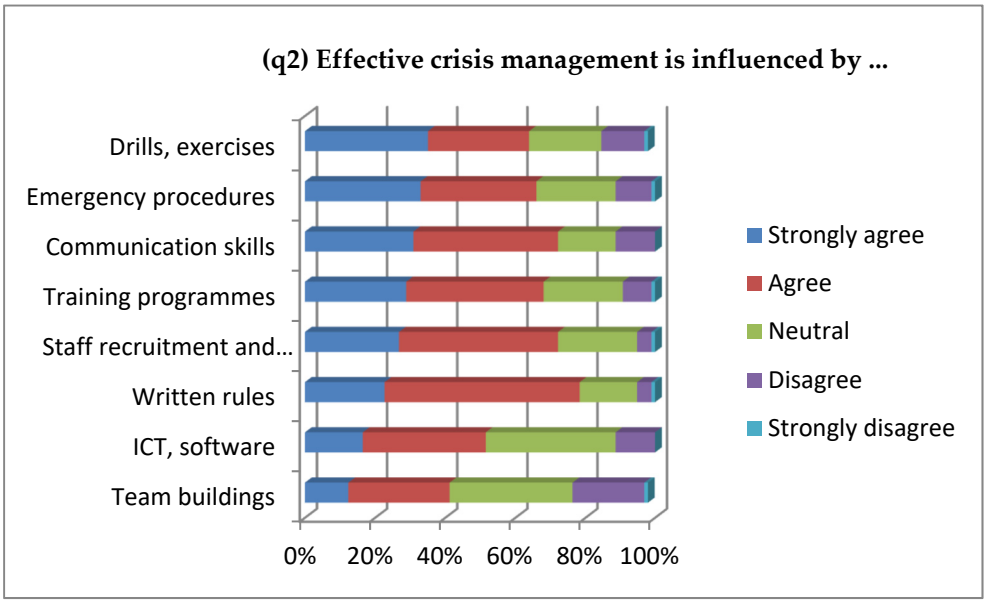

Figure 4. Respondents' answers for (q2).

These results show that even in the case industries with high level of automation the employees does not rely much on the information technology. The answers are strong arguments for better human-machine integration at the studied companies. The ICT should be seen as a trustful tool in handling crises, but certainly only under extremely controlled and monitored circumstances.

Taking in account the dominant technical background of the respondents, it is less surprising the moderate trust in the importance of social connections during crisis. Team buildings are intended to facilitate inter-human connections, to develop common skills and facilitate group creativity. All these characteristics are extremely valuable assets during emergency situations. Based only in these two findings our research shows to the top managers of the studied organization that there is a room for improvement in the organization's preparedness for unexpected situations.

The survey provided interesting descriptive results also for the third question q3). In this question the participants were asked about who is allowed or entitled to communicate to some stakeholders during crises. There were seven types of stakeholders, as it is presented in the columns of Table 2, and there were also presented seven job positions of their company (shown in the rows of the same table).

Table 2. Communication duties during crises.

Job Title	Customers	Suppliers	Police	Mayor	NGOs	Bank	Neighbours
Managing director	58%	48%	82%	60%	29%	29%	24%
Finance director	49%	41%	11%	4%	9%	82%	4%
Production director	74%	46%	13%	1%	21%	7%	37%
Shop mgr/head of dept.	81%	56%	21%	13%	13%	1%	17%
Team leader/head of office	75%	48%	13%	13%	23%	3%	9%
Marketing/PR expert	75%	52%	30%	32%	36%	13%	34%
Executant/worker	9%	5%	19%	4%	21%	0%	30%

At this question there was a restriction: the respondents must indicate at least one stakeholder to whom a certain position is entitled to communicate. This restriction might raise questions in the case of executants/workers; some may argue that these categories shall not have any communication duties during crises. By this restriction we wanted to emphasize that during crises each member of the organization might be involved a communication issues, and each member must know with whom might be necessary to communicate.

The values in the Table 2 shows on what percentage of the participants was indicated a possible communication for a given stakeholder/job title pair. For example, 58% of the respondents considered that the managing director is allowed or is entitled to communicate with the customers. This very first value from the first cell of the table provides interesting data. There are many other interesting values in Table 2, but the most important remark about the results might be that there is no position-stakeholder pair that reached a 90% or above value. Equally surprising is the number with highest percentage (81%) for the head of department/ customers pair. The respondents considered that the head of a department or a shop manager is the most entitled to communicate with customers during emergencies. Obviously, the answers were given based on certain personal professional experiences. As more than half of the respondents come from technical departments, the managers of technical fields obtained higher scores on the stakeholder relations. This explains why just only 124 out of 151 respondents considered that it would be the competence of the finance director to communicate with the bank in the crises. Interestingly the general manager got maximum values for the communication duties to the police and the mayor, and the technical director to the customers. These data show the need for information, education of the personnel of organizations regarding the roles and competences of the different departments, respectively, the need to improve the interdepartmental communication.

In order to test the hypotheses of the research, we used the answers for other two questions: (q4) 'If in a crisis situation, after 10 min, your request for support is unsuccessful, what is your next move?' and (q5) 'Will you break any internal rule in order to handle a crisis the situation?' We admit that the answers to these questions need to be treated with some reserve. It is almost impossible for a person

from a non-military organization to anticipate how he/she will act individually in a crisis situation. The behaviour can be largely influenced by the nature of the event, the degree of perceived danger and many other factors. Question (q4) refers to the persistence of using a communication method that has been witnessed to be inefficient. Figure 5 shows that the most likely behaviour is "I seek for other means of communication", and the least likely option is "I wait". Same to (q4), in the case of (q5) the participants had to answer how they may act in a hypothetical, but very sensitive, situation. Without questioning the honesty of the respondents, there is a room for a slight suspicion: the respondents might not think about their real behaviour, but they tried to put themselves in the place of a character they might like to be. By the answer 'yes', the respondents could assume a hero-like behaviour –with no consequences, this time-, respectively by the answer 'no' we can think that the respondent may have wanted to align to the qualities of a model employee, who tries to follow the rules of the company in any circumstances.

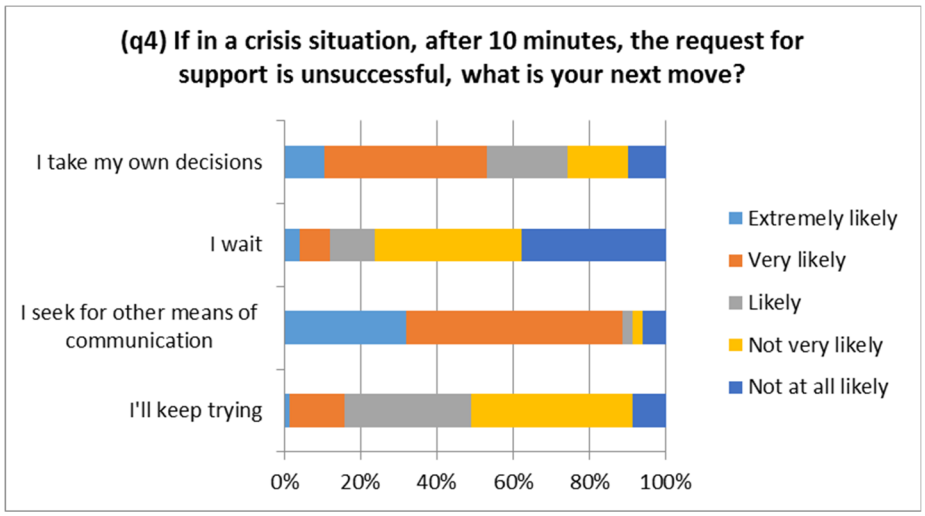

Figure 5. Respondents' answers for (q4).

The answers to the question in fact show what the respondents think as likely behaviour in the case of a situation that is not yet experienced. In Figure 6 it can be seen that over one third (36%) of the respondents answered with "I don't know", which can also be seen as the neutral, but probably the most realistic, answer to this question.

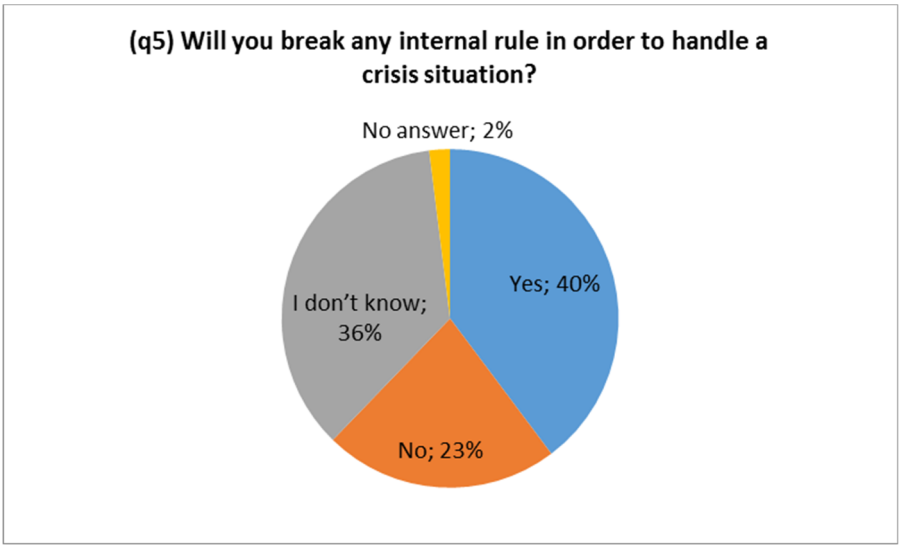

Figure 6. Respondents' answers for (q5).

4.2. Reliability, Validity and Test of Hypotheses

The analysis of the hypotheses is done with the IBM's SPSS software. In order to test the first hypothesis, (H1: in the studied organization the preparation for the crisis situations is limited to those situations that can be solved on the basis of predetermined protocols), we will use the answers of the first two questions from our questionnaire. It is assumed here that apart from some explicitly regulated by law areas –fire safety, occupational health and safety, and issues related to some technological failures -, the studied organizations are not prepared for emergencies. The analysis starts with the statistical data from the answers for (*q1*). In this question the participant expressed their opinion related to the readiness of their organization for certain situations. As a first step, we used the KMO (Kaiser-Meyer-Olkin) test and the Bartlett's test of sphericity to see the adequacy of the sample for factor analysis and to check if the correlation matrix is an identity matrix. The KMO test is equal to 0.721, so our variables are suitable for factor analysis. Also, the Bartlett sphericity test with its value of 321,668, and a significance level of 0.000, shows unequivocally that the variables are correlated with each other. These values indicate the presence of one or more common factors which motivates the application of variable reduction procedure and to detect a structure in the relationships between variables. Table 3 presents the total explained variance generated by the SPSS Statistics, and as it shows we can distinguish 12 components.

Table 3. Total Variance Explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	4.584	38.200	38.200	4.584	38.200	38.200
2	1.642	13.681	51.882	1.642	13.681	51.882
3	1.584	13.203	65.084	1.584	13.203	65.084
4	1.098	9.148	74.232			
5	0.766	6.387	80.619			
6	0.622	5.186	85.805			
7	0.549	4.572	90.377			
8	0.401	3.341	93.718			
9	0.325	2.711	96.429			
10	0.261	2.173	98.602			
11	0.168	1.398	100.000			
12	5.551E-17	4.626E-16	100.000			

Extraction Method: Principal Component Analysis.

We will note only three factors whose values are greater than 1. The principal component analysis extraction method shows that the main components own values in the first factor is 38.2%, in the second factor we have the value of 13.68% respectively in the third is 13.20%. Before the rotation the three factors explains cumulatively 65,084% of the total variance analysed. We used oblique rotation in order to have a better view of the components matrix. The correlation matrix of the components showed that we have a correlation of 0.413 between component 1 and 2, 0.361 between 1 and 3, respectively 0.389 between component 2 and 3. Following the rotation we find a redistribution of the three factors, obtaining 3,597 for the first factor respectively 3,478 and 3,005 for the other two factors. We will name the factors as follows: factor 1 will be called 'Expected emergency situations', factor 2 'Foreseen emergency situations with high impact and low probability' and the last factor will be 'Unforeseen emergency situations'. The names of the factors were determined by the content of the variables related to these factors. In Table 4 we present the data obtained for these factors resulted from the calculations.

Table 4. Variables and factors.

Factor Nr.	Factor Name	Component	
	Variables	**Pattern**	**Structure**
	Expected emergency situations		
1.	technological breakdown	0.998	0.960
	work accident	0.998	0.960
	fire	0.756	0.785
	strike	0.677	0.688
	Foreseen emergency situation with high impact and low probability		
2.	sudden raw material shortage	0.964	0.860
	the logistic partner refuses a delivery	0.931	0.899
	major water pipe burst	0.734	0.800
	group of activists at the front gate	0.538	0.734
	garnishment of all bank accounts	0.526	0.726
	Unforeseen emergency situation		
3.	assault squad in the office	0.921	0.883
	emergency helicopter landing in the backyard	0.868	0.747
	50 aggressive foreigners in the lobby	0.583	0552

The analysis of similarities/differences among the established factors were compared with the answers provided for the first variable of (q2) (to what extent do the participants consider that effective crisis management is influenced by emergency protocols).

We applied the ANOVA method for the analysis and later the Levene's homogeneity test (test F) on the factors. The ANOVA test showed (Table 5) that in the case of the first and last factor, we have significant differences between the different groups (the groups consist of the answer alternatives from the questionnaire). In the case of factor 2, 'Emergency situations foreseen with high impact and low probability' we have no significant differences, the test value is over 0.05, so the answers are inconclusive.

Table 5. ANOVA test.

		Sum of Squares	**Mean Square**	**F**	**Sig.**
Expected emergencies	Between Groups	8.227	2.742	4.054	**0.013**
	Within Groups	29.762	0.676		
	Total	37.989			
Foreseen emergencies with high impact and low probability	Between Groups	3.907	1.302	2.015	0.126
	Within Groups	28.443	0.646		
	Total	32.350			
Unforeseen emergencies	Between Groups	10.492	3.497	4.170	**0.011**
	Within Groups	36.898	0.839		
	Total	47.390			

Because there are significant differences at the answers given for the factors 1 and 3 for different groups (we have the value of significance below 0.05) at the ANOVA test, we will analyse where these differences are. Since we have the condition of homogeneity satisfied, we will use the Tukey test, also known as the HSD test (Table 6). The reason for this choice is that this test is among the most severe tests and can be used in groups larger than three (we have four groups here, because the 'strongly disagree' option in the questionnaire could not be interpreted statistically, there is only one answer at the (q2) for variable 'emergency procedures'.

Table 6. Multiple Comparisons. Tukey HSD.

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Expected emergencies	Disagree	Neutral	−0.11	0.44	0.994	−1.30	1.07
		Agree	−0.72	0.42	0.337	−1.84	0.41
		Strongly Agree	−1.07	0.42	0.066	−2.20	0.05
	Neutral	Disagree	0.11	0.44	0.994	−1.07	1.30
		Agree	−0.60	0.32	0.253	−1.46	0.26
		Strongly Agree	−0.96 *	0.32	**0.023**	−1.82	−0.10
	Agree	Disagree	0.72	0.42	0.337	−0.41	1.84
		Neutral	0.60	0.32	0.253	−0.26	1.46
		Strongly Agree	−0.36	0.29	0.607	−1.14	0.42
	Strongly Agree	Disagree	1.07	0.42	0.066	−0.05	2.20
		Neutral	0.96 *	0.32	**0.023**	0.10	1.82
		Agree	0.36	0.29	0.607	−0.42	1.14
Foreseen emergencies with high impact and low probability	Disagree	Neutral	0.00	0.43	1.000	−1.16	1.16
		Agree	−0.11	0.41	0.993	−1.21	0.99
		Strongly Agree	−0.65	0.41	0.396	−1.75	0.45
	Neutral	Disagree	0.00	0.43	1.000	−1.16	1.16
		Agree	−0.11	0.31	0.985	−0.95	0.73
		Strongly Agree	−0.65	0.31	0.179	−1.49	0.19
	Agree	Disagree	0.11	0.41	0.993	−0.99	1.21
		Neutral	0.11	0.31	0.985	−0.73	0.95
		Strongly Agree	−0.54	0.28	0.239	−1.30	0.22
	Strongly Agree	Disagree	0.65	0.41	0.396	−0.45	1.75
		Neutral	0.65	0.31	0.179	−0.19	1.49
		Agree	0.54	0.28	0.239	−0.22	1.30
Unforeseen emergencies	Disagree	Neutral	−0.79	0.49	0.391	−2.11	0.53
		Agree	−0.85	0.47	0.283	−2.10	0.40
		Strongly Agree	−1.53 *	0.47	**0.011**	−2.79	−0.29
	Neutral	Disagree	0.79	0.49	0.391	−0.53	2.11
		Agree	−0.06	0.36	0.998	−1.02	0.90
		Strongly Agree	−0.75	0.36	0.171	−1.71	0.21
	Agree	Disagree	0.85	0.47	0.283	−0.40	2.10
		Neutral	0.06	0.36	0.998	−0.90	1.02
		Strongly Agree	−0.69	0.32	0.158	−1.56	0.17
	Strongly Agree	Disagree	1.53 *	0.47	**0.011**	0.29	2.79
		Neutral	0.75	0.36	0.171	−0.21	1.71
		Agree	0.69	0.32	0.158	−0.17	1.56

The multiple comparisons show a significant difference between the 'Neutral' and 'Strongly Agree' (0.023) factors in the case of 'expected emergencies' factor. We also have significant difference for 'Unforeseen emergency situations' for the group 'Disagree' and 'Strongly Agree' where the value is 0.011. For the case 'Foreseen emergency situations with high impact and low probability', because the values are above 0.05, we have no significant differences among the groups.

In the case of the two factors where we have significant differences between different groups, for the factor 'expected emergencies' the average value for the group 'Strongly Agree' is much more higher than for 'Neutral' (0.57 against 0.39). Thus, it becomes obvious that the respondents for the factor 'expected emergencies' strongly agreed on the high degree of readiness of the organization for these types of

emergencies. Regarding the second factor, 'unforeseen emergencies' here the average for 'Disagree' (1.08) is much higher than the average for 'Strongly Agree' (0.46), so the respondents agreed on that their organization is not prepared for unforeseen emergencies. The last factor, 'Foreseen emergencies with high impact and low probability' did not produce homogeneous answers regarding the organization's preparedness regarding these situations. This means that the respondents do not know how to proceed in these cases, thus the organization is not prepared for such situations. In conclusion we can state that the respondents agreed on the following:

- the organization is prepared for the expected emergency situations,
- the organization is not prepared for unforeseen situations,
- for situations with high impact, but low probability, they could not formulate a coherent opinion, so they do not know how to proceed in these cases

Taking into account the values determined by the factorial analysis of the main components on the crisis management performance based on predetermined protocols, we can conclude that the research hypothesis no.1 that assumes in the studied organizations the preparation for crisis situations is limited only to situations that can be managed on the basis of previously set protocols, is confirmed.

The second hypothesis presumes that in the studied organization the non-executive members of the organization do not have the professional maturity to manage a crisis situation. By this hypothesis we want to see if the members of the organization, others than top managers, are ready to be involved in solving crisis situations. We assumed that in the studied organizations the employees are not prepared to handle 'off job-description' situations, -cases for which they do not have predefined tasks-, they do not possess the necessary skills to manage the crisis and therefore they will avoid being involved in managing crisis situations. In order to test this hypothesis we analysed the factors that influence the behaviour of members in certain crisis situations. The data for the test was obtained from the answers for (q4) 'If in a crisis situation, after 10 min, the request for support is unsuccessful, what is your next move?') and (q5) ('Do you consider breaking internal rules to handle a crisis the situation?)'. The influence factors are based on the answers to (q4). The KMO test's value is 0, 744. Being greater than 0.5, the value means that the sample is adequate and no corrections are needed; the factorial analysis will be effective. We have a significance value of 0.002 for the chi-square test, which is below the limit of 0.05, under these conditions efficient factorial analysis is possible, the variables are correlated. In Table 7 we show the Eigenvalues, for the 4 components. Using the principal component analysis extraction method we define two factors.

Table 7. Total Variance Explained for q3).

Comp.	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cum.%	Total	% of Variance	Cum.%	Total	% of Variance	Cum.%
1	1.567	39.187	39.187	1.567	39.187	39.187	1.419	35.478	35.478
2	1.109	27.732	66.919	1.109	27.732	66.919	1.258	31.441	66.919
3	0.748	18.688	85.607						
4	0.576	14.393	100.000						

Extraction Method: Principal Component Analysis.

Before the rotation, the two factors explain cumulatively 66,919% of the total variance analysed. This time *varimax* rotation method offered by SPSS was applied in order to simplify the interpretation. After three rotations the resulted component matrix is presented below in Table 8.

Table 8. Rotated Component Matrix.

q4	Component	
	1	**2**
I'll keep trying	0.852	0.005
I wait	0.823	0.134
I take my own decisions	0.003	0.810
I seek for other means of communication	−0.127	0.764

The values show a strong correlation between the factors and the analysed variables. The two factors will be named as follows: factor 1 will be 'passive attitude' and factor 2 will be 'active attitude'. In order to test the hypothesis H2 these two factors will be used for the analysis of the answers from q5 ('Do you consider breaking internal rules to handle a crisis the situation?'). Our goal is to see by ANOVA analysis if there are differences among the respondent groups. The ANOVA analysis shows only the existence of differences (Table 9); in order to spot where these differences are we'll use later the Tamhane test.

Table 9. The ANOVA test for H2.

Factor 1 Passive attitude				
	Sum of Squares	Mean Square	F	Sig.
Between Groups	7.889	3.944	4.296	0.017
Within Groups	66.111	0.918		
Total	74.000			
Factor 2 Active attitude				
Between Groups	3.684	1.842	1.886	0.159
Within Groups	70.316	0.977		
Total	74.000			

For the factor 'passive attitude' we can notice that the factorial analysis produces a significant result ($p = 0.017$); so we have differences among the means. In this case pairwise multiple comparisons can determine which means differ. We choose the Tamhane test for the comparison, being appropriate when the variances are unequal. The test showed that there is a significant difference between the answers 'no' and 'I do not know'. The averages of these groups we found, show: those who responded they are not willing to violate the internal rules are more passive (average: 0.57), than those who responded with 'I do not know' (average: 0.28). This allows us to conclude that those respondents who adopt a passive attitude during crises are not willing to break the rules of the organization.

In the case of the second factor, 'active attitude', the result of the ANOVA analysis ($p = 0.159$) shows that the averages of the different groups do not show significant differences. The respondents characterized by an active attitude, had a non-evaluable statistical behaviour in the described situation of breaking certain internal rules. This ambiguous behaviour during crises confirms that the members of the organization are not prepared for such situations. Taking into account these results we consider that hypothesis 2 is tested, in crisis situations, the non-executive members do not have the professional maturity to manage the situation.

5. Conclusions

The study explored the readiness of the human factor in highly regulated industries during unexpected events or crises situations. The stake of the behaviour of the human factor during crises can be short term resilience and the long term sustainability of the company. During the study we emphasized the importance of the communication to stakeholders, stating that a well handled crisis

can become an opportunity to grow and to prove sustainability. This can be achieved by a careful communication to all stakeholders. The study showed that the employees are not familiar to whom and who shall communicate during a crisis. In the studied organizations there is a need for guidance and education for the personnel regarding the roles and competences of the different departments regarding the relationship with certain stakeholders, and also there is a room for improvement in interdepartmental communication.

In the preliminary phase of the quantitative research the poor human-machine communication was identified as an important cause of inefficient disturbance handling. In the era of impressive evolution of the information technology the human-machine interaction can be at the same time the cause and the solution of the crises. In the new world of cyber-physical systems, the human-machine scholars emphasize the decentralized, human – machine cooperation based disturbance handling. The main studied question during the research was if the human component of these cyber-physical systems is ready for this challenge. We choose two industries in which the human-machine cooperation is a reality. In all the studied organizations numerically controlled machines, robots and high-tech devices perform under the supervision of the human factor. Under these circumstances the results of our survey revealed that the studied organizations are only prepared for predictable situations. We confirmed that apart from some explicitly regulated by law areas –fire safety, occupational health and safety, and some technological failures -, the studied organizations are not prepared for emergencies. We noticed that the managers were not afraid about the lack of awareness about the unpreparedness; they argued it is not possible to be prepared for any kind of crises and the management of organization definitively will handle all kind of situations, as they previously did. Also, our survey revealed that the members of the organization, others than top managers, are not prepared to handle 'off the job-description' situations. Even those respondents who presumably will adopt an active attitude during crises are not willing to break the rules of the organization. The respondents presumably will have an ambiguous behaviour during crises, fact that confirms that the members of the organization are not prepared for such situations. In one hand they would like to follow the rules under any circumstances, and in the other hand they are aware about the fact that the rules set to normal working conditions might not be applicable during crises. Since the respondents of our survey belong to highly regulated industries, we can plausibly assume that in other industries there is a much less degree of preparation for special situations. But this statement must be confirmed in a future work.

6. Limitations and Future Research Directions

Same to other studies, this research has its limitations. First of all the size of the sample, the restricted number of companies from only two industries, located nearby each to other, certainly represents limitations of the research. Therefore, it would be interesting to compare the results of the present study with the results from less standardized industries and/or to extend the research to a much broader geographical area. The size of the existing sample is a sufficient number for the experimental set-up of this study, but larger samples shall be used in further research. Certainly represents a limitation of the present study the fact that over 80% the participants have technical background, attribute that definitively influence their behaviour under unpredicted circumstances. Future research should more explore other staff categories from these industrial organizations. Obviously, some of these limitations may set the future research directions.

During the study, the management of the studied companies spotted some of the weaknesses of their organizations. They identified, mostly, gaps between the reality and what they presumed about the skills of their subordinates in handling unexpected situations. According to some managers, soon drills, trainings and team-buildings will take place in order to develop other emergency skills than those related to fire safety or workplace accident preventions. In this context a longitudinal research should appropriate, in order to evaluate the improvements.

Author Contributions: Conceptualization, L.B., D.D.D. and K.H.; methodology, D.D.D. and K.H.; software, K.H.; validation, L.B., D.D.D. and K.H.; formal analysis, L.B., D.D.D. and K.H.; investigation, L.B.; resources, L.B.; data curation, L.B.; writing—original draft preparation, L.B.; writing—review and editing, L.B., D.D.D. and K.H.; visualization, L.B.; supervision, D.D.D.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

References

1. Bratianu, C. *Organizational Knowledge Dynamics: Managing Knowledge Creation, Acquisition, Sharing, and Transformation*; IGI Global: Hershey, PA USA, 2015.
2. Heath, R.L.; Millar, D.P. A rhetorical approach to crisis communication: Management, communication processes, and strategic responses. In *Responding to Crisis: A Rhetorical Approach to Crisis Communication*; Millar, D.P., Heath, R.L., Eds.; Lawrence Erlbaum Associates: Mahwah, NJ, USA, 2004; pp. 1–17.
3. Sheridan, T.B. *Telerobotics, Automation, and Human Supervisory Control*; MIT Press: Cambridge, MA, USA, 1992.
4. Qin, J.; Liu, Y.; Grosvenor, R. A Categorical Framework of Manufacturing for Industry 4.0 and Beyond. *Procedia CIRP* **2016**, *52*, 173–178. [CrossRef]
5. Wang, S.; Wan, J.; Zhang, D.; Zhanga, C. *Towards Smart Factory for Industry 4.0: A Self-Organized Multi-Agent System with Big Data Based Feedback and Coordination*; Computer Networks; Elsevier BV: Amsterdam, The Netherlands, 2016; Volume 101, pp. 158–168.
6. Muller-Schloer, C.; Tomforde, S. *Organic Computing–Technical Systems for Survival in the Real World*; Series: Autonomic Systems; Springer International Publishing AG: Birkhauser, Basel, Switzerland, 2017.
7. Strunk, J.D.; Ganger, G.R. A Human Organization Analogy for Self-* Systems. In Proceedings of the First Workshop on Algorithms and Architectures for Self-Managing Systems, On conjunction with Federated Computing Research Conference (FCRC), San Diego, CA, USA, 11 June 2003.
8. Bonilla, S.H.; Silva, H.R.O.; da Silva, M.T.; Gonçalves, R.F.; Sacomano, J.B. Industry 4.0 and Sustainability Implications: A Scenario-Based Analysis of the Impacts and Challenges. *Sustainability* **2018**, *10*, 3740. [CrossRef]
9. Coombs, W.T. Conceptualizing crisis communication. In *Handbook of Crisis and Risk Communication*; Heath, R.L., O'Hair, H.D., Eds.; Routledge: New York, NY, USA, 2009; pp. 100–119.
10. Freeman, R.E. The politics of stakeholder theory: Some future directions. *Bus. Ethics Q.* **1994**, *4*, 409–421. [CrossRef]
11. Frow, P.; Payne, A. A stakeholder perspective of the value proposition concept. *Eur. J. Mark.* **2011**, *45*, 223–240. [CrossRef]
12. Evans, S.; Fernando, L.; Yang, M. Sustainable Value Creation—From Concept towards Implementation. In *Sustainable Manufacturing. Sustainable Production, Life Cycle Engineering and Management*; Stark, R., Seliger, G., Bonvoisin, J., Eds.; Springer: Cham, Switzerland, 2017; pp. 203–220.
13. Bocken, N.; Short, S.W.; Evans, S. A literature and practice review to develop sustainable business model archetypes. *J. Clean. Prod.* **2014**, *65*, 42–56. [CrossRef]
14. Glavas, A.; Mish, J. Resources and Capabilities of Triple Bottom Line Firms: Going Over Old or Breaking New Ground? *J. Bus. Eth.* **2015**, *127*, 623–642. [CrossRef]
15. Kwarteng, A.; Dadzie, S.; Famiyeh, S. Sustainability and competitive advantage from a developing economy. *J. Glob. Responsib.* **2016**, *7*, 110–125. [CrossRef]
16. Lakatos, E.S.; Cioca, L.I.; Dan, V.; Ciomoș, A.O.; Crișan, A.C.; Barsan, G. Studies and Investigation about the Attitude towards Sustainable Production, Consumption and Waste Generation in Line with Circular Economy in Romania. *Sustainability* **2018**, *10*, 865. [CrossRef]
17. Evan, W.; Freeman, R. A stakeholder theory of the modern corporation: Kantian capitalism. *Ethical Theor. Bus.* **1988**, 97–106.
18. Parmar, L.; Freeman, R.; Harrison, J.S.; Wicks, A.C.; Purnell, L.; de Simone, C. *Stakeholder Theory: The State of the Art*; Cambridge University Press: Cambridge, UK, 2010; Volume 3, pp. 403–445.

19. Hillman, A.; Keim, G. Shareholder value, stakeholder management, and social issues: What's the bottom line? *Strateg. Manag. J.* **2001**, *22*, 125–139. [CrossRef]
20. Barton, L. *Crisis in Organizations II*, 2nd ed.; College Divisions South-Western: Cincinnati, OH, USA, 2001.
21. Sheffi, Y.; Rice, J., Jr. A Supply Chain View of the Resilient Enterprise. *MIT Sloan Manag. Rev.* **2005**, *47*, 41–48.
22. Kantabutra, S. Achieving Corporate Sustainability: Toward a Practical Theory. *Sustainability* **2019**, *11*, 4155. [CrossRef]
23. Avery, G. *Leadership for Sustainable Futures: Achieving Success in a Competitive World*; Edward Elgar: Cheltenham, UK, 2005.
24. Pauchant, J.B.; Mitroff, I. *Transforming the Crisis-Prone Organization: Preventing Individual, Organizational, and Environmental Tragedies*; Jossey-Bass: San Francisco, CA, USA, 1992; p. 20.
25. Casti, J.L. *X-Events: Complexity Overload and the Collapse of Everything*; Harper Collins Publishers: New York, NY USA, 2012.
26. Mitroff, I.I.; Anagnos, G. *Managing Crises before They Happen: What Every Executive and Manager Needs to Know about Crisis Management*; Amacom: New York, NY, USA, 2001; pp. 145–155.
27. Monostori, L.; Kádár, B.; Bauernhansl, T.; Kondoh, S.; Kumara, S.; Reinhart, G.; Sauer, O.; Schuh, G.; Sihn, W.; Ueda, K. Cyber-physical systems in manufacturing. *CIRP Ann. Manuf. Technol.* **2016**, *65*, 621–641. [CrossRef]
28. Zheng, P.; Wang, H.; Sang, Z.; Zhong, R.; Liu, Y.; Liu, C.; Mubarok, K.; Yu, S.; Xu, X. Smart manufacturing systems for Industry 4.0: Conceptual framework, scenarios, and future perspectives. *Front. Mech. Eng.* **2018**, *13*, 137–150. [CrossRef]
29. Boy, G.A. Dealing with the Unexpected in Our Complex Socio-Technical World. In Proceedings of the 12th IFAC Symposium on Analysis, Design, and Evaluation of Human-Machine Systems, Las Vegas, NV, USA, 11–15 August 2013; p. 404.
30. Millot, P.; Trentesaux, D. A Human-Centred Design to Break the Myth of the "Magic Human" in Intelligent Manufacturing Systems. In *Service Orientation in Holonic and Multi-Agent Manufacturing*; Borangiu, T., Thomas, M., Eds.; Studies in Computational Intelligence; Springer: Cham, UK, 2016; Volume 640, pp. 103–113.
31. Stark, R.; Bonvoisin, J. *Sustainable Manufacturing, Challenges, Solutions and Implementation Perspectives*; Springer: Berlin, Germany, 2007; pp. 3–20.
32. Stock, T.; Seliger, G. *Opportunities of Sustainable Manufacturing in Industry 4.0*; Procedia CIRP 40; Elsevier BV: Amsterdam, The Netherlands, 2016; pp. 536–541.
33. Valckenaers, P.; Van Brussel, H. *Design for the Unexpected. From Holonic Manufacturing Systems towards a Humane Mechatronics Society*; Butterworth-Heinemann; Elsevier BV: Amsterdam, The Netherlands, 2015; p. 36.