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Abstract

The dissertation examines the issues related to the human resource management in emergency situations and introduces the measures helping to solve these issues. The prime aim is to analyse complexly a human resource management, built environment resili-ence management life cycle and its stages for the purpose of creating an effective Human Resource Management in Emergency Situations Model and Intelligent System. This would help in accelerating resilience in every stage, managing personal stress and reducing disaster-related losses.

The dissertation consists of an Introduction, three Chapters, the Conclusions, References, List of Author's Publications and nine Appendices.

The introduction discusses the research problem and the research relevance, outlines the research object, states the research aim and objectives, overviews the research methodology and the original contribution of the research, presents the practical value of the research results, and lists the defended propositions. The introduction concludes with an overview of the author's publications and conference presentations on the topic of this dissertation.

Chapter 1 introduces best practice in the field of disaster and resilience management in the built environment. It also analyses disaster and resilience management life cycle ant its stages, reviews different intelligent decision support systems, and investigates researches on application of physiological parameters and their dependence on stress. The chapter ends with conclusions and the explicit objectives of the dissertation.

Chapter 2 of the dissertation introduces the conceptual model of human resource management in emergency situations. To implement multiple criteria analysis of the research object the methods of multiple criteria analysis and mahematics are proposed. They should be integrated with intelligent technologies.

In Chapter 3 the model developed by the author and the methods of multiple criteria analysis are adopted by developing the Intelligent Decision Support System for a Human Resource Management in Emergency Situations consisting of four subsystems: Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management; Text Analytics Subsystem; Recommender Thermometer for Measuring the Preparedness for Resilience and Subsystem of Integrated Virtual and Intelligent Technologies.

The main statements of the thesis were published in eleven scientific articles: two in journals listed in the *Thomson Reuters ISI Web of Science*, one in a peer-reviewed scientific journal, four in peer-reviewed conference proceedings referenced in the *Thomson Reuters ISI* database, and three in peer-reviewed conference proceedings in Lithuania. Five presentations were given on the topic of the dissertation at conferences in Lithuania and other countries.

Reziumė

Disertacijoje nagrinėjamos žmogiškųjų išteklių valdymo ekstremaliose situacijose problemos bei pateikiamos priemonės, padedančios spręsti šias problemas. Pagrindinis tikslas – išanalizuoti žmogiškųjų išteklių valdymo, užstatytos aplinkos greito atsistatymo po katastrofų gyvavimo ciklo ir jo etapų kompleksiškumą, siekiant sukurti žmogiškųjų išteklių valdymo ekstremaliose situacijose modelį ir intelektinę sistemą, kuri paspartintų atsistatymą po katastrofų kiekviename etape, padėtų valdyti stresą ir mažintų su katastrofomis susijusias išlaidas.

Disertaciją sudaro įvadas, trys skyriai ir rezultatų apibendrinimas, literatūros sąrašas, autoriaus publikacijų sąrašas ir devyni priedai.

Įvadiniame skyriuje aptariama tiriamoji problema, darbo aktualumas, aprašomas tyrimų objektas, formuluojamas darbo tikslas ir uždaviniai, aprašoma tyrimų metodika, darbo mokslinis naujumas, darbo rezultatų praktinė reikšmė, ginamieji teiginiai. Įvado pabaigoje pristatomos disertacijos tema autorės paskelbtos publikacijos ir pranešimai konferencijose.

Pirmajame skyriuje išanalizuota pasaulinė patirtis katastrofų ir atsistatymo po jų valdymo užstatytos aplinkos srityje. Taip pat atlikta geriausios pasaulinės patirties intelektinių sprendimo paramos sistemų taikymo analizė. Išanalizuoti fiziologiniai parametrai, taikomi žmogiškųjų išteklių valdymui ekstremaliose situacijose. Skyriaus pabaigoje formuluojamos išvados ir tikslinami disertacijos uždaviniai.

Antrajame disertacijos skyriuje pateikiamas žmogiškųjų išteklių valdymo ekstremaliose situacijose koncepcinis modelis. Disertacijos tyrimo objekto daugiakriterei analizei atlikti siūloma taikyti daugiakriterės analizės ir matematinius metodus bei integruoti intelektines technologijas.

Trečiajame skyriuje autorės sukurtas modelis ir daugiakriteriai metodai pritaikomi kuriant žmogiškųjų išteklių valdymo ekstremaliose situacijose sistemą, susidedančią iš keturių posistemių: fiziologinės rekomendacinės posistemės, skirtos vartotojo stresui po katastrofų valdyti; žmogiškųjų išteklių valdymo ekstremaliose situacijose teksto analitikos posistemės; rekomendacinio termometro, skirto matuoti pasiruošimą greitam atsistatymui po katastrofų; integruotų virtualių ir intelektinių technologijų posistemės.

Pagrindiniai disertacijos rezultatai buvo publikuojami vienuolikoje mokslinių straipsnių: du – mokslo žurnaluose, įtrauktuose į *Thomson Reuters ISI Web of Science* sąrašą, vienas – recenzuojamame mokslo žurnale, keturi – recenzuojamuose tarptautinių konferencijų leidiniuose ir trys – recenzuojamuose Lietuvos konferencijų straipsnių rinkiniuose. Disertacijos tema perskaityti penki pranešimai Lietuvos ir kitų šalių konferencijose.

Notations

Symbols

$a_r(x)$ – the *r*th feature of instance *x*;

c – the number of solutions considered in determining a built environment resilience management life cycle;

$d(x_i, x_j)$ – the distance between instances x_i and x_j;

d_{ij} – dimensionless weighted index values;

e – repayment time of a project;

$e(x)$ – the vector of errors;

E_{ji} – efficiency deg;

f_i – monetary evaluation of a measure unit of the *i* criterion;

g – the number of quantitative criteria included into the compared standard;

gX – the gradient value;

i – criterion;

j – alternative of a solution;

$J(x)$ – Jacobian matrix;

$J^T(x)$ – the transpose of the Jacobian matrix;

k – closest training instances to the test instance;

k – maximum number of the resilience management projects obtained;

K – the maximum number of the resilience management projects obtained;

k_j – the average deviation of the utility degree N_j of the alternative a_j from the same index of other alternative (n–1);
m – the number of criteria;
n – the number of the alternatives compared;
N_f – the number of words in a phrase;
n_i – is the number of i solution alternatives to be used in developing a built environment resilience management life cycle;
N_i – utility degree of alternative a_i;
N_j – utility degree of alternative a_j;
N_{kwr} – the number of times a specific keyword repeats;
p – the number of the best variants of every solution used in developing a built environment resilience management life cycle;
$P(\#i)$ – probability of the test instance belonging to group i;
p_1, p_2, p_3, p_4, p_5 – the proportions of members of the statistical population respectively who would answer "poor", "fair", "good", "very good", and "excellent";
p_i – initial weight of the i criteria;
P_i – the total monetary expression of every quantitative criterion describing the investigated project;
q_i – weight of i-th criterion;
Q_j – relative significance of each project a_j;
Q_{max} – significance of the most rational alternative;
q_z – the weight of z quantitative criterion included into the compared standard;
ree of money invested into alternative a_j;
S_- – sum of weights of minimizing criteria;
s – the accuracy, %;
S_+ – sum of weights of maximizing criteria;
S_{+j} – maximizing indexes;
S_i – the determination of the sum of values for every quantitative criterion;
S_{-j} – minimizing indexes;
t – the number of quantitative criteria;
T_j – the "temperature" of preparedness for flood resilience of built environment in the j-th alternative;
T_{vw} – the total number of words in the text under analysis;
V – the overall quantitative criteria magnitude sum expressed in money terms;
x – arbitrary instance;
x – the vector of independent variables;
X – weight and bias value;
x_{ij} – the value of the i-th criterion in the j-th alternative of a solution;
y^* – the exact but unobserved dependent variable (perhaps the exact level of agreement with the statement proposed by the pollster);
z – quantitative criterion;
β – the vector of regression coefficients which we wish to estimate;
$\Delta \underline{x}$ – the Marquardt-Levenberg Modification to the Gauss-Newton method;

ε – residual;
μ – Marquardt parameter.

Abbreviations

AHCI – Arts and Humanities Citation Index;
AHP – analytic hierarchy process;
AI – artificial intelligence;
ANDROID – Academic Network for Disaster Resilience to Optimise educational Development;
ANFIS – adaptive neuro-fuzzy inference system;
ASR – Affective Self Report;
CADRE – Collaborative Action towards Disaster Resilience Education;
CART – classification and regression tree;
CBT – cognitive behavioral therapy;
CLAVIRE – Cloud Applications Virtual Environment;
CPT – Cold Pressor Test;
DFA – discriminant function analysis;
DSS – decision support system;
EEG – electroencephalogram;
ELSSVR – ensemble least squares support vector regression;
EWS – early warning system;
FDSS – fuzzy decision support system;
FP7 – Seventh Framework Programme;
GHQ-12 – 12-item general health questionnaire;
IDSS – intelligent decision support system;
IES-R – Impact of Event Scale – Revised;
IRT – Infrared Thermography;
KNN – *k*-Nearest neighbor algorithm;
LDA – linear discriminate analysis;
LSSVR – least squares support vector regression;
MBP – Marquardt back-propagation;
MCDM – multicriteria decision making;
MCH – Modified Cooper Harper Scale;
MLP – Multilayer Perceptron;
MMC – Meta-multiclass;
NDM – natural disaster management;
NER – Named-entity Recognition;
NPV – normalized pulse volume;
OASIS – advancing open standards for the information society;
PA – Physiological Advisory;
PCL – posttraumatic stress disorder checklist;
PTSD – posttraumatic stress disorder;

RBP – Resilient Back-propagation;

RESINT – Collaborative Reformation of Curricula on Resilience Management with Intelligent Systems in Open Source and Augmented Reality;

RTN – representational theory of the mind;

SADT – Structured Analysis and Design Technique;

SCI – Science Citation Index;

SEM – standard error of mean;

SOM – self-organizing map;

SSCI – Social Sciences Citation Index;

SVM – support vector machines;

TPR – total peripheral resistance;

TS – thermal spectra;

TSST – Trier Social Stress Test;

UIMA – Unstructured Information Management Architecture;

VS – visible spectra.

Contents

Introduction

Problem Formulation

Disasters pose significant concerns and challenges among many communities in the EU and beyond. The world's exposure to hazards – both of a natural and of a man-made origin – is increasing, as populations and infrastructures continue growing. Economic losses are also partially explained by floods and storms. Weather related disasters have devastating effects on infrastructures. Gaps exist in the entire world, which have to be closed in the form of pre-disaster planning, before some hazard visits a community. Effective mitigation and preparedness can greatly reduce the threats posed by all types of hazards. Timely reconstruction can minimize broader economic and social damage, which may otherwise result.

A built environment has a function of supporting and serving human endeavours, which means that the ability of society to function – economically and socially – is severely disrupted when its elements are damaged or destroyed. Disasters have the ability to interrupt an economic growth severely and hinder a population's ability to emerge from poverty. The characteristics of a built environment offer an important means of protection by which humanity can reduce the risk of disasters.

Relevance of the Thesis

The stress incurred by a human is influenced not only by everyday tasks, but also by disasters in the environment, e.g. emergency situations causing stress. In these stressful situations human is not able to manage his emotions. This changes his behaviour, labour productivity and response to different circumstances. These problems are not fully discussed in management science, they are often not taken into account when analysing human resource management. Resiliency is the ability to overcome different challenges and to become stronger. This ability can be improved by assessing disaster-related damage, developing financial, training and knowledge transfers and linking up with other professions. This analysis encompasses the entire life cycle of resilience management.

There are now 11 EU policy areas contributing to disaster risk management and emphasizing its importance: Civil Protection, Climate Change, Environment, Cohesion Policy, Solidarity Fund, Health, Insurance, Research, Industry and Infrastructure, Humanitarian Aid and Development, and Security and Conflict Prevention. EU Regulations and Directives take the major part of these EU strategies, legislation or programmes which are related to the disaster risk management and Member States (one of them is Lithuania) must comply with these legislative provisions. A "regulation" is a binding legislative act. It must be applied in its entirety across the EU (European Union… 2015). Potentially dangerous objects in Lithuania included in Minister's of the Environment of the Republic of Lithuania Order No. D1-207, April 18, 2005 (Lietuvos Respublikos... 2005). Full list of potentially dangerous objects in Lithuania can be found in Appendix C. There are many of resilience management target groups in Lithuania. The list of these target groups can be found in Appendix D.

The scientific literature indicates that decision support systems, intelligent technologies and systems facilitate better decision-making advantages of expert systems. The integration of these systems give the ability to handle a wider range of problems with the less time to perform a task. They can help to offload mental tasks from knowledge workers thereby increasing performance productivity, to transfer knowledge from one location or source to users, to provide problem-specific, just-in-time education, to deal with a dynamic, uncertain, complex management environment; they can act as an advisor to guide workers in complicated situations, intelligent technologies can improve decision quality and work productivity (Holsapple 2003; Prelipcean, Boscoianu 2011).

The current studies show that approaches which incorporate text analytics systems, systems to analyse disaster resilience, intelligent decision support systems and physiological parameters support effective real problem-based teaching and learning and practical problem solving.

The Object of Research

The object of the research is the whole built environment's resilience management life cycle including the stakeholders participating in emergency situations.

The Aim of the Thesis

The main aim of this research is to increase the efficiency of a human resource management in emergency situations with the help of the suggested model, system and multiple criteria method of analysis.

The Objectives of the Thesis

The objectives of the thesis are:

1. To develop a model for complexly analysing a human resource management in emergency situations.
2. To present a quantitative analysis and a conceptual analysis of a built environment's resilience management life cycle, the parties involved in it and its environmental affects.
3. To apply the methods for complexly determining criteria weights by considering their quantitative and qualitative characteristics, for multiple criteria complex analysis with a proportional evaluation of the human resource management in emergency situations, to define the utility and market value and a method of multiple criteria design of a human resource management in emergency situations.
4. To develop an Intelligent Decision Support System for the Human Resource Management in Emergency Situations including Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management, Text Analytics Subsystem, Recommender Thermometer for Measuring the Preparedness for Resilience and integrating these subsystems with virtual reality.

Research Methodology

Comprehensive research on the object of the thesis required application of a multiple criteria analysis, recommender methods and physiological and intelligent technologies (text analytics, recommender and decision support) that enable users to assess thoroughly their economic, technical, qualitative, technological, social, psychological, physiological, ethical, emotional, religious, ethnic, legislative, infrastructural and other aspects. The diversity of the factors being assessed should correspond to the various ways of presenting the data needed for decision making.

Scientific Novelty of the Thesis

Aspects of scientific innovation regarding the theoretical and experimental investigations of human resource management in emergency situations are as follows:

1. An original model has been developed for a complex analysis of a human resource management in emergency situations enabling a user to analyse a built environment's resilience management life cycle and its stages, the stakeholders involved as well as its micro, meso and macro environment, as an integral entity.
2. The author has described, from various perspectives in numerous publications and projects, a built environment's resilience management life cycle as well as the stakeholders involved and certain environmental impacts on it by quantitative forms (a system and subsystems of criteria, units of measure, values and weights) and conceptual forms (texts, formulas, drawings, graphs, diagrams and augmented realities).
3. The methods for a complex determination of criteria weights, for multiple criteria, complex, proportional evaluations of the human resource management in emergency situations, to determine the utility degree and market value of objects and of a multiple criteria, multivariant design of a human resource management in emergency situations were applied.
4. An original Intelligent Decision Support System for the Human Resource Management in Emergency Situations was developed consisting of four subsystems. This System was used for a multivariant design and multiple criteria analysis of a built environment's resilience management regarding its mitigation, preparedness, response and recovery stages.

Practical Value of the Research Findings

The practical significance of the results is the complex analysis of a built environment's resilience management life cycle and its stages, which are used to create an Intelligent Decision Support System for the Human Resource Management in

Emergency Situations to accelerate resilience in each of its stages, to manage personal stress and to reduce disaster-related losses.

The research findings can be applied in any organisation involved in emergency situations. The system presented in the dissertation can be used by the managers of the organisations, striving to improve work efficiency. This system can also be used by state organisations' representatives, which are striving to increase economic indicators and to reduce the negative impact of disasters. The proper preparation for disasters and the ability to recover quickly after them can help to improve management efficiency and reduce negative impact of disasters to society and economics.

The Defended Statements

The following statements that are based on the results of the present investigation may serve as the official hypotheses to be defended:

1. The original model for a complex analysis of a human resource management in emergency situations assesses more objectively a built environment's resilience management life cycle and its stages integrating the stakeholders involved in the project as well as its micro, meso and macro environments, making it an integral entity.
2. The Intelligent Decision Support System for the Human Resource Management in Emergency Situations integrates the multiple criteria analysis with recommender methods as well as with physiological and intelligent technologies (text analytics, recommender and decision support). It more objectively assesses a built environment's resilience management life cycle with its mitigation, preparedness, response and recovery stages, its involved parties and its micro, meso and macro level environmental factors. Next, it selects the most rational alternatives.

Approval of the Research Findings

The main statements of the thesis were published in eleven scientific articles: two articles in the Thomson ISI Web of Science Register (Kaklauskas *et al.* 2011 [5-year *Impact* factor – 2,339] and Kaklauskas *et al.* 2013 [5-year *Impact* factor – 2,339]); one article in a reviewed scientific journal on an international database (Matuliauskaitė & Žemeckytė 2011); four articles in the Thomson ISI database proceedings (Kaklauskas *et al.* 2012, Kaklauskas *et al.* 2013, Kaklauskas *et al.* 2014 and Kaklauskas *et al.* 2014) and three more in other publications (Girkantaitė *et al.* 2011, Bartkienė *et al.* 2013 and Pališkienė & Pečiūrė 2014).

The main statements of the thesis were discussed during five international and national scientific conferences:

- the *4th International Conference on Building Resilience, Incorporating the 3rd Annual Conference of the ANDROID Disaster Resilience Network*, held in Salford, United Kingdom, 2014;
- the International Conference *Informatics in Control, Automation and Robotics (CAR 2011)*, held in Shenzhen, China, 2011;
- the Conference of Lithuanian Young Scientists *Science – Future of Lithuania*, held in Vilnius, Lithuania, 2011, 2013 and 2014.

The data obtained in the research were used while participating in three international Erasmus – Lifelong Learning Programme projects: Academic Network for Disaster Resilience to Optimise Educational Development (ANDROID), Collaborative Action towards Disaster Resilience Education (CADRE) and Collaborative Reformation of Curricula on Resilience Management with Intelligent Systems in Open Source and Augmented Reality (RESINT).

The data obtained in the research were used in the educational process, introducing them into the lecture courses on Web-Based and Biometric Decision Support in Business Management, Internet and Biometric Web Based Business Management Decision Support and Biometric and Intelligent Decision Support for Master's degree studies at Vilnius Gediminas Technical University.

Structure of the Dissertation

The dissertation consists of an Introduction, three Chapters, the General Conclusions, References, List of Author's Publications on the topic of the Dissertation and nine Appendices.

The thesis is 162 pages long, not including its appendices and contains 37 numbered formulas for use, 20 illustrations and 17 tables. Preparation of this thesis was based on 213 references.

1

Human Resource Management in Emergency Situations: Scientific View and Problematic

This Chapter analyses disaster and resilience management life cycle ant its stages, reviews different intelligent decision support systems (artificial intelligence, text analytics and text mining, fuzzy sets, recommender thermometers IDSS), and investigates researches on application of physiological parameters (dependence of physiological parameters and stress).

On the thematic of this chapter 2 publications (Girkantaite *et al.* 2011; Bartkiene *et al.* 2013) were published.

1.1. Management Science and Operations Research

Operations research is a discipline that deals with the application of advanced analytical methods to help make better decisions. The terms management science and analytics are sometimes used as synonyms for operations research. Because of its emphasis on human-technology interaction and because of its focus on practical applications, operations research has overlap with other disciplines, notably industrial engineering and operations management, and draws on psychology and organization science (Strickland 2015).

Operations research is applied to problems that concern how to conduct and coordinate the operation (i.e., the activities) within an organization. The research part of the name means that operations research uses an approach that resembles the way research is conducted in established scientific fields. To a considerable extent, the scientific method is used to investigate the problem of concern. In fact, the term management science sometimes is used as a synonym for operations research (Selvaraj 2010).

Operations research is in fact undertaken under a variety of different names. They include synonyms and near-synonyms (e.g., management science, decision technology, operations analysis, analytics, etc.) (Pries, Quigley 2012).

Management Science is concerned with developing and applying models and concepts that help to illuminate management issues and solve managerial problems. It is an interdisciplinary branch of applied mathematics, engineering and sciences that uses various scientific research-based principles, strategies, and analytical methods including mathematical modelling, statistics and algorithms to improve an organization's ability to enact rational and meaningful management decisions (informs.org). Due to application of operations research in industries, the new term called management science came to being. Now the terms management science and decision science are sometimes used as synonyms (Ravindran 2007).

Management science describes any application of science to the study of management. Originally a synonym for operations research, the term management science (often used in the plural) now designates a distinct field. Whereas operations research affords analytical data, statistics, and methods to increase the efficiency of management systems, management science applies these tools in such fields as data mining, engineering, economic forecasting, and logistics (Encyclopædia Britannica 2015).

Management science, also called operations research, applies mathematical models and statistical techniques to management decision-making (Study.com 2015).

Operations research and Management Science has matured over the last 60 years. As a formal discipline, operations research originated in the efforts of military planners during World War II. In the decades after the war, the techniques began to be applied more widely to problems in business, industry and society. Today, operations research is used by virtually every business and government throughout the world and remains an active area of academic research (INFORMS 2015). It is a truly interdisciplinary field, intermixing theories and methodologies from mathematics, management science, computer science, operations management, economics, engineering, decision support, soft computing and many more, even reaching into psychology, ergonomics, knowledge management, education, quality management and biology (Elsevier B.V. 2015). Currently regarded as a body of established mathematical models and methods essential to solving complicated management issues, operations research provides quantitative analysis of problems from which managers can make objective decisions. Operations research and Management Science methodologies continue to flourish in numerous decision making fields (Ravindran 2007).

Ravindran (2007) summarizes that most of the definitions of operations research emphasize its methodology, namely its unique approach to problem solving, which may be due to the use of interdisciplinary teams or due to application of scientific and mathematical models. Each problem may be analysed differently, through the same basic approach of operations research is employed. As more research went into the development of operations research, the researchers were able to classify to some extent many of the important management problems that arise in practice. The theoretical research in operations research concentrated on developing appropriate mathematical models and techniques for analysing these problems under different conditions. Thus, whenever a management problem is identified as belonging to a particular class, all the models and techniques available for that class can be used to study that problem. In this context operational research is a collection of mathematical models and techniques to solve complex management problems (Ravindran 2007).

Operations research and management science aims to provide rational bases for decision making by seeking to understand and model complex situations and to use this understanding to predict system behavior and improve system performance (Cornell University 2015). Decision making as part of management science is described in different books (Anderson *et. al.* 2015; Gal et. al. 1999; Ravindran 2007; Johnston *et al.* 2012; Price et. al. 2015).

Operational research and management science is widely analysed in scientific literature. For example, International Journal of Operations and Quantitative Management provides an international forum for discussions of advancements in operations management, operations research, quantitative management and management science. Journal Surveys in Operations research and Management Science analyses computer science, economics and econometrics, finance, information systems, and management science and operations research fields. The number of ranked journals on the topic “Management Science and Operations research” is listed in Attachment G (Scimago Lab 2014).

Graduate programs leading to advanced degrees at the master’s and doctorate level are introduced in different universities, e.g. Masters in Operational Research and Management Science (Lancaster University, Tilburg University,), MSc Management Science (Operational Research) or MSc Management Science (Decision

Sciences) (London School of Economics and Political Science), Management Science and Operations Management (University of Chicago), Ph.D. program in Operations research (Stanford University).

Operations research develops and uses mathematical and computational methods for decision-making. The field revolves around a mathematical core consisting of several fundamental topics including optimization, stochastic systems, simulation, economics and game theory, and network analysis. The broad applicability of its core topics places operations research at the heart of many important contemporary problems such as telecommunications, health care, capital budgeting and finance, marketing, public policy, military operations research, service operations, transportation systems, etc. (Stanford University 2015).

Scientific methods (statistical and mathematical modeling, experiments, simulation, and optimization) applied to the solution of complex human resource management in emergency situations problems are described by the term operations research. Decision support and mathematical methods were used in the research on human resource management in emergency situations. First chapter of the thesis describes the most relevant researches on decision support systems used to analyse human resource management in emergency situations (intelligent decision support systems, text analytics and text mining systems, fuzzy sets intelligent decision support systems and other systems), which as described above are part of management science and operations research. In the second chapter of the thesis, the author describes methods of multiple criteria analysis (Method of Complex Determination of the Weights of the Criteria taking into Account their Quantitative and Qualitative Characteristics; Method of Multiple Criteria Complex Proportional Evaluation of the Resilience Management Projects; Method of Multiple Criteria Multivariant Design of a Human Resource Management in Emergency Situations) and mathematical methods (Ordered Logit Model; *k*-Nearest Neighbor Algorithm; Marquardt Backpropagation Algorithm), which were applied to develop the systems and to improve an organization's ability to enact rational and meaningful management decisions in emergency situations. The application of these methods is essential to solving complicated management issues. The third chapter is intended to present how the described methods, which are part of operations research science, help to increase the efficiency of management systems and to make better decisions. For this purpose Intelligent Decision Support System for the Human Resource Management in Emergency Situations including four subsystems (Physiological Advisory Subsystem to Analyse a User’s Post-Disaster Stress Management; Text Analytics for Human Resource Management in Emergency Situations in ANDROID Project; Recommender Thermometer for Measuring the Preparedness for Resilience and Subsystem of Integrated Virtual and Intelligent Technologies) was developed.

1.2. Disaster and Resilience Management Life Cycle

Disaster management aims to reduce, or avoid the potential losses from hazards, assure prompt and appropriate assistance to victims of disaster, and achieve rapid and effective recovery (Warfield 2008). The Disaster management life cycle illustrates the on-going process by which governments, businesses, and civil society plan for and reduce the impact of disasters, react during and immediately following a disaster, and take steps to recover after a disaster has occurred. Appropriate actions at all points in the cycle lead to greater preparedness, better warnings, reduced vulnerability or the prevention of disasters during the next iteration of the cycle. The complete disaster management life cycle includes the shaping of public policies and plans that either modify the causes of disasters or mitigate their effects on people, property, and infrastructure.

Many authors (Zhang *et al.* 2006; Vasilescu *et al.* 2008; Malaysian… 2012; Sena *et al.* 2014; Dimersar 2014; Palukuri, Jain 2014; Bally *et al.* 2014, etc.) analysed built environment resilience management life cycle stages and phases. Based on the literature analysis the most common and relevant phases are mitigation, preparedness, response and recovery. For example, Zhang *et al.* 2006 describes pre-disaster risk reduction and post-disaster recovery phases. The pre-disaster risk reduction phase includes mitigation and preparedness with the main activity – risk management. The post-disaster recovery phase includes emergency relief, rehabilitation and reconstruction with the main activity – consequence management. The total disaster risk management cycle includes prevention mitigation, preparedness, response/recovery and rehabilitation/reconstruction phases (Malaysian… 2012). The same phases are described in flood risk management cycle (Vanneuville *et al.* 2011) and disaster management cycle (Palukuri, Jain 2014).

A built environment resilience management life cycle in turn consists of four key closely interrelated stages:

1. Mitigation. Mitigation activities actually eliminate or reduce the probability of disaster occurrence, or reduce the effects of unavoidable disasters. Mitigation measures include building codes; vulnerability analyses updates; zoning and land use management; building use regulations and safety codes; preventive health care; and public education. Mitigation will depend on the incorporation of appropriate measures in national and regional development planning. Its effectiveness will also depend on the availability of information on hazards, emergency risks, and the countermeasures to be taken. The mitigation phase, and indeed the whole disaster management cycle, includes the shaping of public policies and plans that either modify the causes of disasters or mitigate their effects on people, property and infrastructure (Warfield 2008).

2. Preparedness. The goal of emergency preparedness programs is to achieve a satisfactory level of readiness to respond to any emergency situation through programs that strengthen the technical and managerial capacity of governments, organisations, and communities. These measures can be described as logistical readiness to deal with disasters and can be enhanced by having response mechanisms and procedures, rehearsals, developing long-term and short-term strategies, public education and building early warning systems. Preparedness can also take the form of ensuring that strategic reserves of food, equipment, water, medicines and other essentials are maintained in cases of national or local catastrophes. During the preparedness phase, governments, organisations and individuals develop plans to save lives, minimise disaster damage and enhance disaster response operations. Preparedness measures include preparedness plans, emergency exercises/training, warning systems, emergency communications systems, evacuations plans and training, resource inventories, emergency personnel/contact lists, mutual aid agreements and public information/education. As with mitigations efforts, preparedness actions depend on the incorporation of appropriate measures in national and regional development plans. In addition, their effectiveness depends on the availability of information on hazards, emergency risks and the countermeasures to be taken, and on the degree to which government agencies, non-governmental organisations and the general public are able to make use of this information (Warfield 2008).
3. Response. The aim of emergency response is to provide immediate assistance to maintain life, improve health and support the morale of the affected population. Such assistance may range from providing specific but limited aid, such as assisting refugees with transport, temporary shelter, and food, to establishing semi-permanent settlement in camps and other locations. It also may involve initial repairs to damaged infrastructure. The focus in the response phase is on meeting the basic needs of the people until more permanent and sustainable solutions can be found. Humanitarian organisations are often strongly present in this phase of the disaster management cycle (Warfield 2008).
4. Recovery. As the emergency is brought under control, the affected population is capable of undertaking a growing number of activities aimed at restoring their lives and the infrastructure that supports them. There is no distinct point at which immediate relief changes into recovery and then into long-term sustainable development. There will be many opportunities during the recovery period to enhance prevention and increase preparedness, thus reducing vulnerability. Ideally, there should be a

smooth transition from recovery to on-going development. Recovery activities continue until all systems return to normal or better. Recovery measures, both short and long term, include returning vital lifesupport systems to minimum operating standards, temporary housing, public information, health and safety education, reconstruction, counselling programmes and economic impact studies. Information resources and services include data collection related to rebuilding, and documentation of lessons learned (Warfield 2008).

The mitigation and preparedness phases occur as disaster management improvements are made in anticipation of a disaster event. Developmental considerations play a key role in contributing to the mitigation and preparation of a community to effectively confront a disaster. As a disaster occurs, disaster management actors, in particular humanitarian organisations become involved in the immediate response and long-term recovery phases. Often phases of the cycle overlap and the length of each phase greatly depends on the severity of the disaster (Khan *et al.* 2008).

There are now 11 EU policy areas on built environment contributing to disaster risk management (the number of EU strategies, legislation or programmes related to these policy areas is indicated in the parentheses, more information about these EU strategies, legislation or programmes can be found in Appendix E): Civil Protection (2), Climate Change (1), Environment (12), Cohesion Policy (5), Solidarity Fund (1), Health (1), Insurance (1), Research (1), Industry and Infrastructure (17), Humanitarian Aid and Development (13), and Security and Conflict Prevention (11). Of note is the fact that many of these EU policies comprise disaster risk management and emphasize the importance of disaster risk management. EU Regulations and Directives take the major part of these EU strategies, legislation or programmes which are related to the disaster risk management and Member States (one of them is Lithuania) must comply with these legislative provisions. A “regulation” is a binding legislative act. It must be applied in its entirety across the EU (European Union… 2015). A “directive” is a legislative act that sets out a goal that all EU countries must achieve. However, it is up to the individual countries to decide how (European Union… 2015).

Potentially dangerous objects in Lithuania included in Minister‘s of the Environment of the Republic of Lithuania Order No. D1-207, April 18, 2005 (Lietuvos Respublikos... 2005):

- potentially dangerous objects that can cause extreme danger to people and the environment of possible emergencies (objects in the area of regulation of European Parliament and Council Directive 96/82/EC) – 18 objects (including AB “Achema”; AB “Mažeikių nafta”; AB “Suskystintos dujos”; Būtingė branch; etc.);

- potentially dangerous objects, which in case of accident could cause damage to people and the environment – 69 objects (including Ignalina Nuclear Power Plant; AB "Alytaus tekstilė"; AB "Snaigė"; AB "Vilniaus energija"; UAB "Statoil Lietuva"; etc.);
- environmentally dangerous objects – 60 objects (including AB "Pieno žvaigždės" Mažeikiai dairy; AB "Žemaitijos pienas"; AB "Krekenavos agrofirma" tanks of slurry accumulation; etc.).

Full list of potentially dangerous objects in Lithuania can be found in Appendix C. Documents regulating EU policy to disaster risk management can be found in Appendix E.

Although the Ignalina Nuclear Power Plant was closed in 2009 but dismantlement and disposal works of hazardous waste will take about 25 years. Belarus and Russia are planning to build two nuclear power plants (NPPs) adjacent to Lithuania's eastern and southwestern borders. In case of emergency these NPPs pose a grave danger to Lithuania and the hazardous waste cause long-term very dangerous negative effects on humans and the environment (Bačkaitis 2012).

There are many of resilience management target groups in Lithuania. The list of these target groups can be found in Appendix D.

1.3. Analysis and Application of Intelligent Decision Support Systems

1.3.1. Intelligent Decision Support Systems and Productivity

According to Escorpizo (2008) productivity is an important indicator of economic growth and social health. It plays a crucial role in describing business opportunities in the society and it can also be vital in identifying key factors that are attributed to how healthy (or unhealthy) the working population is. However, the term productivity is broad in scope in that it depends on which setting it is being used and how it is being used in that setting. Productivity in "economic" terms has been the traditional way of conceptualization – that being synonymous to the relationship between input (e.g. number of hours worked) and output (e.g. number of units made). Productivity can also be seen in terms of efficiency – the number of output units given the usual or less input hours (Escorpizo 2008). Productivity is commonly defined as a ratio between the output volume and the volume of inputs. In other words, it measures how efficiently production inputs, such as labour and capital, are being used in an economy to produce a given level of output (OECD 2014). Productivity is considered a key source of economic growth and competitiveness and, as such, is basic statistical information for many international comparisons and country performance assessments.

The scientific literature indicates that DSS, IDSS, intelligent technologies and systems facilitate better decision-making and increase productivity. For example, as one of the decision support systems advantages Cioca and Cioca (2010) identifies increase in work productivity by extending capacity of decision-makers to directly process information. O'Keefe *et al.* (1993) stated that implemented expert systems in use are providing a number of work level benefits in accounting. These benefits appear to be evenly spread over the commonly quoted advantages of expert systems: ability to handle a wider range of problems, less time to perform a task, etc. Whereas an increase in the amount of data needed to perform the task is not significant, data figures considerably in the various correlations, suggesting that, at least in accounting, the more data a system uses the higher benefits (O'Keefe *et al.* 1993). According to Holsapple (2003), intelligent systems reason actively to offload mental tasks from knowledge workers thereby increasing performance productivity. In collaborative settings, they can act as a mentor or advisor to guide workers in complicated situations, provide analysis capabilities using embedded models, reason to locate relevant information by accessing databases and converting collected information to fit the business task, transfer knowledge from one location or source to users, or provide problem-specific, just-in-time education (Holsapple 2003). Lemass and Young (1997) claimed that by partially cloning human expert knowledge and supplementing it with deep algorithmic knowledge, it seems likely that successful intelligent decision support systems (IDSS) could improve user understanding and work productivity, reduce designer uncertainty and anxiety, and preserve the valuable knowledge of experts in short supply. They could also effectively save time and investment capital by making domain knowledge readily available throughout the design process. As claimed Prelipcean and Boscoianu (2011), the need for IDSS arrives from the growing need for relevant/effective DSS to deal with a dynamic, uncertain, complex management environment, the need to build context-tailored, not general purpose systems, the increased acceptance that intelligent technologies can improve decision quality and work productivity.

1.3.2. Introduction to Intelligent Decision Support Systems

The first to offer a definition of an intelligent decision support system was Holsapple (Holsapple 1977; Holsapple, Whinston 1987). The title of the dissertation by Holsapple (1977) was "Framework for a Generalized Intelligent Decision Support System". The development of Intelligent decision support systems (IDSSs), by this or by some other name, began from the early years of the 1990s (Jelassi 1986; Murphy, Stohr 1986; Teng *et al.* 1988; Slowinski, Stefanowski 1992; Pomerol *et al.* 1995; Matsatsinis, Siskos 1999). IDSS, which reflected an environment demanding increasingly more complicated and faster decision-making, continued improving over time and gained additional capabilities.

Currently IDSS provides decision support via text analytics and mining based DSSs; ambient intelligence and the internet of things-based DSSs; biometrics-based DSSs; recommender, advisory and expert systems, data mining, data analytics, neural networks, remote sensing and their integration with decision support systems and other IDSSs. These other IDSSs include GA-based DSS, fuzzy sets DSS, rough sets-based DSS, intelligent agent-assisted DSS, process mining integration to decision support, adaptive DSS, computer vision based DSS, sensory DSS and robotic DSS. The changes in the definitions of IDSS describe this transformation from its earliest days to the present time. These are provided in-brief next.

IDSSs are interactive computer-based systems that use data, expert knowledge and models for supporting decision makers in organisations to solve semi-structured problems by incorporating artificial intelligence techniques (Sarma 1994). IDSSs, incorporating knowledge-based methodology, are designed to aid the decision-making process through a set of recommendations reflecting domain expertise (Wang 1997).

A typical IDSS consists of five main components, database system, model-base system, knowledge-based system, user interface and kernel/inference engine (Matsatsinis, Siskos 1999). IDSS is needed and is economically feasible for generic problems that require repetitive decisions. IDSSs are interactive computer-based systems that use data, expert knowledge and models for supporting decision makers in organizations to solve semi structured problems by incorporating artificial intelligence techniques (Turban, Aronson 2000).

IDSSs use expert systems technology to enhance the capabilities of decision makers in understanding a decision problem and selecting a sound alternative. Because of the people-centred focus of such technologies, it is important not only to assess their technical aspects and overall performance but also to seek the views of potential users (Papamichail, French 2005).

IDSSs, incorporating knowledge-based methodology, are designed to aid the decision-making process through a set of recommendations reflecting domain expertise. IDSSs are able to provide services to users and they try to satisfy the user's requirements through interaction, cooperation, and negotiation. IDSSs also offer tremendous potential in support of well-defined tasks such as data conversion, information filtering, and data mining, as well as supporting ill-structured tasks in dynamic cooperation (Gao *et al.* 2007).

Intelligent decision support systems aim to provide decision makers with timely, useful and valid information based on some pre-coded domain knowledge (Burstein, Carlsson 2008).

IDSS add artificial intelligence functions to traditional DSS with the aim of guiding users through some of the decision making phases and tasks or supplying new capabilities. This notion has been applied in various ways (Phillips-Wren *et al.* 2009, Wan, Lei 2009, Yang *et al.* 2012).

Decision support systems (DSS), as a kind of interactive computer-based information systems, help decision makers utilize data and models to solve mostly semi-structured or unstructured decision problems in practice. Intelligent DSS, along with knowledge-based decision analysis models and methods, incorporate well databases, model bases and intellectual resources of individuals or groups to improve the quality of complex decisions. In the recent years, multicriteria DSS, group DSS, and web-based customer recommender systems have had unimaginable developments and improvements in dealing with complex, uncertain, and unstructured decision problems under the support of computational intelligent technologies (Lu *et al.* 2010).

Quintero *et al.* (2005) analyse the relationship of a decision maker with IDSS. An IDSS, as its name implies, is used to support decision-making and is not intended to replace the decision maker. In fact, an intelligent decision support system works under the assumption that the decision maker is familiar with the problem to be solved and the data required for its solution. The IDSS bring together human judgment and computerized information providing support to decision makers primarily in the analysis of poorly or unstructured situations (Quintero *et al.* 2005).

DSSs need to "evolve" over time for many reasons, including changing user needs, technologies and problem understanding. There has been a limited amount of research on "evolution" of DSS, mostly aimed at individual characteristics or components of DSS. Those components include the technology on which the DSS is based, database (database schema and metadata), user interface, application and knowledge built into the system (O'Leary 2008). Phillips-Wren *et al.* (2009) and Turban *et al.* (2006) express similar thoughts about developing intelligent decision support systems.

Researchers from different time periods have analysed artificial intelligence approaches, concepts, techniques and division into "foundational" and "application" areas. This is analysed next while focusing extra attention on AI methods on which a DSS is based.

Hopgood (2005) defines Artificial intelligence, as a concept of mimicking human intelligence in a computer. AI consists of many branches, such as, expert systems, artificial neural networks, genetic algorithms and fuzzy logic and various hybrid systems, which are combinations of two or more of the branches mentioned previously (Medsker 1996). In the opinion of Chrisley (2008), although the last half-century or so has seen the introduction of various new approaches to artificial intelligence, including connectionism/neural networks, dynamical systems engineering, embodied/situated robotics, and artificial life, the term "artificial intelligence" is often used more narrowly, to refer to approaches that emphasize symbolic computation (Chrisley 2008).

Turban *et al.* (2004) describe artificial intelligence concepts: Expert systems, Natural language processing, Speech recognition, Speech understanding Sensory systems, Robotics, Vision and scene recognition, Neural computing, Intelligent computer-aided instruction, Language translation, Computer vision and scene recognition, Fuzzy logic, Genetic algorithms and Intelligent agents.

The widely used term artificial intelligence refers, in the field of process engineering, to programs and systems that utilise intelligent implementation techniques, such as rule-based expert systems, fuzzy logic and neural networks, to extend the power of computers beyond the strictly mathematical and statistical functions (Järvensivu *et al.* 2001). Attonaty *et al.* (1999) present potential opportunities provided by the new techniques offered by artificial intelligence, such as automatic machine learning and multi-agent modeling. García-Cascales, Lamata (2007) analyse alternative techniques within artificial intelligence, such as fuzzy logic and soft computing, the possibility theory, distributed artificial intelligence (intelligent agents), neural networks, adaptive systems and many hybrid techniques (neuro-fuzzy networks, expert agents, etc.). For example, Şişman-Yılmaz *et al.* (2004) propose a temporal neuro-fuzzy system which is designed to provide an environment that keeps temporal relationships between the variables and to forecast the future behavior of data by using fuzzy rules. The system takes the multivariate data and the number of lags needed to construct the unfolded model in order to describe a variable and predicts the future behavior. Computer simulations are performed by using real multivariate data and a benchmark problem (Şişman-Yılmaz *et al.* 2004).

Artificial intelligence can be roughly divided into "foundational" and "application" areas. Foundational areas include knowledge representation, automated reasoning, probabilistic models, and machine learning. Application areas include planning, vision, robotics, speech, natural language processing, and multi-agent systems. An interface layer for AI must provide the former, and serve the latter (Domingos, Lowd 2009). Additionally fundamental (theoretical) artificial intelligence encompasses mathematical, logical, statistical, psychological, linguistic, cognitive, philosophical, biological and other aspects.

Artificial intelligence is applied in practice in numerous areas further described. Knowledge representation systems are an important component of many artificial intelligence applications, such as planners, robots, natural language processors, and game-playing systems (Doan *et al.* 2012). Artificial intelligence applications such as industrial robotics, military surveillance, and hazardous environment clean-up require situation understanding based on partial, uncertain, and ambiguous or erroneous evidence (Levitt 1986). McCarthy (2007) deliberates various AI applications. Chablo (1994) discusses the potential applications within telecommunications of the whole range of artificial intelligence technologies (i.e., expert systems, natural language understanding, speech recognition and understanding, machine translation, visual recognition and analysis, and robotics). Jothiprakash and Magar (2012) analyse applications of artificial intelligent in adaptive systems.

The typical issues for applying AI methods that other authors mention include pattern recognition (handwriting, speech and face recognitions), image processing, natural language processing, translation, artificial life, semantic web, remote sensing, robotics (behavior-based robotics, cognitive, cybernetics, evolutionary robotics), intelligent control, applied data mining, natural language processing, voice technology, artificial intuition, noisy text analytics, question answering and text mining.

1.3.3. Text Analytics and Text Mining Systems

Text mining, sometimes alternately referred to as text data mining, roughly equivalent to text analytics, refers to the process of deriving high-quality information from text. Text analytics systems developed worldwide are analysed in this chapter.

1.3.3.1. Text Analytics and Text Mining

High-quality information is typically derived through the divining of patterns and trends through means such as statistical pattern learning. Text mining usually involves the process of structuring the input text (usually parsing, along with the addition of some derived linguistic features and the removal of others, and subsequent insertion into a database), deriving patterns within the structured data, and finally evaluation and interpretation of the output. “High quality” in text mining usually refers to some combination of relevance, novelty, and interestingness. Typical text mining tasks include text categorization, text clustering, concept/entity extraction, production of granular taxonomies, sentiment analysis, document summarization, and entity relation modeling (i.e., learning relations between named entities) (Machine Learning Market 2013).

Text analytics software can help by transposing words and phrases in unstructured data into numerical values which can then be linked with structured data in a database and analysed with traditional data mining techniques. With an iterative approach, an organization can successfully use text analytics to gain insight into content-specific values such as sentiment, emotion, intensity and relevance. Because text analytics technology is still considered to be an emerging technology, however, results and depth of analysis can vary wildly from vendor to vendor (Business Analytics 2013).

Text analytics is the process of deriving information from text sources. It is used for several purposes, such as: summarization (trying to find the key content across a larger body of information or a single document), sentiment analysis (what is the nature of commentary on an issue), explicative (what is driving that commentary), investigative (what are the particular cases of a specific issue) and classification (what subject or what key content pieces does the text talk about) (Gartner 2014).

Text mining is the activity of obtaining information resources relevant to an information need from a collection of information resources. Searches can be based on metadata or on full-text indexing. Text mining is vast area as compared to information retrieval. Typical text mining tasks include document classification, document clustering, building ontology, sentiment analysis, document summarization, Information extraction etc. Where as information retrieval typically deals with crawling, parsing and indexing document, retrieving documents (Stackoverflow 2013).

Research shows that various researchers have specialised in depth the different and very important areas of text analytics and mining (blogs and social networks (He *et al.* 2013; Marwick 2014; Mostafa 2013; Kamel Boulos *et al.* 2010; Babbie 2008; Loshin 2012; Li, Wu 2010; Li *et al.* 2011; Guo *et al.* 2010; Wilson 2009; Yu *et al.* 2008; Lloret, Palomar 2013), students' online interaction (He *et al.* 2013), digital libraries (Fagan 2014; Nguyen 2014), process industry (Liew *et al.* 2014), medicine (Anholt *et al.* 2014), legal, business intelligence, security (Truyens, Van Eecke 2014), entity recognition and extraction (Yang *et al.* 2008; Sobhana *et al.* 2010; Loshin 2012; Nothman *et al.* 2013), retrieval systems (US Patent No. 5297042 1989; Patent US 2006/0047656 A1 2006), intelligent libraries (Chen 2008; Du 2012; Li *et al.* 2012, Ropero *et al.* 2012;), etc.

Social media have been adopted by many businesses. More and more companies are using social media tools such as Facebook and Twitter to provide various services and interact with customers. To increase competitive advantage and effectively assess the competitive environment of businesses, companies need to monitor and analyse not only the customer-generated content on their own social media sites, but also the textual information on their competitors' social media sites. The results reveal the value of social media competitive analysis and the power of text mining as an effective technique to extract business value from the vast amount of available social media data. Recommendations are also provided to help companies develop their social media competitive analysis strategy (He *et al.* 2013).

Marwick (2014) investigate the use of Twitter at a major conference of professional and academic anthropologists. Marwick (2014) identifies the demographics of the community, the structure of the community of Twitter-using anthropologists, and the topics that dominate the Twitter messages. A key finding is that the transformative effect of Twitter in academia is to easily enable the spontaneous formation of information-sharing communities bound by an interest in an event or topic (Marwick 2014).

Blogs and social networks have recently become a valuable resource for mining sentiments in fields as diverse as customer relationship management, public opinion tracking and text filtering. In fact knowledge obtained from social networks such as Twitter and Facebook has been shown to be extremely valuable to marketing research companies, public opinion organizations and other text mining entities. However, Web texts have been classified as noisy as they represent considerable problems both at the lexical and the syntactic levels (Mostafa 2013). Mostafa (2013) research results indicate a generally positive consumer sentiment towards several famous brands. By using both a qualitative and quantitative methodology to analyse brands' tweets, Mostafa (2013) study adds breadth and depth to the debate over attitudes towards cosmopolitan brands.

With the availability of open and structured data, digital libraries become an important source of data in recent data mining techniques. The inherent structure of digital libraries comes with information about date, authorship, involved institutions, geographic context, and large volumes of text (Nguyen 2014). As an illustration of digital libraries analysis, Nguyen (2014) focus on a space of scientific publications related to some science discipline and extract patterns and text-related information from the dataset. Nguyen (2014) discuss text preparation techniques, the use of the latent Dirichlet allocation to classify content, and the analysis of text features, like cooccurrence matrices. Simple similarity measures between authors and between papers is used to illustrate cluster cohesion within the dataset (Nguyen 2014).

As the demand for library assessment grows, academic libraries are becoming more interested in Web analytics. Data are automatically gathered and provide information about a wide variety of online interactions (Fagan 2014).

Four main sectors of the process industry are studied by Liew *et al.* (2014): oil/petrochemicals, bulk/specialty chemicals, pharmaceuticals, and consumer products. Liew *et al.* (2014) study reveals that the top sustainability focuses of the four sectors are very similar: health and safety, human rights, reducing greenhouse gas, conserving energy/energy efficiency, and community investment.

Text analysis implies the need for concept taxonomies in which like terms can be collected and aggregated at different levels of precision, such as car makes, models. Algorithms for entity recognition, entity extraction, and text analysis need to be more sophisticated in relation to the text's structure. While simple, pattern-based unstructured entities (such as telephone numbers) can be scanned using techniques such as regular expression parsing, more complex pattern and context sensitive techniques are increasingly used. A standard for content analytics called the Unstructured Information Management Architecture (UIMA) was established by OASIS (Advancing Open Standards for the Information Society) in 2009 (Loshin 2012).

Text analysis components allow to analyse documents and identify terms that appear with relative frequency, identify statistically improbable terms, determine sentinel or signal terms, build concept hierarchies, create dictionaries, and document rules for phrase recognition and for concept extraction, among other techniques. Once this analysis is completed, the information contained within the documents can be clustered, categorized, and organized to support intelligent searches, and filtering concepts from streaming text helps identify important text artifacts that can be routed directly to individuals with a particular interest in the supplied content. Once the concepts have been ordered, identified, extracted, and organized, they can be subjected to data mining and other types of analysis to help the knowledge worker draw conclusions from actionable information (Loshin 2012).

There is a known document retrieval system that includes an inputting unit for inputting a retrieval condition that includes one keyword or a plurality of them along with a weight value for each keyword, an operating unit having first factors corresponding to relationship values with each relationship value being defined as a degree of the relationship between two keywords from the predetermined keywords in the document retrieval system and second factors corresponding to importance values (US Patent No. 5297042 1989); computer-readable code system and method for retrieving one or more selected text materials from a library of documents (Patent US 2006/0047656 A1 2006).

1.3.3.2. Bag of Concepts Space

Concepts are the constituents of thoughts. Consequently, they are crucial to such psychological processes as categorization, inference, memory, learning, and decision-making. The three main options are to identify concepts with mental representations, with abilities, and with Fregean senses (Stanford Encyclopedia… 2014):

1. Concepts as mental representations, where concepts are entities that exist in the brain. The first of these views maintains that concepts are psychological entities, taking as its starting point the representational theory of the mind (RTM). According to RTM, thinking occurs in an internal system of representation. Beliefs and desires and other propositional attitudes enter into mental processes as internal symbols. According to Peacocke (1992), it is possible for one and the same concept to receive different mental representations in different individuals.
2. Concepts as abilities. Concepts are abilities that are peculiar to cognitive agents.
3. Concepts as Fregean senses. Sense has a unique perspective on its referent – a unique mode of presentation.

Psychologists explore concepts such as perception, cognition, attention, emotion, phenomenology, motivation, brain functioning, personality, behavior, and interpersonal relationships (Psychology 2013).

In information science, formal concept analysis is a principled way of deriving a concept hierarchy or formal ontology from a collection of objects and their properties. Each concept in the hierarchy represents the set of objects sharing the same values for a certain set of properties; and each sub-concept in the hierarchy contains a subset of the objects in the concepts above it (Babylon 2013).

Concepts, the mental categories used to organize events and objects, are often arranged in hierarchical order from general to more specific for example, organism, animal, vertebrate, quadruped, dog, collie (CliffsNotes 2013).

A number of academics in the world analysed concept-based information retrieval (Grootjen, Van Der Weide 2006; Styltsvig 2006; Yi, Allan 2009) and bag of concepts in Wikipedia representation (Gabrilovich, Markovitch 2007; Hu *et al.* 2008, Huang *et al.* 2008, Milne, Witten 2008; Sorg, Cimiano 2012).

In general, information retrieval research and technology can be divided into two broad categories: semantic and statistical. Information retrieval systems that fall into the semantic (auxiliary structures, local cooccurrence statistics, transform techniques) category will attempt to implement some degree of syntactic and semantic analysis of the natural language text that a human user would provide. Systems that fall into the statistical category will find results based on statistical measures of how closely they match the query. However, systems in the semantic category also often rely on statistical methods to help them find and retrieve information (Greengrass 2000).

After the concept is categorised, it can be given the definition by a classification process. Classification is determining where in the conceptual structure a new concept belongs. For this purpose, either an existing conceptual structure (like dictionary, thesaurus or ontology) or automatically generated one can be used. It is reported in many papers that pre-existing dictionaries often do not meet the user's needs for interesting concepts, or ontology like WordNet does not include proper nouns. The main types of conceptual structures used in concept-based information retrieval systems are as follows: Conceptual taxonomy, Formal or domain ontology, Semantic linguistic network of concepts, Thesaurus, Predictive model (Haav, Lubi 2001).

1.3.4. Fuzzy Sets Intelligent Decision Support Systems

Under uncertain and imprecise conditions, fuzzy sets are used with multicriteria decision-making to provide techniques for modelling preferences, evaluating alternatives, aggregating preferences, selecting best alternatives, and ranking or sorting alternatives into categories. Multicriteria decision making and fuzzy measurement assist in the representation of domain knowledge for modelling decision problems during the Intelligence and Design stages, whereas intelligent features of analogical reasoning, learning, and memory are facilitated by the case-based reasoning component during analysis for making choices and implementing selected strategies (Burstein, Carlsson 2008). Prototypes of fuzzy IDSS have been applied to solving decision-making problems, such as resilience management.

For example, the cost of seismic upgrading in a critical infrastructure system is large but the financial resources are limited. Hence, a priority list of infrastructure components for upgrading is necessary (Javanbarg *et al.* 2009). Javanbarg *et al.* (2009) develop a fuzzy decision support system (FDSS) for priority evaluation of the components upgrading in the urban infrastructure systems considering customers importance, component properties, hazard factors and economic analysis. To deal with the uncertain judgment of decision makers, a fuzzy modification of the analytic hierarchy process (AHP) method is applied as an evaluation tool, where uncertain and imprecise judgments of decision makers are translated into fuzzy numbers. The proposed fuzzy AHP method is applied to a case study of Osaka City water distribution network. It demonstrates that the proposed FDSS can be utilized as an effective tool for tackling the uncertainty and imprecision associated with priority evaluation of seismic mitigation and upgrading in a civil infrastructure system (Javanbarg *et al.* 2009).

Coordination deficiencies have been identified after the March 2011 earthquakes in Japan in terms of scheduling and allocation of resources, with time pressure, resource shortages, and especially informational uncertainty being main challenges (Wex *et al.* 2012). Wex *et al.* (2012) address this issue of operational emergency response in natural disaster management (NDM) by suggesting a decision support model and a Monte Carlo heuristic which account for these challenges by drawing on fuzzy set theory and fuzzy optimization. Deriving requirements for addressing NDM situations from both practice and literature, Wex *et al.* (2012) propose a decision model that accounts for the following phenomena: a) incidents and rescue units are spatially distributed, b) rescue units possess specific capabilities, c) processing is non-preemptive, and d) informational uncertainty occurs due to vague and linguistic specifications of data. Wex *et al.* (2012) computationally evaluate our heuristic and benchmark the results with current best practice solutions. Wex *et al.* (2012) results indicate that applying the new heuristic can substantially reduce overall harm.

Text and data analytics, text, data and process mining, expert and advisory systems, neural networks, intelligent software agents, natural language processing, voice recognition, speech understanding, language translation, robotics and sensory systems, computer vision, fuzzy logic, rough sets, case based reasoning and genetic algorithms become important components in designing IDSS.

1.3.5. Other Systems to Analyse Disaster Resilience

Various thermometers and similar scales are used in different human and disaster management activities: Depression Thermometer, Anxiety Thermometer, Help Thermometer, Emotion Thermometer (Mitchell *et al.* 2012), Anger Thermometer (Goldstein *et al.* 2013), Panic Thermometer (Complete Resource… 2014), Problem Thermometer (Michigan State University 2014), Mood Thermometer (Gil *et al.* 2005), Fear Thermometer (Heyne *et al.* 2002), Distress Thermometer (Patel *et al.* 2011a), Feeling Thermometer (Swanbrow 2001), Hurricane Scale, Richter Magnitude Scale, Fire Danger Rating, the Torino Scale (assessing asteroid and comet impact hazard predictions). Also different neural networks (Kong-A-Siou *et al.* 2013; Liu *et al.* 2014a), early warning (Krzhizhanovskaya *et al.* 2011; Alfieri *et al.* 2012; Borga *et al.* 2014; Hissel *et al.* 2014; Van Veen *et al.* 2014), fuzzy (Kou *et al.* 2014), expert (Karnib *et al.* 2002; Kou *et al.* 2014) and decision support (Krzhizhanovskaya *et al.* 2013; Hubbard *et al.* 2014) systems are used for flood resilience management.

Krzhizhanovskaya *et al.* (2013) present a decision support system for flood early warning and disaster management. It includes the models for data-driven meteorological predictions, for simulation of atmospheric pressure, wind, long sea waves and seiches; a module for optimization of flood barrier gates operation; models for stability assessment of levees and embankments, for simulation of city inundation dynamics and citizens evacuation scenarios. All the models are wrapped as software services in the CLAVIRE (Cloud Applications Virtual Environment) platform for urgent computing, which provides workflow management and resource orchestration (Krzhizhanovskaya *et al.* 2013).

The Seventh Framework Programme (FP7) Theseus research project (2009–2013) aims to develop and assess innovative technologies and methodologies for coastal protection against erosion, flooding and environmental damages. While protection structures may help to reduce the level of hazard and the expected degree of loss, some danger of technical failures or human errors will always remain. For extreme events, the implementation of non-structural measures as early warning systems and disaster management practices is required to ensure the protection of population. A methodology for helping the local authorities to prepare an action plan in case of coastal flooding was developed and tested on the estuary of Gironde in France. The methodology builds over the return of experience from past events and tries to clearly identify all the stages of an evacuation and the thinking process that can lead to a robust evacuation plan. It relies on a conceptual framework – SADT (Structured Analysis and Design Technique) – which helps to understand how data should be processed from its collection to its use in the plan. The risk scenarios were calculated for current and future conditions of the XXIst century, taking into account the effects of climate change (Hissel *et al.* 2014).

For implementation of a regional Tsunami Early Warning System (EWS) in Sumatra Island in Indonesia, a set of detailed and accurate tsunami propagation and flooding models using Delft3D were developed. The purpose of the models was not only to reproduce the 2004 Indian Ocean tsunami, but also to determine tsunami flood hazard maps with different return periods. The model outputs have then been used to build a tsunami flooding database covering 1250 hypothetical sources for different earthquake parameters. The model simulations produced detailed information of near-shore tsunami wave height, tsunami inundation length and run-up. Smart storage of computational results, in a geo-referenced database, allows quick access to the requisite information. The result is a system capable of issuing a warning within few minutes after a detection of an earthquake (Van Veen *et al.* 2014).

Flash floods and debris flows develop at space and time scales that conventional observation systems for rainfall, streamflow and sediment discharge are not able to monitor. Consequently, the atmospheric, hydrological and geomorphic controls on these hydrogeomorphic processes are poorly understood, leading to highly uncertain warning and risk management. On the other hand, remote sensing of precipitation and numerical weather predictions have become the basis of several flood forecasting systems, enabling increasingly accurate detection of hazardous events (Borga *et al.* 2014). The objective of Borga *et al.* (2014) research paper is to provide a review on current European and international research on early warning systems for flash floods and debris flows.

Hubbard *et al.* (2014) developed a spatiotemporal framework for identifying building vulnerabilities and content evacuations during riverine flooding events. Hubbard *et al.* (2014) investigate the spatiotemporal properties required to trigger building contents evacuations in the floodplain during a flood event. The spatial properties for building risks are based on topography, flood inundation, building location, building elevation, and road access to determine five categories of vulnerability, vulnerable basement, flooded basement, vulnerable first-floor, flooded first-floor, and road access. Using this framework, a model designed to track the spatiotemporal patterns of building evacuations is presented. The model is based upon real-time flood forecast predictions that are linked with building properties to create a model that captures the spatiotemporal ordering of building vulnerabilities and building content evacuations (Hubbard *et al.* 2014).

As it is the case with many karst aquifers, the Lez basin (southern France) is heterogeneous and thus difficult to model. Due to its supply of fresh water and its ability to reduce flooding however, more in-depth knowledge of basin behavior has proven critical. In addressing this challenging issue, an original methodology based on neural networks is presented by Kong-A-Siou *et al.* (2013) so as to better understand the hydrodynamic behavior of such systems.

Most of the existing disaster assessment models are based on single method, such as expert system, or one of the multicriteria decision making (MCDM) methods (Kou *et al.* 2014). Kou *et al.* 2014 propose an efficient disaster assessment expert system, which integrates fuzzy logic, survey questionnaire, Delphi method and MCDM methods. Two simulation experiments on typhoon and earthquake are introduced to validate the integrated expert system. The experimental results show that the proposed expert system is not only efficient, fast and accurate, but also robust through self-adaptive study and has strong adaptability to different environments (Kou *et al.* 2014).

Liu *et al.* (2014a) propose a novel data-driven modeling method, i.e. ensemble least squares support vector regression (ELSSVR), to construct a unified correlation for prediction of the flooding velocity for packed towers with random packings. The flooding data are first clustered into several classes by the fuzzy c-means clustering algorithm. Then, several single least squares support vector regression (LSSVR) models can be trained using each sub-class of samples to capture the special characteristics. Moreover, a weighted least squares approach is adopted to integrate these single LSSVR models. Consequently, the ELSSVR model can extract the feature information of flooding data effectively and improve the prediction performance (Liu *et al.* 2014a).

The objective of Alfieri *et al.* (2012) research is to review current European operational warning systems for water-related hazards induced by severe weather conditions. In details, it includes systems for detecting surface water flooding, flash floods, debris flows, mud flows, rainfall-induced landslides, river floods and coastal floods (Alfieri *et al.* 2012).

Karnib *et al.* (2002) presents an expert system based on fuzzy inference to evaluate the sensitivity of urban areas to network failure. The produced results allow the designer to classify various network upgrading alternatives according to their impacts on urban areas and to introduce this order in a multicriteria method. A practical application of the expert system is given and its applicability is discussed (Karnib *et al.* 2002).

To determine posttraumatic stress symptoms the Impact of Event Scale – Revised (IES-R) is applied by different authors.

Arnberg *et al.* (2014) evaluated the properties of Swedish versions of self-report measures of posttraumatic stress disorder (PTSD), with emphasis on the IES-R. The Swedish IES-R and posttraumatic stress disorder checklist (PCL) are sound measures of chronic PTSD, and the findings illustrate important temporal aspects of PTSD assessment. In summary, the findings provide support for the use of the IES-R and PCL as sound measures of chronic PTSD (Arnberg *et al.* 2014).

Shooshtary *et al.* (2008) evaluated the effectiveness of cognitive behavioral therapy (CBT) among adolescents exposed to the 2004 earthquake in Bam, Iran.

Two therapists were trained in CBT in 3-day classes according to a manual provided by mental health services. After conducting CBT in the case group, both groups were evaluated again with IES-R. The severity of posttraumatic stress symptoms significantly decreased among the subjects given CBT in the case group. The findings demonstrate the efficacy of CBT in alleviating posttraumatic stress symptoms among adolescents after a catastrophic disaster (Shooshtary *et al.* 2008).

Dancause *et al.* (2011) assessed women's psychological reaction to the storm in the first questionnaire using a validated French version of the IES-R. This 22-item scale, widely used for assessing distress following trauma exposure, describes symptoms from three categories relevant to post-traumatic stress: Intrusive Thoughts, Hyperarousal, and Avoidance. Participants responded on a 5-point Likert scale, from “Not at all” to “Extremely,” the extent to which each behavior described how they felt over the preceding seven days. Items were written to reflect symptoms relative to the ice storm. The total score was used in analyses (Dancause *et al.* 2011).

Heir *et al.* (2010) examined posttraumatic stress symptom clusters associations with psychopathology and functional impairment in 899 Norwegian survivors of the 2004 South-East Asia tsunami six months post-disaster. Posttraumatic stress symptoms were assessed with the Impact of Event Scale-Revised (IES-R) with intrusion, avoidance, and hyper-arousal subscales. Heir *et al.* (2010) findings indicate that symptoms of hyperarousal may be more closely linked to psychopathology and functional impairment than other symptoms of posttraumatic stress following a sudden onset, short duration, natural disaster event.

The purpose of Chen *et al.* (2011) study was to validate the Impact of Event Scale-Revised (IES-R) for adolescents who had experienced the floods and mudslides caused by Typhoon Morakot in Taiwan. The internal consistency, construct validity, and criteria validity of the instrument were examined. Principal component analysis followed by an oblique rotation was used to derive a three-factor solution. These factors were labeled intrusion, hyperarousal, and avoidance. According to Chen *et al.* (2011) the IES-R can be used as a reliable and valid instrument when evaluating psychological distress among adolescents who have experienced a natural disaster, such as flooding and mudslides.

As though the IES-R has strong psychometric properties (the internal consistency reliability and convergent validity (King *et al.* 2009) and is applied to measure symptoms of posttraumatic stress to various natural disasters and within various cultural context, so this scale was chosen for further research.

1.4. Application of Physiological Parameters

Statistics show that the cost of work-related stress in the European Union countries is no less than 20 billion Euros annually. Stress on the job can cause depression, anxiety, increased chronic fatigue and heart disease. This has tremendous effects on work productivity, creativity and competitiveness.

Research shows that various scientists have specialised in depth the different and very important areas of speech and emotion analysis (Clavel *et al.* 2008), emotion detection (Altun, Polat 2009), emotion annotation (Callejas, López-Cózar 2008), evaluation and the estimation of emotions in speech (Grimm *et al.* 2007), ensemble methods for spoken emotion recognition (Morrison *et al.* 2007), speech and emotion (Douglas-Cowie *et al.* 2003), emotional states that are expressed in speech (Cowie, Cornelius 2003), voice quality in communicating emotion, mood and attitude (Gobl, Chasaide 2003), emotions, speech (Bosch 2003), vocal communication of emotion (Scherer 2003), emotional speech recognition (Ververidis, Kotropoulos 2006), speech recognition (Avci, Akpolat 2006), speaking improvement (Hsu 2010), voice dialog (Tsai 2006), recognition of musical genres (Mostafa, Billor 2009), command recognition (Savage-Carmona *et al.* 1998), intelligent home appliance control (Hsu *et al.* 2010). According to Ververidis and Kotropoulos (2006) the most frequent acoustic features used for emotional speech recognition are pitch, formants, vocal tract cross-section areas, mel-frequency cepstral coefficients, Teager energy operator-based features, the intensity of speech signals, and speech rates. Ververidis and Kotropoulos (2006) reviewed appropriate techniques in order to classify speech into emotional states. Classification techniques based on hidden Markov models, artificial neural networks, linear discriminate analysis, *k*-nearest neighbours, support vector machines were reviewed by Ververidis and Kotropoulos (2006). However, the above speech and emotion analysis systems cannot generate (perform a multivariant design, multicriteria analysis and selection out the best tips) different recommendations.

Globally systems for establishing the level of stress are rather widely applied (Bou-Ghazale, Hansen, 1996; Lee *et al.* 2002; Fernandez, Picard 2003; Casale *et al.* 2007). Several of these are briefly analysed here.

According to Casale *et al.* (2007), in literature, various techniques are used to classify emotional/stressed states on the basis of speech often using different speech feature vectors at the same time. Casale *et al.* (2007) propose a new feature vector that will allow better classification of emotional/stressed states. The components of the feature vector are obtained from a feature subset selection procedure based on genetic algorithms. A good discrimination is obtained between neutral, angry, loud and Lombard states for the simulated domain of the Speech under

Simulated and Actual Stress database and between neutral and stressed states for the actual domain of the Speech under Simulated and Actual Stress database.

Fernandez and Picard (2003) explore the use of features derived from multi-resolution analysis of speech and the Teager energy operator for classification of drivers' speech under stressed conditions. Fernandez and Picard (2003) apply this set of features to a database of short speech utterances to create user-dependent discriminants of four stress categories.

The objective of the research of Bou-Ghazale and Hansen (1996) here is to generate stressed, perturbed speech from neutral speech using a source generator framework previously employed for stressed speech recognition. The approach is based on (i) developing a mathematical model that provides a means for representing the change in speech production under stressed conditions for perturbation and (ii) employing this framework in an isolated word speech processing system to produce emotional/stressed perturbed speech from neutral speech. A stress perturbation algorithm is formulated based on a code-excited linear prediction speech synthesis structure. The algorithm is evaluated using four different speech feature perturbation sets. The stressed speech parameter evaluations from this study revealed that pitch is capable of reflecting the emotional state of the speaker, while formant information alone is not as good a correlate of stress. However, the combination of formant location, pitch and information gained proved to be the most reliable indicator of emotional stress under a code-excited linear prediction speech model. Results from formal listener evaluations of the generated stressed speech show successful classification rates of 87 percent for angry speech, 75 percent for Lombard effect speech and 92 percent for loud speech (Bou-Ghazale, Hansen 1996).

Thermometers of anger and other types of distress are also rather popular in the world. The Anger Thermometer is usually used for treating anger in groups wherein the treating physician participates right along with the people being treated. Generally the level of anger and other types of distress is established by using different questionnaires (often on paper). The persons being treated are taught to recognise signs that indicate a rise in the level of anger.

There are also various other question-answer, Internet systems being offered for establishing the level of anger and distress which automatically determine the level of anger/distress once the user has replied to questions submitted on-line (e.g., Buss and Perry 1992). However, these systems do not provide users with any advice. These are merely a one-shot chance to determine anger. If the level is high, the system suggests seeking help from professionals but it does not contain a database of recommendations; thus it does not generate them.

1.4.1. Dependence of Blood Pressures and Heart Rate on a Person's Experienced Stress

Worldwide scientific research has shown that stress causes increased blood pressure and that heart rate increases during stressful times. Light *et al.* (1999) analysed cases of daily and of heavy stress as well as their effects on systolic and diastolic blood pressure fluctuations. Gray *et al.* (2007) investigated the effect of psychological stress on systolic and diastolic blood pressures. Adrogué and Madias (2007) described the effects of psychological, emotional and chronic stress on blood pressure. All of these scholars unanimously concluded that diastolic as much as systolic blood pressure and heart rate are dependent on stress and increase depending on the level of stress.

Blair *et al.* (1959) researched the effect of stress on heart rate and concluded that heart rate rises sharply in 3 min after stress strikes and only begins to fall after another 5–6 min pass. The article by Gasperin *et al.* (2009) concludes that chronic stress has an effect on high blood pressure. The results from a number of studies showed that patients with a pulse count higher than 70 beats/min are more likely to develop heart and blood vessel diseases or to die from them. Tests have proven that a rapid pulse rate increases the risk of death by 34 percent, of myocardial infarction (heart attack) by 46 percent and of heart insufficiency by 56 percent.

Briese (1992) and Okada *et al.* (2007) discussed stress and body temperature dependencies in animals. They assert that, under stress, animals experience a rise in temperature.

Briese (1992) claims that changes in ambient temperature should not affect changes in core temperature due to set-point shifts. Nevertheless, when the colonic temperature of rats was taken in a cold environment, the usual emotional rise was higher and, when the colonic temperature was taken in a warm environment, the emotional rise was lower. The results of Briese (1992) contradict the hypothesis that an emotionally induced rise in the temperature of rats is a fever. Okada *et al.* (2007) exposed rats to restrained stress for 60 min. Biting on a wooden stick while restrained significantly inhibited the rise in core temperature for 30, 60, 120 and 180 min, as compared to rats that were restrained but did not bite anything.

However, the results gained from all the studies were not the same. For example, Nakayama *et al.* (2005) monitored facial temperature changes of monkeys under stressful and threatening conditions. Their study revealed that a decrease in nasal skin temperature is relevant to a change from a neutral to a negative affective state. Vianna and Carrive (2005) monitored temperature changes in rats when they were experiencing fearful situations. They observed that temperature increased in certain body parts (i.e., eyes, head and back) while, in other body parts (i.e., tail and paws), temperature dropped simultaneously.

Table 1.1. Analysis of Previous Studies on Stress and Emotion Recognition

Authors	Emotions	Signals measured	Data analysis method	Accuracy
Kim *et al.* 2004	Sadness, anger, stress, surprise	Electrocardiogram, skin temperature variation, electrodermal activity	Support vector machine	Correct-classification ratios were 78.4% and 61.8%, for the recognition of three and four categories, respectively
Lisetti, Nasoz 2004	Sadness, anger, fear, surprise, frustration, and amusement	Galvanic skin response, heart rate, temperature	*k*-Nearest neighbor algorithm (KNN), discriminant function analysis (DFA), Marquardt backpropagation algorithm (MBP)	KNN, DFA, and MBP, could categorize emotions with 72.3%, 75.0%, and 84.1% accuracy, respectively
Healey, Picard 2005	Three levels of driver stress	Electrocardiogram, electromyogram, skin conductance and respiration	Fisher projection matrix and a linear discriminant	Three levels of driver stress with an accuracy of over 97%
Li, Chen 2006	Fear, neutral, joy	Electrocardiogram, skin temperature, skin conductance, respiration	Canonical correlation analysis	Correct-classification ratio is 85.3%. The classification rates for fear, neutral, joy were 76%, 94%, 84% respectively
Leon *et al.* 2007	Neutral, positive and negative in real time	Heart rate, skin resistance, blood volume pressure, skin resistance and the speed of the changes in the data	The combination of auto-associative neural networks and sequential analysis, namely the sequential probability ratio test	Recognition level of 71.4%
Katsis *et al.* 2008	The emotional classes identified are high stress, low stress, disappointment, and euphoria	Facial electromyograms, electrocardiogram, respiration, electrodermal activity	Support vector machines (SVM) and adaptive neuro-fuzzy inference system (ANFIS)	The overall classification rates achieved by using tenfold cross validation are 79.3% and 76.7% for the SVM and the ANFIS, respectively.

Continuation of the Table 1.1

Nasoz *et al.* 2010	Neutrality, panic/fear, frustration/anger, boredom/sleepiness	Galvanic skin response, heart rate, temperature	KNN, MBP, and Resilient Backpropagation (RBP) Algorithms	RBP was the best classifier of these three emotions with 82.6% accuracy, followed by MBP with 73.26% and by KNN with 65.33%
Patel *et al.* 2011	Fatigue caused by driving for extended hours	Heart rate variability	Neural network	The neural network gave an accuracy of 90%
De Santos Sierra *et al.* 2011	Stress	Heart rate, galvanic skin response	Fuzzy logic	An accuracy of 99.5%
Jang *et al.* 2012	Boredom, pain, surprise	Electrodermal activity, electrocardiogram, photoplethysmography, skin temperature	Machine learning algorithms: linear discriminate analysis (LDA), classification and regression tree (CART), self-organizing map (SOM), and SVM	Accuracy rate of LDA was 78.6%, 93.3% in CART, and SOMs provided accuracy of 70.4%. The result of emotion classification using SVM showed accuracy rate of 100%
Monajati *et al.* 2012	Negative, neutral emotions	Galvanic skin response, heart rate, respiration rate	Fuzzy Adaptive Resonance Theory (Fuzzy-ART)	Negative emotions from actual ones with accuracy of 80% and neutral emotions from actual ones with 96%
Soleymani *et al.* 2012	The arousal classes were calm, medium aroused; and the valence classes were unpleasant, neutral, and pleasant	Electroencephalogram, pupillary response, gaze distance	Support vector machine	The best classification accuracies of 68.5 percent for three labels of valence and 76.4 percent for three labels of arousal

End of the Table 1.1

Sun *et al.* 2012	Mental stress detection	Electrocardiogram, galvanic skin response, accelerometer data	Decision Tree, Bayes Net, and support vector machine	92.4% accuracy of mental stress classification for 10-fold cross validation and 80.9% accuracy for between-subjects classification.
Chang *et al.* 2013	Sadness, fear, pleasure	Electrocardiogram, galvanic skin responses, blood volume pulse, pulse.	Support vector regression	Recognition rate up to 89.2%
Liu *et al.* 2014b	Frustration, satisfaction, engagement, challenge	Electroencephalography, galvanic skin resistance/electrocardiography	Fuzzy logic	84.18% for frustration, 76.83% for satisfaction, 97% for engagement, 97.99% for challenge
Singh *et al.* 2013	Driver‘s overall stress level	Galvanic skin response, photoplethysmography	Neural network concluded that Layer Recurrent Neural Networks are most optimal for stress level detection	Average precision of 89.23%, sensitivity of 88.83% and specificity of 94.92%
Verma, Tiwary 2013	Terrible, love, hate, sentimental, lovely, happy, fun, shock, cheerful, depressing, exciting, melancholy, mellow	Electroencephalogram (32 channels) and peripheral (8 channels: galvanic skin response, blood volume pressure, respiration pattern, skin temperature, electromyogram, electrooculogram	Support Vector Machine, Multilayer Perceptron (MLP), KNN and Meta-multiclass (MMC),	The average accuracies are 81.45%, 74.37%, 57.74% and 75.94% for SVM, MLP, KNN and MMC classifiers respectively. The best accuracy is for ‘Depressing’ with 85.46% using SVM. Accuracy of 85% with 13 emotions

Most findings indicate that the psychological stress-induced rise in core temperature is a fever, a rise in the thermoregulatory set point. Thus these mechanisms might be involved in psychogenic fever in humans (Oka *et al.* 2001).

Analysis of previous studies on emotion recognition is presented in Table 1.1.

Leon *et al.* (2007) research presents an approach for recognizing and classifying positive and negative emotional changes in real time using physiological signals. In this research, the Statistical probability ratio test and Autoassociative neural networks residual values were used to detect changes from a neutral to a nonneutral state and, once a change was detected, determine whether it was negative or positive results from applying proposed methodology on real-time data demonstrated a recognition level of 71.4% which is comparable to the best results achieved by others through offline analysis (Leon *et al.* 2007). The other investigation on negative emotions states recognition was made by Monajati *et al.* (2012). In this research, the three physiological applied signals are galvanic skin response, heart rate and respiration rate. Physiological responses were analysed by Fuzzy Adaptive Resonance Theory to recognize the negative emotions. Detecting negative emotions from neutral is obtained with total accuracy of 94% (Monajati *et al.* 2012).

Healey and Picard (2005), De Santos *et al.* (2011), Sun *et al.* (2012), Singh *et al.* (2013) presented methods for stress detection. For example, Healey and Picard (2005) presented methods for collecting and analysing physiological data during real world driving tasks to determine a driver's relative stress level. De Santos *et al.* (2011) presented an approach which proposes a stress detection system wherein only two phsyiological signals are required, namely galvanic skin response (skin conductivity) and heart rate, since both provide accurate and precise information on the physiological situation of individuals. Sun *et al.* (2012) presented an activity-aware mental stress detection scheme. Electrocardiogram, galvanic skin response, and accelerometer data were gathered from 20 participants across three activities: sitting, standing, and walking. The Decision Tree classifier has the best performance in our experiments using 10-fold cross validation. Singh *et al.* (2013) work proposes a neural network driven based solution to learning driving-induced stress patterns and correlating it with statistical, structural and time-frequency changes observed in the recorded bio signals.

Kim *et al.* 2004 and Katsis *et al.* 2008 analysed not only stress, but also other emotions. In Kim *et al.* (2004) research, the input signals were electrocardiogram, skin temperature variation and electrodermal activity, all of which were acquired without much discomfort from the body surface, and can reflect the influence of emotion on the autonomic nervous system. Katsis *et al.* (2008) presented a methodology and a wearable system for the evaluation of the emotional states of car-racing drivers. The proposed approach performs an assessment of the emotional states using facial electromyograms, electrocardiogram, respiration, and electrodermal activity. The emotional classes identified are high stress, low stress, disappointment, and euphoria. Support vector machines (SVMs) and adaptive neuro-fuzzy inference system (ANFIS) have been used for the classification.

Lisetti and Nasoz (2004), Li and Chen (2006), Nasoz *et al.* (2010), Patel *et al.* (2011), Jang *et al.* (2012), Chang *et al.* (2013), Soleymani *et al.* (2012), Liu *et al.* (2014b), Verma and Tiwari (2013) analysed a number of other emotions. For example, Lisetti and Nasoz (2004) introduced the overall paradigm for their multimodal system that aims at recognizing its users' emotions and at responding to them. They then described the design of the emotion elicitation experiment they conducted by collecting physiological signals from the autonomic nervous system (galvanic skin response, heart rate, temperature) and mapping them to certain emotions (sadness, anger, fear, surprise, frustration, and amusement). Li and Chen (2006) proposed to recognize emotion using physiological signals (electrocardiogram, skin temperature, skin conductance and respiration) obtained from multiple subjects without much discomfort from the body surface. Nasoz *et al.* (2010) described a new approach to enhance driving safety via multi-media technologies by recognizing and adapting to drivers' emotions with multi-modal intelligent car interfaces. A controlled experiment was designed and conducted in a virtual reality environment to collect physiological data signals from participants who experienced driving-related emotions and states. *k*-Nearest neighbor, Marquardt-Backpropagation, and Resilient Backpropagation Algorithms were implemented to analyse the collected data signals and to find unique physiological patterns of emotions.

Patel *et al.* (2011) presented an AI based system which could detect early onset of fatigue in drivers using heart rate variability as the human physiological measure. The detection performance of neural network was tested using a set of electrocardiogram data recorded under laboratory conditions. The neural network gave an accuracy of 90%. This heart rate variability based fatigue detection technique can be used as a fatigue countermeasure (Patel *et al.* 2011). Jang *et al.* 2012 classified three emotions (boredom, pain, and surprise) by 4 machine learning algorithms (linear discriminate analysis (LDA), classification and regression tree (CART), self-organizing map (SOM), and support vector machine (SVM)). Soleymani *et al.* (2012) presented a user-independent emotion recognition method with the goal of recovering affective tags for videos using electroencephalogram, pupillary response and gaze distance. Chang *et al.* (2013) designed a specific emotion induction experiment to collect five physiological signals of subjects including electrocardiogram, galvanic skin responses, blood volume pulse, and pulse. Chang *et al.* (2013) used support vector regression (SVR) to train the trend curves of three emotions (sadness, fear, and pleasure). Experimental results show that the proposed method achieves high recognition rate up to 89.2% (Chang *et al.* 2013).

Liu *et al.* (2014b) proposed and investigated a methodology to determine the emotional aspects attributed to a set of computer aided design tasks by analysing the computer aided design operators' psycho-physiological signals. Verma and Tiwari (2013) proposed a novel approach for multimodal fusion of information from a large number of channels to classify and predict emotions.

1.4.2. Dependence of Skin Temperature on a Person's Experienced Stress

Analysis of results of researches carried out in the temperature data for stress is presented in Table 1.2, while analysis of methods used for stress evaluation is presented in Table 1.3.

The affective experience of a stimulus has traditionally been studied by statistically correlating the Electroencephalogram (EEG) and Affective Self Report (ASR). Here, this method is extended into a three-way correlation by including measurement of changes in forehead temperature on the right and left sides using Infrared Thermography (IRT) (Figure 1.1). Sixteen male undergraduate designers were given a cognitive task whilst simultaneous IRT and EEG measurements were conducted. Measures of Arousal and Valence were recorded along with an additional post-test measure of Task Engagement.

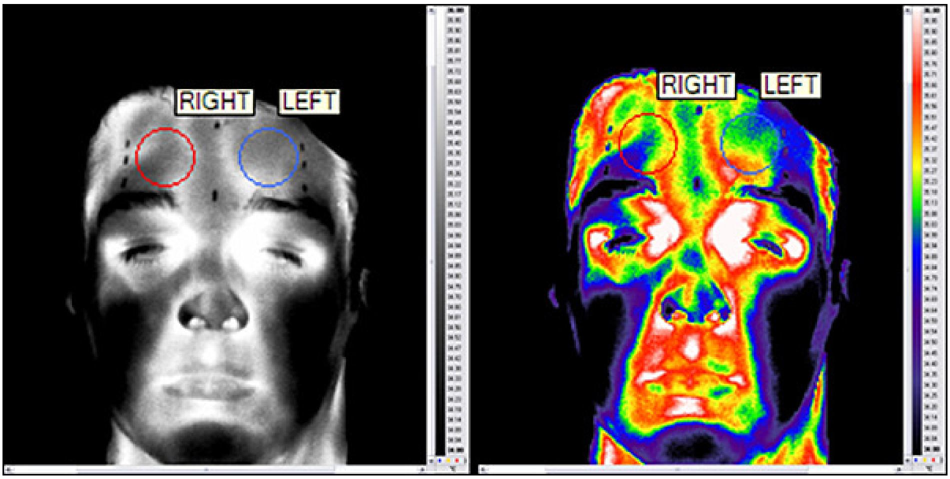


Fig. 1.1. Thermal Images Indicating Regions of Interest's. Gray Scale and ROYGBIV Colour Palettes Were Used (Jenkins *et al.* 2009)

Table 1.2. Analysis of Results of Researches Carried out in the Temperature Data for Stress

Authors	Research object	Measured temperature parameters and other factors	Temperature changes	
Jenkins *et al.* (2009)	Cognitive work and affective state	Forehead temperature, EEG	Left side	Right side
			↓↑	↑↑
Tanaka *et al.* (1998)	Mental stress	Nasal skin temperature	↓	
Kistler *et al.* (1998)	Psychological stress	Fingertip temperature	↓	
Genno *et al.* (1997)	Stress	Forehead and nasal temperature	Forehead	Nasal
			No changes	↓
Kataoka *et al.* (1998)	Stress (stressfull task)	Skin temperatures on nose and forehead	Forehead	Nose
			High correlation	
Rimm-Kaufman and Kagan (1996)	Performance anxiety, positive e-motions, fear, and anxiety	Temperature of the inner eyes, measured using infrared ther-mography	Temperature of the inner eyes was sensitive only to the task meant to elicit anxiety	
Or and Duffy (2007)	Driver workload with and without a mental arithmetic task	Forehead and nose temperatures	Forehead	Nose
			No changes	↓
Itoh (2009)	Driver mental condition	Nose tip	↓	
Yamakoshi *et al.* (2008)	Driver stress	Facial skin temperature	↓	
Ruff and Rötting (2013)	Driver mental workload	Nose-tip and forehead tempera-ture	Forehead	Nose
			No changes	↓
Kang *et al.* (2006)	Human learning process	Changes in nose temperature, reaction time, accuracy on task, and subjective perceptions of mental workload	↓	

End of the Table 1.2

Stemberger *et al.* (2010)	Cognitive workload levels	Facial skin temperature, head pose estimation	The system was capable of accurately classifying mental workload into high, medium and low workload levels 81% of the time.
Jzerman *et al.* (2012)	Mental work, the working environment	Finger temperatures	↓
Zhai and Barreto (2006)	Psychological stress	Physiological signals (Galvanic Skin Response, Pulse, Pupil Diameter, Skin Temperature)	+ (observed changes in temperature)

Table 1.3. Analysis of Methods Used for Stress Evaluation According to the Determination of the Temperature Data

Authors	Research object	Measured temperature parameters and other factors	Methods of data analysis
Kang *et al.* (2006)	Human learning process	Changes in nose temperature, reaction time, accuracy on task, and subjective perceptions of mental workload	Procedure of analysis of variance
Stemberger *et al.* (2010)	Cognitive workload levels	Facial skin temperature, head pose estimation	Artificial neural network classifier
Ruff and Rötting (2013)	Driver mental workload	Nose-tip and forehead temperature	Friedman's Two-Way Analysis of Variance
Jzerman *et al.* (2012)	Mental work, work environment	Finger temperatures	Growth-model
Seoane *et al.* (2014)	Mental stress	Temperature from fingers or arms	Genetic algorithm, Linear Discriminant Classifier

The premise of Jenkins *et al.* (2009) work was that the observed temperature changes at the Regions of Interest on the forehead arise from a combination of cognitive and emotional psychophysical effects. Puzzle-solving was selected as it could be viewed both as a representation of the activity of designing and of interaction with a complex product. This work demonstrated that there were significant changes in forehead temperature dynamics of subjects engaged in puzzle-solving activity and that these can be accurately measured using IRT.

The facial skin temperature of a living body under stress is said to decrease, indicating that stress and facial skin temperature are correlated (Tanaka, Ide 1998). Thermography and digital infrared image are used to measure facial skin temperature. Results of experiments show that nasal skin temperature declines (Table 1.4). Nasal skin temperature is thus considered important in evaluating stress.

Living bodies cope by activating the sympathetic nervous system when encountering stress. According to physiopsychological studines, stress inflicted on a living body stimulates the sympathetic nervous system and contracts capillaries, which decreases skin temperature. Significant variations in skin temperature were reported observed, particularly around the nose (Tanaka, Ide 1998).

Table 1.4. Nasal Skin Temperature at Rest and under Mental Stress (Tanaka, Ide 1998)

Subjects	Nasal skin temperature, ºC		
	At rest	Under mental stress	Temperature difference
Subject A	35.42	31.73	2.79
Subject B	35.45	34.44	1.01
Subject C	35.56	34.63	0.93
Subject D	35.70	35.22	0.48
Subject E	35.48	34.57	0.91

Changes of acral skin blood flow are a commonly used indicator for sympathetic reflex responses to various stimuli (Kistler *et al.* 1998). The goal of Kistler *et al.* (1998) study was to determine whether decreases in fingertip temperature are indicative for sympathetic induced changes in microcirculation.

Genno *et al.* (1997) found that while there was no change in forehead temperature under stress, nasal temperature decreased. Using data from previous studies, the authors derived a linear model to predict subjective stress ratings using the difference between the forehead temperature and the nasal temperature. The predicted ratings correlated with the actual ratings with r=0.51 (Genno *et al.* 1997).

Skin temperature is an effective indicator for objectively evaluating human sensations, because it is controlled by sympathetic nerve activity which reflects the course of information processing in the brain. In this research, Kataoka *et al.*

(1998) show a method to evaluate stress from skin temperature and an equipment which continuously measures skin temperature of a subject working in front of a computer terminal. An experiment is performed to investigate a relationship between stressful task and the skin temperature. The experiment shows that there is a high correlation among stress, skin temperatures on nose and forehead. A non-contact skin temperature measuring system is developed based on knowledge obtained in the experiment. The system comprised of an infrared camera, color camera, image processing unit and workstation. The features are the abilities to track nose and forehead positions of a subject doing computer operation automatically and to evaluate the stress continuously (Kataoka *et al.* 1998).

Thermography has been applied to investigations of emotion. Rimm-Kaufmann and Kagan (1996) asked participants to perform tasks meant to elicit performance anxiety, positive emotions, fear, and anxiety. Temperature of the inner eyes, measured using infrared thermography, was sensitive only to the task meant to elicit anxiety.

Facial temperature has also been used to assess driver workload while driving in simulated city and highway settings with and without a mental arithmetic task (Or, Duffy 2007). Forehead and nose temperatures were measured immediately before and after each three-minute trial and subjective workload scores were obtained via the Modified Cooper-Harper scale. Forehead temperature remained stable while nose temperature dropped significantly during all conditions. The decrease in nose temperature was significantly greater for the trials that included the arithmetic task and was correlated with the subjective workload scores ($r = 0.32$, $p = 0.009$).

Interactions with in-vehicle human-machine interface systems place demands on drivers that can increase stress, frustration, and cognitive load. These effects can undermine driver performance and enjoyment of the vehicle and are revealed by a complex pattern of physical and physiological behavior (Or, Duffy 2007). Several researches have pointed out that the temperature at the nose tip is possibly effective for evaluating driver mental condition (Itoh 2009). Physiological measures provide a useful complement to performance-based and subjective measures because they promise an estimate of the affective response of drivers to an in-vehicle system in a way that requires no overt response by the driver. Reyes *et al.* (2009) research explored how facial temperature might reflect the drivers' response to the demands they confront when interacting with in-vehicle systems. Prolonged monotonous driving may lower a driver's awareness level as well as increasing their stress level due to the compulsion to maintain safe driving, which may result in an increased risk of a traffic accident (Yamakoshi *et al.* 2008). There is a relation to the accident of a car and the physiological and psychological state of a driver. The stress may lead to the fall of a fatigue or attentiveness. Therefore, it is an important subject from viewpoint such as accident prevention to evaluate the mental state of a driver (Hirotoshi *et al.* 2011). To avoid accidents caused by an inappropriate amount of mental workload it is crucial to continuously and non-intrusively monitor the actual workload state of a driver (Ruff and Rötting 2013).

High resolution thermal infrared imaging is a pioneering method giving indices of sympathetic activity via the contact-free recording of facial tissues (thermal imprints) (Engert *et al.* 2014). The goal of the study was to pilot the use of thermal infrared imaging in the classical setting of human stress research. Thermal imprints were compared to established stress markers in 15 participants undergoing anticipation, stress and recovery phases of two laboratory stress tests, the Cold Pressor Test (CPT) and the Trier Social Stress Test (TSST). Means and ±SEM (standard error of mean) of all dependent variables (raw or logged scores) during baseline, anticipation, stress and recovery (sampling time points for alpha-amylase and cortisol) of CPT and TSST were presented. The majority of the thermal imprints proved to be change-sensitive in both tests. While correlations between the thermal imprints and established stress markers were mostly non-significant, the thermal imprints (but not the established stress makers) did correlate with stress-induced mood changes (Engert *et al.* 2014).

The aim for the Sharma *et al.* (2013) work was to use thermal imaging of facial regions to detect stress automatically. The work uses facial regions captured in videos in thermal (TS) and visible (VS) spectra and introduces the database ANU StressDB. It describes the experiment conducted for acquiring TS and VS videos of observers of stressed and not-stressed films for the ANU StressDB. Further, it presents an application of local binary patterns on three orthogonal planes on VS and TS videos for stress recognition. It proposes a novel method to capture dynamic thermal patterns in histograms to utilise thermal and spatio-temporal characteristics associated in TS videos. Individual-independent support vector machine classifiers were developed for stress recognition. Results show that a fusion of facial patterns from VS and TS videos produced significantly better stress recognition rates than patterns from only VS or TS videos (Sharma *et al.* 2013).

Stemberger *et al.* (2010) have developed and evaluated the feasibility of a system for estimation of cognitive workload levels based on analysis of facial skin temperature. The system is based on thermal infrared imaging of the face, head pose estimation, measurement of the temperature variation across regions of the face and an artificial neural network classifier. The technique was evaluated in a controlled laboratory experiment using subjective measures of workload across tasks as a standard. The system was capable of accurately classifying mental workload into high, medium and low workload levels 81% of the time. The suitability of facial thermography for integration into a multimodal augmented cognition sensor suite is discussed (Stemberger *et al.* 2010).

1.5. Conclusions of Chapter 1 and Formulation of Thesis Objectives

1. The analysis of literature in this field showed that there is no intelligent decision support system developed that is integrated with a human resource management in emergency situations providing a comprehensive assessment of alternative versions from economic, technical, infrastructural, qualitative, technological, legislative and other perspectives. Furthermore no decision support system has been developed that enables a user to analyse human resource management in emergency situations quantitatively (subsystems of criteria, units of measure, values and weights) and conceptually (texts, formulas, drawings, graphs, diagrams, augmented realities).
2. A sufficient number of studies have been performed worldwide that apply physiological technologies to establish different human states of stress, and quite many systems have been developed accordingly. These systems do not determine the level and symptoms of post-disaster stress, perform multivariant designs of a resilience management life cycle (mitigation, preparedness, response, recovery) providing alternative recommendations applicable to a specific user (on ways to reduce post-disaster stress), perform a multiple criteria analysis of the alternatives nor select the most rational ones (disaster stress management life cycle and tips) for that user. However, all these functions are much needed.
3. Most advanced text analytic and text mining tasks include text classification, text clustering, building ontology, concept/entity extraction, summarization, derivation of patterns within the structured data, production of granular taxonomies, sentiment and emotion analyses, document summarization, entity relation modelling and interpretation of the output. Nonetheless, the already existing text analytics and text mining cannot develop text material alternatives (perform a multivariant design), perform multiple criteria analysis or automatically select the most effective variant according to different aspects, such as by a citation index of papers (Scopus, ScienceDirect, Google Scholar), authors (Scopus, ScienceDirect, Google Scholar), the Top 25 papers, impact factor of journals, supporting phrases, document name and contents or density of keywords. Furthermore they do not calculate utility degree or market value.
4. Different human and resilience management activities employ a range of various thermometers and similar scales: Distress Thermometer, Panic Thermometer, Fear Thermometer, fire danger rating, hurricane scales, earthquake scales (Richter Magnitude Scale and Mercalli Scale), Anxiety Thermometer, Help Thermometer, Problem Thermometer, Emotion

Thermometer, Depression Thermometer, Torino Scale (assessing asteroid/comet impact prediction), Excessive Heat Watch etc. These developed thermometers do not have the capacity to automatically measure the "temperature" of the preparedness for flood resilience management nor do they compile multiple alternative recommendations customised for a specific user involving preparedness for floods, including one's own home; taking precautions against a threat of floods, retrofitting for flood-prone areas and checking home insurance or preparedness for bush fires, for cyclones, for severe storms, for heat waves etc. Furthermore the aforementioned thermometers do not perform a multiple criteria analysis of the recommendations and do not select the ten most rational ones for that user.

5. The analysis of literature in this field showed that systems created by other authors do not integrate virtual reality with the stress analysis, resilience management, text analytics systems, thermometers and other scales.

2

Human Resource Management in Emergency Situations Model and Research Methods

This Chapter presents the human resource management in emergency situations model, the research methods applied and the practical realisation of the model. Method of complex determination of the weights of the criteria taking into account their quantitative and qualitative characteristics, method of multiple criteria complex proportional evaluation of the resilience management projects, method of defining the utility and market value of an alternative, method of multiple criteria multivariant design of a human resource management in emergency situations and methods used for stress recognition are applied. The human resource management in emergency situations model was used in three international Erasmus – Lifelong Learning Programme projects: Academic Network for Disaster Resilience to Optimise educational Development (ANDROID), Collaborative Action towards Disaster Resilience Education (CADRE) and Collaborative Reformation of Curricula on Resilience Management with Intelligent Systems in Open Source and Augmented Reality (RESINT).

On the thematic of this chapter 2 publications (Matuliauskaite, Zemeckyte 2011; Kaklauskas *et al.* 2014c) were published.

2.1. A Model for a Complex Analysis of the Human Resource Management in Emergency Situations

In order to design and realize a high-quality built environment resilience management, it is necessary to take care of its efficiency from the brief to the end of service life. The entire process must be planned and executed with consideration of goals aspired by participating stakeholders and micro, meso and macro level environment. In order to realize the above purposes an original model of a complex analysis of the human resource management in emergency situations was developed enabling to analyse the built environment resilience management life cycle, the stakeholders involved in the project as well as its micro, meso and macro environment as one complete entity.

A model for a complex analysis of a human resource management in emergency situations was being developed step by step as follows (see Figure 2.1):

- a comprehensive quantitative and conceptual description of a research object;
- multivariant design of the human resource management in emergency situations;
- multple criteria analysis of the human resource management in emergency situations;
- selection of the most rational version of the human resource management in emergency situations;
- development of rational micro, meso and macro level environment.

The above model will be now described in more detail.

For more comprehensive study of a research object and methods and ways of its assessment major constituent parts of the above object will be briefly analysed. They are as follows: a built environment resilience management life cycle, the parties involved in the project development and micro, meso and macro environment having a particular impact on it.

The built environment resilience management life cycle stages were selected based on different authors (Zhang et al. 2006; Vasilescu et al. 2008; Malaysian… 2012; Sena et al. 2014; Dimersar 2014; Palukuri, Jain 2014; Bally et al. 2014, etc). These four stages of built environment resilience management life cycle were discussed commonly in Section 1.1.

At the mitigation stage stakeholders state major requirements and limitations regarding the human resource management in emergency situations in question.

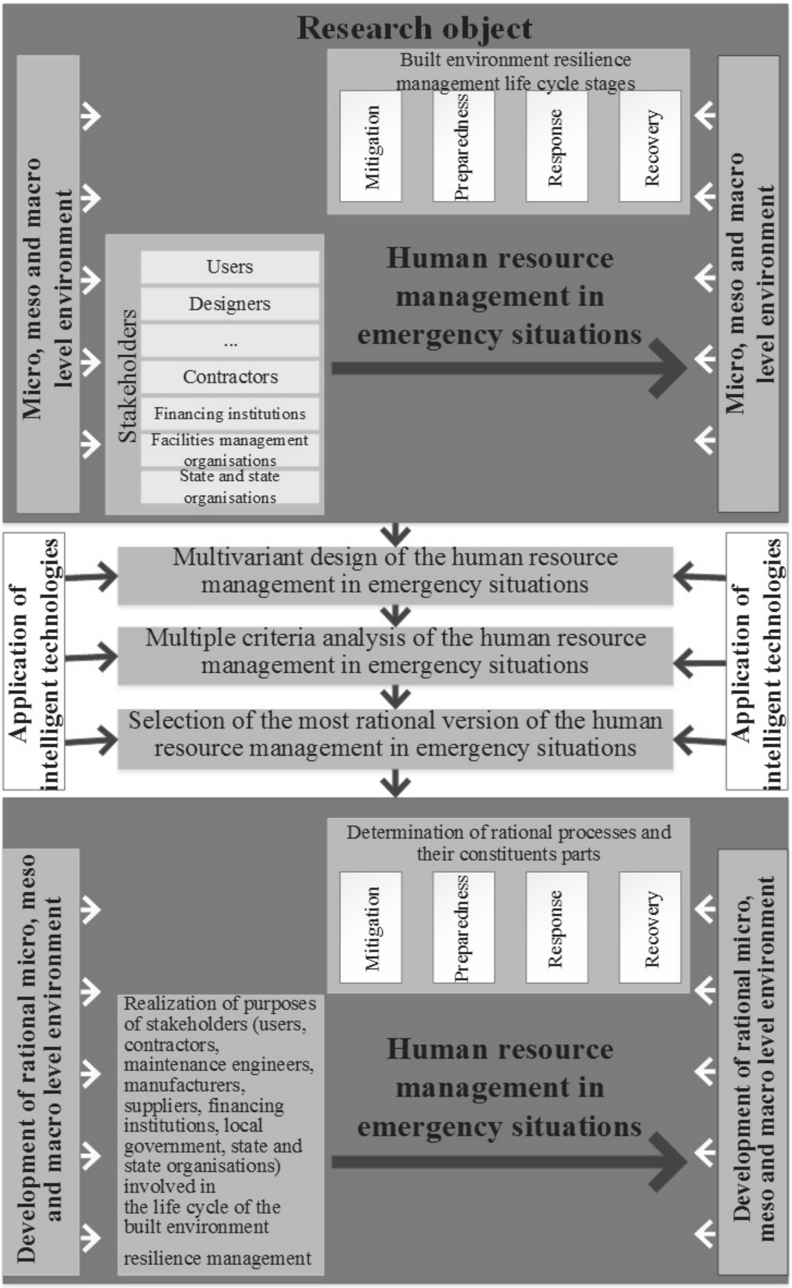


Fig. 2.1. A Model for a Complex Analysis of the Human Resource Management in Emergency Situations

A human resource management in emergency situations is being designed with account of the client's needs as well as the possibilities of designers, constructors, suppliers, facilities managers, etc. At the preparedness stage human resource management in emergency situations multivariant design and multiple criteria analysis should be carried out taking into account the experience gained in realizing similar projects and seeking to harmonize the activities of various stakeholders. At a preparedness stage, the strategy and means of its realization related to human resource management in emergency situations maintenance and facilities management should be defined. These should ensure that maintenance and facilities management problems are continually dealt with, starting from the mitigation stage.

A human resource management in emergency situations may have a lot of alternative versions. These variants are based on the alternative mitigation, preparedness, response and recovery and facilities management processes and their constituent parts. The above solutions and processes may be further considered in more detail. For instance, the alternative human resource management in emergency situations variants may be developed by varying its three-dimensional planning, as well as structural and engineering solutions. Thus, dozens of thousands of human resource management in emergency situations alternative versions can be obtained.

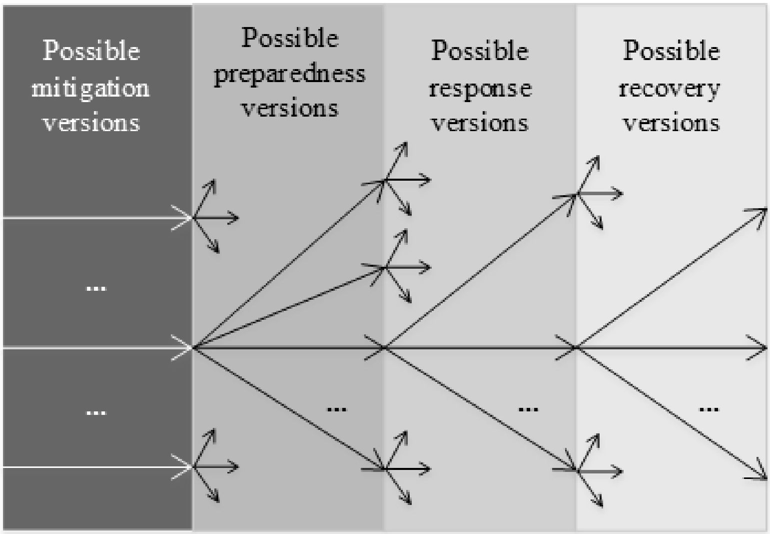


Fig. 2.2. Development of Possible Built Environment Resilience Management Life Cycle Versions and Relationship of Its Various Stages

In working out the project layout, elevations, sectional views were used to determine possible versions of structural (human resource management in emergency situations methods and materials) and utilities systems. The same relationship is found between the mitigation, preparedness, response and recovery stages (see Figure 2.2), and i.e. the first stages set the limits of the next ones. This process is also complicated by the fact that the considered versions of mitigation, preparedness, response and recovery are plenty and not always compatible. It should also be kept in mind that the improvement of some aspects of certain stage operations may lead to the deterioration of the indices of other stage or processes.

Since the rationality of various aspects of project often depends on a particular interested party only complex design of a life cycle process of a built environment resilience management involving close collaboration of major stakeholders can lead to good results.

Various parties (see Figure 2.3) are involved in the mitigation, preparedness, response and recovery stages of a built environment resilience management lyfe cycle, their cooperation taking rather long period of time.

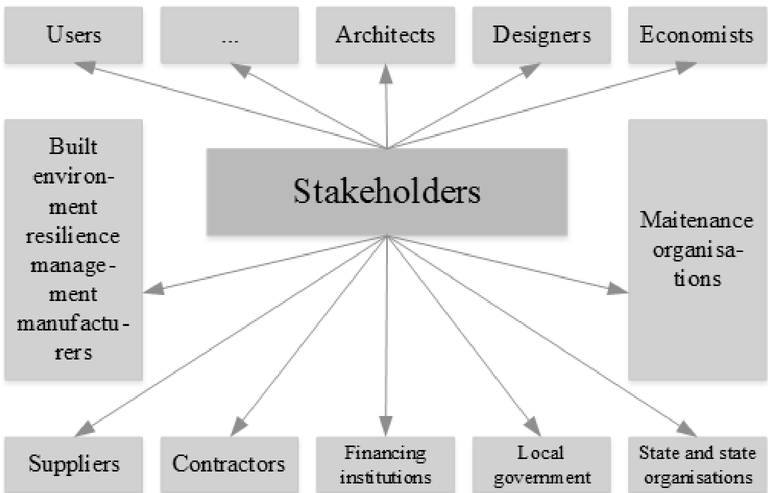


Fig. 2.3. Parties Involved in Built Environment Resilience Management Life Cycle

Every day architects, designers, contractors, suppliers, maintenance specialists, etc. make and analyse the alternative solutions which may have an impact on the decisions made by other professionals as well as affect efficiency of overall human resource management in emergency situations. Designers deal with a built environment resilience management's architectural and aesthetic aspects, three-dimensional planning, its strength and rigidity. They are also interested in getting efficient services. Hygiene professionals determine pollution level and the affect of some construction materials on human health, while economists study the cost of human resource management in emergency situations, costs of maintenance, taxes, insurance and quality (e.g. social, technical and economic indices). Contractors, in their turn, are interested in efficient technology, organization and management methods, whereas maintenance specialists seek effective built environment resilience management maintenance and refurbishment. The information provided by various professionals defines the efficiency of human resource management in emergency situations.

The built environment resilience management life cycle can not be effectively implemented without the satisfaction of the differing goals of stakeholders. Each interested party attempts to satisfy a number of goals (economic, comfort, esthetical, environment, legal, social). Some of these are easily attainable, while others can be attained only with difficulty. Also, they are not equally significant. Therefore, the stakeholders, even if they fail to reach all the desired goals, but attain the sufficiently important ones, can feel quite contented with the situation. In this case, it is very useful to apply the principle of mutual substitution and summary satisfaction of needs. The stakeholders and their aspired goals make up one complete entity. The greater is the scope of realization of the pursued goals (taking into account their significance), the greater (in opinion of stakeholders) is the total efficiency of the project. In other words, the total efficiency of a built environment resilience management life cycle is directly proportional to the realization of the goals of the parties involved.

Major stakeholders are involved in the development of all main life cycle stages. This helps support close links between various stakeholders and built environment resilience management life cycle formation stages. Since only the entity of all built environment resilience management life cycle stages and the parties involved in their development can define the project comprehensively the achievement of an efficient project requires multivariant design and multiple criteria analysis.

The level of the efficiency of built environment sector depends on a number of variables, at three levels: micro, meso and macro level. Although the macro level factors normally influence the level of the whole country or industry, this research considers only their effect on the efficiency of the built environment sector. The efficiency of the of built environment sector depends on the influence of many complex macro level factors (policy executed by the government, legal and institutional infrastructure, physical infrastructure, financial sector, environment issues, unemployment, interest rate, inflation, innovations, exchange rate). The efficiency level will, therefore, vary depending on the aggregate effect of these macro level factors.

The efficiency level of construction industry also depends on various micro level factors (sources of company finance, information system, types of contracts, education and training, brief, designing, manufacture, construction and maintenance processes, etc.) some of which depend on the influence of the macro level factors. For instance, the system of taxation which is set at the macro level (following fiscal policy of the government), exerts a direct influence on wages and salaries (and thereby disposable incomes) and on prices of materials at the micro level (project level). The standpoint of the State (various laws and decrees, working of State institutions, etc.) regarding certain activities exert considerable influence on the efficiency of organizations. The relations of various stakeholders are directly governed by law.

Hence, life cycle efficiency of a built environment resilience management depend to a very great extent not only on the selected most rational processes and solutions, the interest level of the concerned parties involved in the project, expressed as the effectiveness of their participation in the process, but also on the micro, meso and macro level factors. The object of investigation is rather complicated involving not only a built environment resilience management life cycle and its stages but also including stakeholders and micro, meso and macro environment factors having impact on the former. To select a rational project a new built environment resilience management life cycle complex analysis model was developed. Based on this model, professionals involved in design and realization of a built environment resilience management life cycle can develop a lot of the alternative versions as well as assessing them and making the final choice of the most efficient variant. The diversity of solutions available contributes to more accurate evaluation of climatic conditions, risk exposure, maintenance services, as well as making the project cheaper and better satisfying a user's requirements. This also leads to better satisfaction of the needs of all parties involved in the human resource management in emergency situations design and realization.

2.2. Practical Realization of the Model

A practical realization of a model for a complex analysis of a human resource management in emergency situations was being developed step by step as follows (see Figure 2.4):

- a comprehensive quantitative and conceptual description of the built environment resilience management life cycle, its stages, stakeholders and environment;
- development of a complex database based on quantitative and conceptual description of the research object;

- application of mathematical methods and methods of multiple criteria analysis to carry out multivariant design of a human resource management in emergency situations, determine the utility degree of the alternative versions obtained and set the priorities;
- creation of a multiple criteria decision support systems to be used in computer-aided multivariant design of a human resource management in emergency situations, determining the utility degree of the alternative versions obtained and setting the priorities;
- analysis of micro, meso and macro level environment factors influencing a human resource management in emergency situations and possibilities to alter them in a desired direction.

The stages mentioned above will be now described in more detail.

Quantitative and conceptual description of the research object (see Figure 2.4) provides the information about various aspects of a human resource management in emergency situations (i.e. economical, technical, technological, infrastructural, qualitative (architectural, aesthetic, comfortability), legislative, social, etc.).

Quantitative information is based on the criteria systems and subsystems, units of measure, values and initial significances as well as the data on the alternative projects development.

When drawing up the system of criteria fully describing the human resource management in emergency situations, it is worthwhile to take into account the suggestions of other authors. This is explained by the fact that the goals pursued by the stakeholders and the system of criteria describing the projects in a certain sense are rather subjective. Therefore, in order to increase the degree of objectivity, we shall rely on the suggestions of specialists working in this field when drawing up the system of criteria describing the projects.

Conceptual description of a human resource management in emergency situations presents textual, graphical (schemes, graphs, diagrams, drawings), visual (videotapes) information about the projects and the criteria used for their definition, as well as giving the reason for the choice of this particular system of criteria, their values and significances. This part also includes information about the possible ways of multivariant design.

In order to perform a complete study of the research object a complex evaluation of its economic, technical, qualitative (i.e. architectural, aesthetic, comfortability), technological, social, legislative, infrastructural and other aspects is needed. The diversity of aspects being assessed should follow the diversity of ways of presenting data needed for decision making. Therefore, the necessary data may be presented in numerical, textual, graphical (schemes, graphs, charts), formula, videotape and other forms.

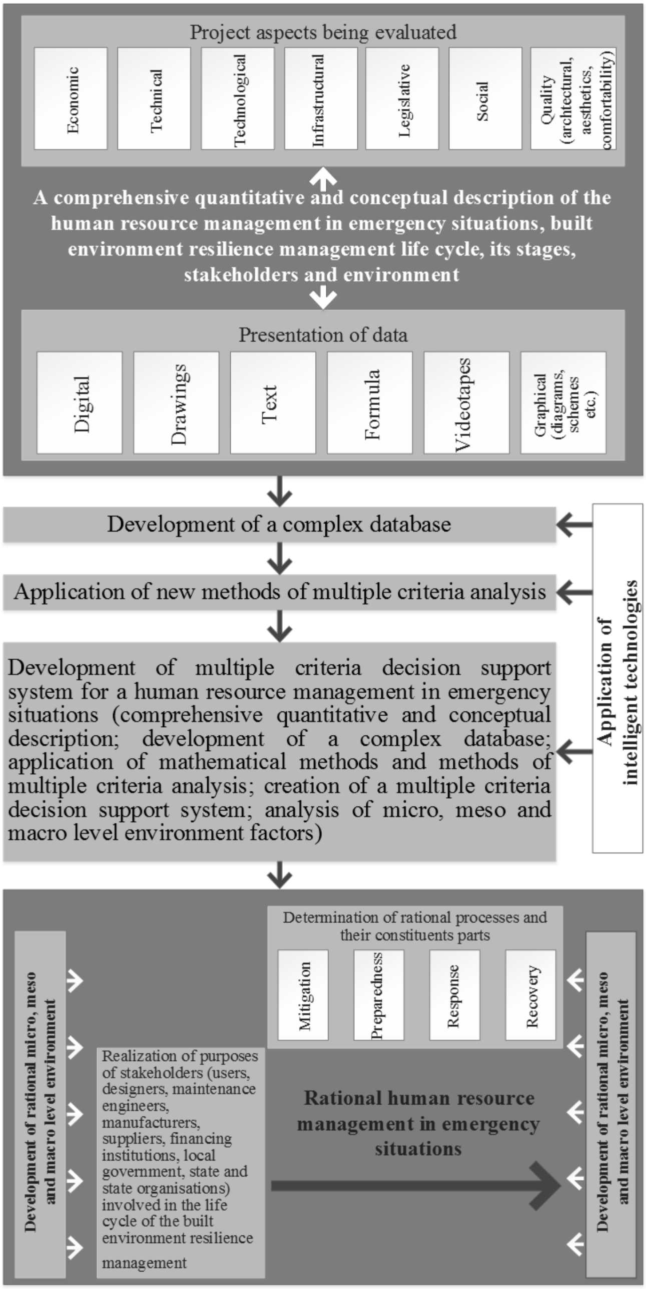


Fig. 2.4. Practical Realization of a Model for a Complex Analysis of a Human Resource Management in Emergency Situations

Quantitative and conceptual description of a built environment resilience management life cycle and its stages made is used as a basis for developing a complex databases containing overall information about it and allowing to carry out its multivariant design and multiple criteria analysis. Since the efficiency of any constituent part of the project depends on a particular party in its execution only complex design of a built environment resilience management life cycle involving close cooperation of all stakeholders can yield good results.

Alternative built environment resilience management life cycle versions include different cost of design and maintenance costs as well as various architectural, aesthetic, space-planning, comfortability characteristics, infrastructure and environment pollution. Particular stakeholders often have their own preferential rating of these criteria, also giving different values to qualitative characteristics. Besides, designing of a human resource management in emergency situations allows for the development of plenty of the alternative versions of its particular stages. This causes a lot of problems in determining the most efficient project. To overcome these difficulties some complex databases were developed. They contain a complex description of the alternative versions available in quantitative and conceptual forms. These data taken together can describe the object to be considered in more detail. The application of complex databases described allows to better satisfy the needs of the parties involved as well as helping to choose an efficient project.

A complex databases consists of the following parts:

1. Initial databases. These contain the initial data provided by various stakeholders allowing to carry out a complex design of the whole project or its parts.
2. Evaluation databases, containing comprehensive quantitative and conceptual information provided by stakeholders allowing to get a full description of the alternative variants. Based on the evaluation databases multiple criteria analysis of a built environment resilience management life cycle and its stages is carried out.
3. Multivariant design databases consisting of comprehensive quantitative and conceptual information about possible combinations of the alternative variants available.

These complex databases can contain data on theoretical and practical experience of the stakeholders, some additional facts as well as the recommendations how to avoid previous mistakes.

For example, a decision support system using these databases can help compare the project being designed or executed with the alternative or already realized projects in order to find its disadvantages and provide recommendations as to how to increase its efficiency.

In this way, the use of complex databases enables the user to take into account experts (including built environment resilience management owners and users, financing organisations, architects, engineers, manufacturers of built environment resilience management materials, contractors, state and its institutions, local governments, etc.) knowledge in various fields and the previous experience gained in developing similar projects applying them to currently developed project. For getting more efficient projects this information should be used at an early stage when the first meeting with a client takes place, which could save from repeating prior mistakes as well as leading to a more advanced and efficient project. In making a complex built environment resilience management life cycle architects, designers, utility engineers, economists, contractors, suppliers, users can more efficiently solve common problems. This results in lower project cost and built environment resilience management time, as well as increasing its quality.

Interacting with the databases the user can get more detailed or integral information on the object considered. Given this opportunity and using the data from complex databases as well as being provided with a decision support system, the user can find an effective project variant in a comparatively short time. In this way time is saved.

In order to design a number of alternative built environment resilience management life cycle versions as well as determine the utility degree of the alternatives obtained and set the priorities the multiple criteria analysis methods were applied.

Based on the above described model and in order to achieve the above-mentioned aims a multiple criteria decision support system consisting of a databases, database management system, a model-base, model-base management system and the user's interface was created to be used for a human resource management in emergency situations design and multiple criteria analysis.

The model and the system were adapted in three international Erasmus – Lifelong Learning Programme projects: Academic Network for Disaster Resilience to optimise educational Development (ANDROID), Collaborative Action towards Disaster Resilience Education (CADRE) and Collaborative Reformation of Curricula on Resilience Management with Intelligent Systems in Open Source and Augmented Reality (RESINT). The main topic of the above mentioned projects is resilience management and its application worldwide.

ANDROID is an academic network that aims to promote cooperation and innovation among European Higher Education Institutes to increase society's resilience to disasters of human and natural origin. The network aims to create a European approach that will help to understand the attributes that enable physical, socio-cultural, politico-economic and natural systems to adapt, by resistance or changing in order to reach and maintain an acceptable level of functioning.

The main goal of the project RESINT is to contribute to the reform and implementing of curricula in resilience management with the collaboration of not academic partners through the elaboration and offer in an open source platform, of a model that comprehensively reflects best practices from business companies, non-governmental organizations and government in managing operational resilience across the disciplines of business continuity management, security management, post catastrophe practices and IT operations management.

CADRE project was developed to address current and emerging labour market demands in the construction industry to increase societal resilience to disasters through identifying market needs across a range of stakeholders, developing a framework for ICU integration and a professional doctorate programme based on a clear demand and involvement from industry and communities, developing industry and community informed open educational resources for disaster resilience education and raising awareness and promoting a common understanding among stakeholders of the importance of disaster resilience education and the essential role of European higher education institutes in improving society's ability to withstand the threat posed by hazards.

2.3. Methods of Multiple Criteria Analysis

2.3.1. A Method of Complex Determination of the Weights of the Criteria Taking into Account their Quantitative and Qualitative Characteristics

When performing multiple criteria assessment of resilience management projects it is necessary to normalize the values of criteria describing the alternatives and then to weight them. This creates a possibility to compare the values of criteria with different measuring units and to determine the most efficient alternatives. The weighting of criteria is performed by the multiplication of their normalized values and their weights. Therefore, the weights of all criteria must be coordinated among themselves, taking into consideration their quantitative and qualitative characteristics. The weights of quantitative criteria can be exactly coordinated among themselves if the values of quantitative criteria are expressed through an equivalent monetary unit (stages 1–4). Having performed strict mutual coordination of quantitative criteria weights, the same is done with the weights of qualitative criteria (stages 5–7). In this case all the weights of qualitative and quantitative criteria are coordinated exactly at the same time.

Having determined the system of criteria describing the alternatives and calculated numerical values and initial weights of criteria and having presented them in the form of grouped decision making matrix, the user should calculate the actual weights of criteria. The values of criteria must be calculated for the whole project. The calculation of the criteria weights is carried out in seven stages. In the stages 1–4 the weights of quantitative criteria are identified whereas in the stages 5–7 the weights of qualitative criteria are identified.

Stage 1. The determination of the sum of values for every quantitative criterion:

$$S_i = \sum_{j=1}^{n} x_{ij}, \ i = \overline{1,t}; j = \overline{1,n}, \tag{2.1}$$

where x_{ij} – the value of the i-th criterion in the j-th alternative of a solution; t – the number of quantitative criteria; n – the number of the alternatives compared.

Stage 2. The total monetary expression of every quantitative criterion describing the investigated project is obtained by:

$$P_i = S_i \cdot p_i, i = \overline{1,t}, \tag{2.2}$$

where p_i – initial weight of the i criteria. p_i should be measured in such a way as, being multiplied by a quantitative criterion value, an equivalent monetary expression could be obtained.

According to their effect on the efficiency of the project in time the quantitative criteria may be divided into:

- short-term factors affecting the project for a certain period of time only;
- long-term factors affecting the project throughout its life cycle.

The initial weight of long-term criteria, like resources needed for the resilience disaster, environment protection, etc. is dependent on the re-payment time of the resilience management projects as well as on the evaluation in money terms of a measure unit of a criterion:

$$p_i = e \cdot f_i, \tag{2.3}$$

where e – repayment time of a project; f_i – monetary evaluation of a measure unit of the i criterion.

The initial weight of a single criteria comprising evaluation of duration and costs of reconstruction, etc. equals the measure unit of a criterion in money terms:

$$p_i = f_i. \tag{2.4}$$

The physical meaning of the initial weight of a quantitative criterion consists in the fact that multiplying it by the value of a quantitative criterion its monetary expression calculated over the whole period of repayment of the project (equivalent to former natural expression) is obtained.

Stage 3. The overall quantitative criteria magnitude sum expressed in money terms is determined:

$$V = \sum_{i=1}^{t} P_i, i = \overline{1,t}. \quad (2.5)$$

Stage 4. The quantitative criteria weights describing the project which can be expressed in money terms are determined as follows:

$$q_i = \frac{P_i}{V}, i = \overline{1,t}. \quad (2.6)$$

If the above method is applied in calculation of weights, the total sum of weights quantitative criteria is always equal to 1:

$$\sum_{i=1}^{t} q_i = 1. \quad (2.7)$$

This allows us to check if the quantitative criteria weights are calculated correctly.

The qualitative criteria weights pertaining to the built environment resilience management life cycle are determined in stages 5–7.

Stage 5. In order to achieve full coordination between the weights of quantitative and qualitative criteria, a compared standard value (*E*) is set. It is equal to the sum of any selected weights of quantitative criteria. One of the main requirements for this compared standard value is that according to utility it should be easily comparable with all qualitative criteria. This compared standard value, for instance, could be:

- reconstruction costs;
- reconstruction duration, etc.

In this case, the weights of all qualitative criteria are determined by the comparison of their utility with the significance of the compared standard value. E is determined according to the following formula:

$$E = \sum_{z=1}^{g} q_z, \quad (2.8)$$

where g is the number of quantitative criteria included into the compared standard; q_z is the weight of z quantitative criterion included into the compared standard.

Stage 6. The initial weights v_i of qualitative criteria are determined by expert methods comparing their relative significance to the significance E of the selected compared standard. In this case, relative weights of qualitative criteria should be expressed in per cent. For instance, if the expert methods revealed that the a reconstruction duration made up 6.2% of the utility of the compared standard (for example, of the cost of a reconstruction costs), the weight of the sound insulation properties $v = 6.2\%$.

Stage 7. The weights of qualitative criteria are determined as follows:

$$q_i = \frac{v_i \cdot E}{100}, i = t + 1, \cdots, m. \quad (2.9)$$

The above method allows to determine weights of criteria which are maximally interrelated and depend on qualitative and quantitative characteristics of all criteria.

2.3.2. A Method of Multiple Criteria Complex Proportional Evaluation of the Resilience Management Projects

It has been already mentioned that mitigation, preparedness, response and recovery make up one entity. However, the improvement (worsening) of separate processes (solutions) of resilience management life cycle changes the rationality of the remaining processes (solutions) and the satisfaction level of goals pursued by stakeholders. It is necessary, therefore, to accurately evaluate and calculate the influence exerted on the end result of the assessment by all such changes.

This method assumes direct and proportional dependence of significance and priority of investigated versions on a system of criteria adequately describing the alternatives and on values and weights of the criteria. The system of criteria is determined and the values and initial weights of criteria are calculated by experts. All this information can be corrected by stakeholders taking into consideration their pursued goals and existing capabilities. Hence, the assessment results of alternatives fully reflect the initial data jointly submitted by experts and stakeholders.

The determination of significance and priority of alternatives is carried out in four stages.

Stage 1. The weighted normalized decision making matrix D is formed. The purpose of this stage is to receive dimensionless weighted values from the comparative indexes. When the dimensionless values of the indexes are known, all criteria, originally having different dimensions, can be compared. The following formula is used for this purpose:

$$d_{ij} = \frac{x_{ij} \cdot q_i}{\sum_{j=1}^{n} x_{ij}}, i = \overline{1,m}; j = \overline{1,n}. \tag{2.10}$$

where x_{ij} – the value of the i-th criterion in the j-th alternative of a solution; m – the number of criteria; n – the number of the alternatives compared; q_i – weight of i-th criterion.

The sum of dimensionless weighted index values d_{ij} of each criterion x_i is always equal to the weight q_i of this criterion:

$$q_i = \sum_{j=1}^{n} d_{ij}, i = \overline{1,m}; j = \overline{1,n}. \tag{2.11}$$

In other words, the value of weight q_i of the investigated criterion is proportionally distributed among all alternative versions a_j according to their values x_{ij}.

Table 2.1. Built Environment Resilience Management Life Cycle Multiple Criteria Analysis Results

Quantitative information pertinent to resilience management projects									
Criteria describing the built environment resilience life cycle	*	Weight	Measuring units	Compared resilience management projects					
				a_1	a_2	…	a_j	…	a_n
X_1	z_1	q_1	m_1	d_{11}	d_{12}	…	d_{1j}	…	d_{1n}
X_2	z_2	q_2	m_2	d_{21}	d_{22}	…	d_{2j}	…	d_{2n}
X_3	z_3	q_3	m_3	d_{31}	d_{32}	…	d_{3j}	…	d_{3n}
…	...	...	...	...	...	…	...	…	...
X_i	z_i	q_i	m_i	d_{i1}	d_{i2}	…	d_{ij}	…	d_{in}
…	...	...	...	...	...	…	...	…	...
X_m	z_m	q_m	m_m	d_{m1}	d_{m2}	…	d_{mj}	…	d_{mn}
The sums of weighted normalized maximizing (resilience management projects 'pluses') indices of the project				S_{+1}	S_{+2}	…	S_{+j}	…	S_{+n}
The sums of weighted normalized minimizing (resilience management projects “minuses”) indices of the project				S_{-1}	S_{-2}	…	S_{-j}	…	S_{-n}
Significance of the project				Q_1	Q_2	…	Q_j	…	Q_n
Priority of the project				P_1	P_2	…	P_j	…	P_n
Utility degree of the project (%)				N_1	N_2	…	N_j	…	N_n

∗ The sign z_i (+ (–)) indicates that a greater (less) criterion value corresponds to a greater significance for a client

Stage 2. The sums of weighted normalized indexes describing the j-th version are calculated. The versions are described by minimizing indexes S_{-j} and maximizing indexes S_{+j}. The lower value of minimizing indexes is better (costs of reconstruction, etc.). The greater value of maximizing indexes is better. The sums are calculated according to the formula:

$$S_{+j} = \sum_{i=1}^{m} d_{+ij};\ S_{-j} = \sum_{i=1}^{m} d_{-ij}\,, i = \overline{1,m}; j = \overline{1,n}. \tag{2.12}$$

In this case, the values S_{+j} (the greater is this value (alternative ‘pluses’), the more satisfied are the stakeholders) and S_{-j} (the lower is this value (alternative ‘minuses’), the better is goal attainment by the stakeholders) express the degree of goals attained by the stakeholders in each alternative. In any case the sums of ‘pluses’ S_{+j} and ‘minuses’ S_{-j} of all alternative resilience management projects are always respectively equal to all sums of weights of maximizing and minimizing criteria:

$$S_{+} = \sum_{j=1}^{n} S_{+j} = \sum_{i=1}^{m} \sum_{j=1}^{n} d_{+ij}\,; S_{-} = \sum_{j=1}^{n} S_{-j} = \sum_{i=1}^{m} \sum_{j=1}^{n} d_{-ij},\ i = \overline{1,m}; j = \overline{1,n}. \quad (2.13)$$

In this way, the calculations made may be additionally checked.

Stage 3. The significance (efficiency) of comparative versions is determined on the basis of describing positive resilience management projects ("pluses") and negative resilience management projects ("minuses") characteristics. Relative significance Q_j of each project a_j is found according to the formula:

$$Q_j = S_{+j} + \frac{S_{-min} \cdot \sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{S_{-min}}{S_{-j}}}, j = \overline{1,n}. \quad (2.14)$$

Stage 4. Priority determination of resilience management projects. The greater is the Q_j the higher is the efficiency (priority) of the project.

The analysis of the method (Table 2.1) presented makes it possible to state that it may be easily applied to evaluating the resilience management projects and selecting most efficient of them, being fully aware of a physical meaning of the process. Moreover, it allowed to formulate a reduced criterion Q_j which is directly proportional to the relative effect of the compared criteria values x_{ij} and weights q_i on the end result.

2.3.3. A Method of Defining the Utility and Market Value of an Alternative

Significance Q_j of alternative a_j indicates satisfaction degree of demands and goals pursued by the stakeholders – the greater is the Q_j the higher is the efficiency of the alternative. In this case, the significance Q_{max} of the most rational alternative will always be the highest. The significances of all remaining alternatives are lower as compared with the most rational one. This means that total demands and goals of stakeholders will be satisfied to a smaller extent than it would be in case of the best alternative.

The degree of alternative utility is directly associated with quantitative and conceptual information related to it. With the increase (decrease) of the significance of an alternative analysed, its degree of utility also increases (decreases). The degree of alternative utility is determined by comparing the alternative analysed with the most efficient alternative. In this case, all the utility degree values related to the alternative analysed will be ranged from 0% to 100%. This will facilitate visual assessment of alternative efficiency.

The degrees of utility of the alternative considered as well as the market value of an alternative being valuated are determined in seven stages.

Stage 1. The formula used for the calculation of alternative a_j utility degree N_j is given below:

$$N_j = \left(Q_j : Q_{max}\right) \cdot 100\%, \qquad (2.15)$$

here Q_j and Q_{max} are the significances of the alternative obtained from the Equation 2.14.

The degree of utility N_j of alternative a_j indicates the level of satisfying the needs of the parties interested in the alternative. The more goals are achieved and the more important they are, the higher is the degree of the alternative utility. Since clients are mostly interested in how much more efficient particular alternative are than the others (which ones can better satisfy their needs), then it is more advisable to use the concept of alternative utility rather than significance when choosing the most efficient solution.

A degree of alternative utility reflects the extent to which the goals pursued by the stakeholders are attained. Therefore, it may be used as a basis for determining alternative market value. The more objectives are attained and the more significant they are the higher will be alternative degree of utility and its market value.

Thus, having determined in such a way the ratio of degree of utility and market value of alternative, one can see what complex effect can be obtained by investing money into anyone of the alternative. There is a complete clarity where it pays better to invest the money and what is the efficiency degree of the investment.

Table 2.2. Calculation of Average Deviations of the Alternatived Utility Degrees

Alternative considered	Utility degree deviation of an alternative analysed compared to other alternative, %					Average deviation k_j of utility degree N_j of alternative a_j compared to other (n-1) alternative, %
	a_1	a_2	a_3	a_i	a_n	
a_1	0	E_{12}	E_{13}	…	E_{1n}	k_1
a_2	E_{21}	0 E_{32}	E_{23}	…	E_{2n}	k_2
a_3	E_{31}	…	0	…	E_{3n}	k_3
…	…	E_{j2}	…	…	…	…
a_j	E_{j1}	…	E_{j3}	…	E_{jn}	k_j
…	…	E_{n2}	…	…	…	…
a_n	E_{n1}		E_{n3}	…	0	k_n

Stage 2. The efficiency degree E_{ji} of money invested into alternative a_j is calculated. It shows by how many percent it is better (worse) to invest money into alternative a_j compared with alternative a_i. E_{ji} is obtained by comparing the degrees of utility of the alternative considered:

$$E_{ji} = N_j - N_i. \qquad (2.16)$$

The received results are presented as a matrix clearly showing utility differences of the alternative (see Table 2.2).

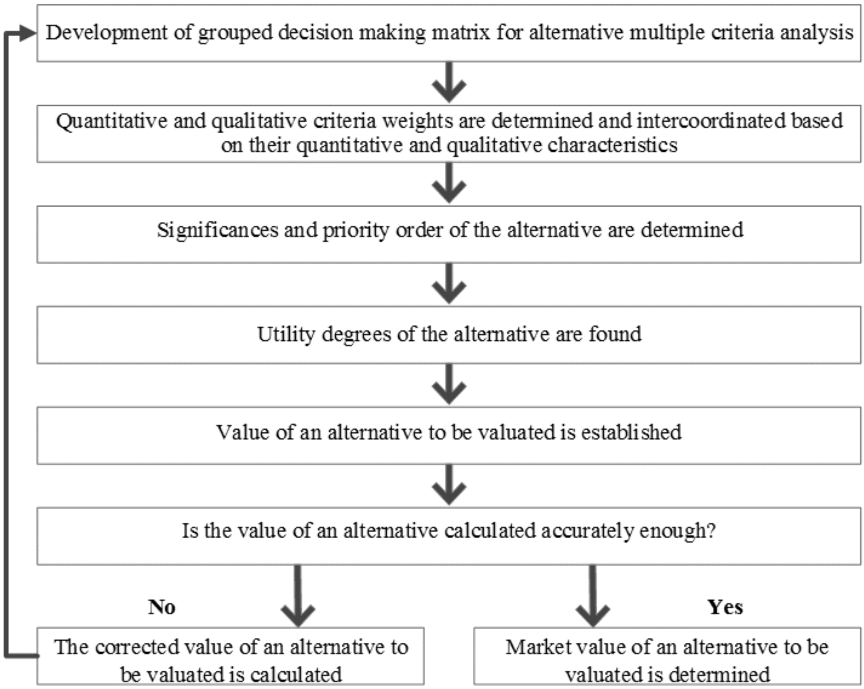


Fig. 2.5. Block-Diagram of Alternative Market Value Estimation

Stage 3. The average deviation k_j of the utility degree N_j of the alternative a_j from the same index of other alternative (n–1) is being calculated.

$$k_j = \sum_{i=1}^{n} E_{ji} : (n-1). \qquad (2.17)$$

Stage 4. The development of a grouped decision making matrix for alternatives multiple criteria analysis. The market value of an alternative being valuated is calculated according to a block-diagram presented in Figure 2.5.

At the beginning, a grouped decision making matrix for alternatives multiple criteria analysis is applied (see Table 2.3), the first criterion of which is based on the actual costs of the alternatives compared and the value of an alternative being valuated. The initial value of an alternative being valuated is obtained from the following equation:

$$x_{11} = \sum_{j=2}^{n} x_{1j} : (n-1). \qquad (2.18)$$

Table 2.3. A Grouped Decision Making Matrix for Alternatives Multiple Criteria Analysis

Criteria describing the compared alternatives	*	Weight	Measu-ring units	Alternative to be valuated and comparison standard alternatives					
				a_1	a_2	…	a_j	…	a_n
1. Price of an alternative a_1 being valuated and actual costs of comparison standard alternatives (a_2 -a_n)	z_1	q_1	m_1	x_{11}	x_{12}	…	x_{1j}	…	x_{1n}
	z_2	q_2	m_2	x_{21}	x_{22}	…	x_{2j}	…	x_{2n}
	…	…	…	…	…	…	…	…	…
Quantitative criteria	z_i	q_i	m_i	x_{i1}	x_{i2}	…	x_{ij}	…	x_{in}
	…	…	…	…	…	…	…	…	…
	z_t	q_t	m_t	x_{t1}	x_{t2}	…	x_{tj}	…	x_{tn}
	z_{t+1}	q_{t+1}	m_{t+1}	$x_{t+1\,1}$	$x_{t+1\,2}$	…	$x_{t+1\,j}$	…	$x_{t+1\,n}$
Qualitative criteria	z_{t+2}	q_{t+2}	m_{t+2}	$x_{t+2\,1}$	$x_{t+2\,2}$	…	$x_{t+2\,j}$	…	$x_{t+2\,n}$
	…	…	…	…	…	…	…	…	…
	z_i	q_i	m_i	x_{i1}	x_{i2}	…	x_{ij}	…	x_{in}
	…	…	…	…	…	…	…	…	…
	z_m	q_m	m_m	x_{m1}	x_{m2}	…	x_{mj}	…	x_{mn}

∗ The sign z_i (+ (–)) indicates that a greater (less) criterion value corresponds to a greater significance for a client

In this matrix, an alternative a_1 to be valuated should be assigned the market value ($x_{11\text{-}R}$). Other comparison standard alternatives (a_2-a_n) were executed, their costs (x_{12}-x_{1n}) known. All the values and weights of the criteria relating to other alternatives are also known (see Table 2.3).

The problem may be stated as follows: what market value $x_{11\text{-}R}$ of a valuated alternative a_1 will make it equally competitive on the market with comparison standard alternatives (a_2-a_n)? This may be determined if a complex analysis of the benefits and drawbacks of the alternative is made.

Using a grouped decision making matrix and the equations 2.1–2.18 the calculations are made.

Stage 5. The corrected value $x_{11\text{-}p}$ of an alternative to be valuated a_1 is calculated:

$$x_{11-p} = x_{11} \cdot (1 + k_1 : 100). \tag{2.19}$$

Stage 6. It is determined whether the corrected value $x_{11\text{-}R}$ of an alternative being valuated a1 had been calculated accurately enough:

$$|k_1| < s, \tag{2.20}$$

where s is the accuracy, %, to be achieved in calculating the market value $x_{11\text{-}p}$ of an alternative a_1. For example, given s = 0,5%, the number of approximations in calculation will be lower than at s = 0,1%.

Stage 7. The market value $x_{11\text{-}R}$ of an alternative a_1 to be valuated is determined. If inequality 2.20 is satisfied the market value of an alternative a_1 may be found as follows:

$$x_{11-R} = x_{11-p}. \tag{2.21}$$

If inequality 2.20 is not satisfied this means that the value of an alternative being valuated had not been calculated accurately enough and the approximation cycle should be repeated. In this case, the corrected value x_{11}=$x_{11\text{-}p}$ of an alternative being valuated is substituted into a grouped decision making matrix of alternatives multiple criteria analysis and the calculations according to the formula 2.1-2.21 should be repeated until the inequation 2.20 is satisfied.

Solving the problem of determining the market value $x_{11\text{-}R}$ of an alternative a_1 being valuated, which would make it equally competitive on the market compared with the alternatives (a_2 - a_n) already executed, a particular method of defining the utility degree and market value of an alternative was applied. This was based on a complex analysis of all the benefits and drawbacks of the alternatives considered.

According to this method the utility degree and the market value of an alternative being estimated are directly proportional to the system of the criteria adequately describing them and the values and weights of these criteria.

2.3.4. A Method of Multiple Criteria Multivariant Design of a Human Resource Management in Emergency Situations

A lot of data had to be processed and evaluated in carrying out multivariant design of a human resource management in emergency situations. The number of feasible alternatives can be as large as 100,000. Each of the alternatives may be described from various perspectives, e.g. by conceptual and quantitative information. The problem arises how to perform computer-aided design of the alternative variants based on this enormous amount of information. To solve this problem a method of multiple criteria multivariant design of a human resource management in emergency situations was applied. According to the above method multiple criteria multivariant design is carried out in 5 stages (Fig. 2.6) which are briefly described below.

In order to reduce the amount of information being used in computer-aided multivariant design the codes of the alternative solutions are used. In this case, any i solution of j alternative is given a_{ij} code providing thorough quantitative (system of criteria, units of measure, weights, values, as well as a minimizing or maximizing criterion) and conceptual (text, drawings, graphics, video, augmented reality) information about the alternative being considered (see Table 2.4). Thus, the use of codes of the alternative solutions in computer-aided multivariant design reduces the volume of information to be processed providing better insight into a physical meaning of computations.

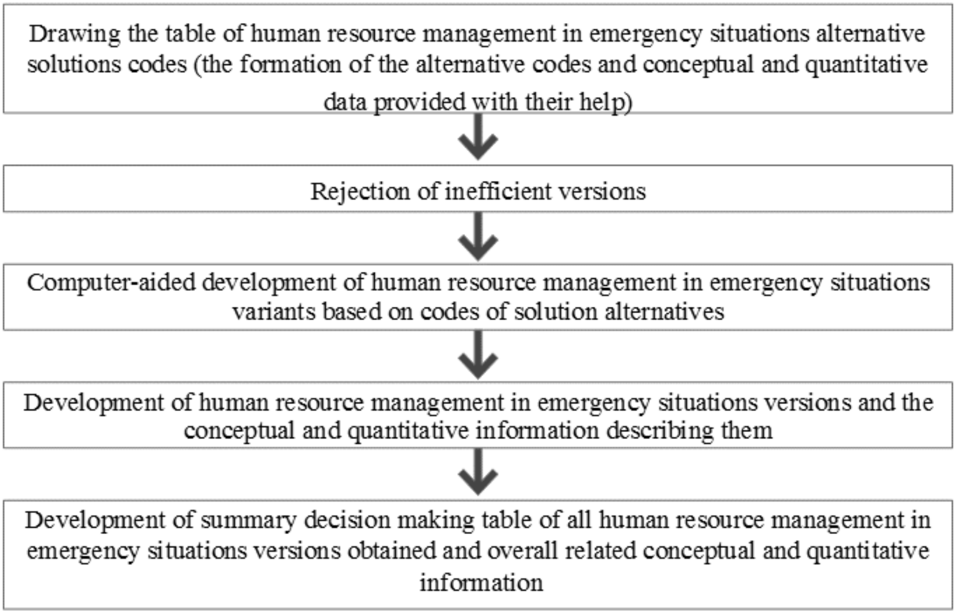


Fig. 2.6. Main Stages of Multiple Criteria Multivariant Design of a Human Resource Management in Emergency Situations

Codes, with conceptual and quantitative information provided, are used for describing all available alternative solutions. The total number of these codes makes the table of codes of human resource management in emergency situations alternatives allowing to get the alternative versions in a more simple way (see Table 2.4). As can be seen from Table 2.4, it contains *c* solutions of a built environment resilience management life cycle (mitigation, preparedness, response, recovery) of the n_i alternative versions codes. Any *i* line of the code table represents the codes of A_i solution a_{ij} alternatives. If the information relating to the solutions in the code table of human resource management in emergency situations alternatives is represented by codes, then the code contains quantitative and conceptual information (see Table 2.4). In this case, n_i alternatives of any *i* solution are being considered in developing the alternative versions of a human resource management in emergency situations.

Table 2.4. Codes of Human Resource Management in Emergency Situations Alternative Solutions with Conceptual and Quantitative Information

Solutions considered	The codes of the alternative solutions considered						
	1	2	3	...	j	...	n_i
1. Mitigation variants	a_{11}	a_{12}	a_{13}	...	a_{1j}	...	$a_{1\,n1}$
2. Preparedness variants	a_{21}	a_{22}	a_{23}	...	a_{2j}	...	$a_{2\,n2}$
...	...	...	...	...	...	...	...
i. Response variants	a_{i1}	a_{i2}	a_{i3}	…	$\mathbf{a_{ij}}$	…	$a_{i\,ni}$
...	...	...	...	...	...	...	...
c. Recovery variants	a_{c1}	a_{c2}	a_{c3}	...	a_{cj}	...	$a_{c\,nc}$

The information provided by code a_{ij} of *i* solution *j* alternative

Conceptual information (text, drawings, graphics, augmented reality)	Quantitative information						
	Recovery costs, X_1	Risk, X_2	Stress, X_3	…	X_j	…	Facilities management costs, X_n
K_{ij}	$x_{ij\,1}$	$x_{ij\,2}$	$x_{ij\,3}$	…	$x_{ij\,j}$	…	$x_{ij\,n}$
Units of measure	Lt	Points	Points	…	…	…	Points
Weight	$q_{i\,1}$	$q_{i\,2}$	$q_{i\,3}$	…	$q_{i\,j}$	…	$q_{i\,n}$

∗ Signs z_{ij} (+ (–)) mean, that corresponding higher (lower) value of the criterion better satisfies the client's needs

Thus, the maximum number of the resilience management projects obtained may be computed as follows:

$$k = \prod_{i=1}^{c} n_i, \tag{2.22}$$

where c is the number of solutions considered in determining a human resource management in emergency situations versions; n_i – is the number of i solution alternatives to be used in developing a built environment resilience management life cycle.

Table 2.5. Most Efficient Solution Alternatives Set according their Priorities

Solutions considered	Priority of the best alternative solutions						
	1	2	3	...	j	...	p
1. Mitigation variants	a_{11}	a_{12}	a_{13}	...	a_{1j}	...	a_{1p}
2. Preparedness variants	a_{21}	a_{22}	a_{23}	...	a_{2j}	...	a_{2p}
...	...	...	...	...	...	...	...
i. Response variants	a_{i1}	a_{i2}	a_{i3}	…	a_{ij}	…	a_{ip}
...	...	...	...	...	...	...	...
c. Recovery variants	a_{c1}	a_{c2}	a_{c3}	...	a_{cj}	...	a_{cp}

For example, if in determining possible human resource management in emergency situations alternative versions 10 alternatives are considered for any of 10 solutions, then, according to Equation 2.22 maximum ten billion such variants will be obtained. It is evident that in this and similar cases it is hardly possible and reasonable to analyze all the versions from various perspectives. Therefore, it is advisable to reduce their number as follows. If a project of c solutions having n_i alternatives allows k combinations (Equation 2.22) then, by using multiple criteria analysis methods, p most efficient versions should be chosen from every solution for further consideration (see Table 2.5). In this way, inefficient variants are being removed. The best solutions alternatives obtained are then grouped according to priority considerations. In Table 2.5 a_{i1} is a code of the best variant of i solution, while a_{ip} is a code of its worst version.

Table 2.6. Computer-Aided Development of Human Resource Management in Emergency Situations Variants Based on Codes of Solution Alternatives

Solutions considered	Development of human resource management in emergency situations variants based on codes of solution alternatives											
	1	2	3	...	p	p+1	p+2	p+3	...	2p	...	K
1. Mitigation variants	a_{11}	a_{11}	a_{11}	...	a_{11}	a_{11}	a_{11}	a_{11}	...	a_{11}	...	a_{1p}
2. Preparedness variants	a_{21}	a_{21}	a_{21}	...	a_{21}	a_{21}	a_{21}	a_{21}	...	a_{21}	...	a_{2p}
…	...	...	...	...	...	...	...	...	...	...	...	...
i. Response variants	a_{i1}	a_{i1}	a_{i1}	...	a_{i1}	a_{i1}	a_{i1}	a_{i1}	...	a_{i1}	...	a_{ip}
…	...	...	...	...	...	...	...	...	...	...	...	...
c-1	$a_{c-1\ 1}$	$a_{c-1\ 1}$	$a_{c-1\ 1}$	...	$a_{c-1\ 1}$	$a_{c-1\ 2}$	$a_{c-1\ 2}$	$a_{c-1\ 2}$	...	$a_{c-1\ 2}$	...	$a_{c-1\ p}$
c. Recovery variants	a_{c1}	a_{c2}	a_{c3}	...	a_{cp}	a_{c1}	a_{c2}	a_{c3}	...	a_{cp}	...	$a_{c\ p}$

Then, project variants are being applied based on the efficient p alternatives of c solutions chosen. At the beginning, this process should involve the codes of the alternative solutions. The first built environment resilience management life cycle variant is obtained by analysing the best solution variants according to the priority order (see Tables 2.5, 2.6). The last variant is based on solution versions from the bottom of priority table, while intermediate variants are obtained with account of the versions found in the middle of this table. For example, the first built environment resilience management life cycle version is based on a_{11} mitigation, a_{21} preparedness, a_{i1} response, a_{c1} disaster, etc. variants. The last built environment resilience management life cycle version takes into account a_{1p} preparedness, a_{2p} built environment resilience management, a_{ip} response, a_{cp} recovery, etc. variants. In this case, combinations are obtained by using p alternatives from any c solutions.

Table 2.7. Development of Human Resource Management in Emergency Situations Variants and Related Conceptual and Quantitative Information

Information related to human resource management in emergency situations versions								
Solutions used in developing human resource management in emergency situations variants	Conceptual	Quantitative						
		Recovery costs, $\mathbf{X_1}$ (Lt)	Risk, $\mathbf{X_2}$ (Points)	Stress, $\mathbf{X_3}$ (Points)	…	$\mathbf{X_j}$	…	Facilities management costs, $\mathbf{X_n}$ (Points)
Information related to life cycle of 1-st built environment resilience management								
1. Mitigation, $\mathbf{a_{11}}$	$\mathbf{K_{11}}$	$\mathbf{x_{11\,1}}$	$\mathbf{x_{11\,2}}$	$\mathbf{x_{11\,3}}$	…	$\mathbf{x_{11\,j}}$	…	$\mathbf{x_{11\,n}}$
2. Preparedness variants, $\mathbf{a_{21}}$	$\mathbf{K_{21}}$	$\mathbf{x_{21\,1}}$	$\mathbf{x_{21\,2}}$	$\mathbf{x_{21\,3}}$	…	$\mathbf{x_{21\,j}}$	…	$\mathbf{x_{21\,n}}$
…		…	…	…	…	…	…	…
i. Response, $\mathbf{a_{i1}}$	$\mathbf{K_{i1}}$	$\mathbf{x_{i1\,1}}$	$\mathbf{x_{i1\,2}}$	$\mathbf{x_{i1\,3}}$	…	$\mathbf{x_{i1\,j}}$	…	$\mathbf{x_{i1\,n}}$
…		…	…	…	…	…	…	…
c. Disaster, $\mathbf{A_{c1}}$	$\mathbf{K_{c1}}$	$\mathbf{x_{c1\,1}}$	$\mathbf{x_{c1\,2}}$	$\mathbf{x_{c1\,3}}$	…	$\mathbf{x_{c1\,j}}$	…	$\mathbf{x_{c1\,n}}$
Information related to life cycle of 2-nd built environment resilience management								
1. Mitigation, $\mathbf{a_{11}}$	$\mathbf{K_{11}}$	$\mathbf{x_{11\,1}}$	$\mathbf{x_{11\,2}}$	$\mathbf{x_{11\,3}}$	…	$\mathbf{x_{11\,j}}$	…	$\mathbf{x_{11\,n}}$
2. Preparedness variants, $\mathbf{a_{21}}$	$\mathbf{K_{21}}$	$\mathbf{x_{21\,1}}$	$\mathbf{x_{21\,2}}$	$\mathbf{x_{21\,3}}$	…	$\mathbf{x_{21\,j}}$	…	$\mathbf{x_{21\,n}}$
…		…	…	…	…	…	…	…
i. Response, $\mathbf{a_{i1}}$	$\mathbf{K_{i1}}$	$\mathbf{x_{i1\,1}}$	$\mathbf{x_{i1\,2}}$	$\mathbf{x_{i1\,3}}$	…	$\mathbf{x_{i1\,j}}$	…	$\mathbf{x_{i1\,n}}$
…		…	…	…	…	…	…	…
c. Disaster, $\mathbf{a_{c2}}$	$\mathbf{K_{c2}}$	$\mathbf{x_{c2\,1}}$	$\mathbf{x_{c2\,2}}$	$\mathbf{x_{c2\,3}}$	…	$\mathbf{x_{c2\,j}}$	…	$\mathbf{x_{c2\,n}}$
…	…	**…**	**…**	**…**	.	**…**	.	**…**
Information related to life cycle of p-th built environment resilience management								

End of the Table 2.7

1. Mitigation, **a_{11}**	**K_{11}**	**$x_{11\,1}$**	**$x_{11\,2}$**	**$x_{11\,3}$**	…	**$x_{11\,j}$**	…	**$x_{11\,n}$**
2. Preparedness variants, **a_{21}**	**K_{21}**	**$x_{21\,1}$**	**$x_{21\,2}$**	**$x_{21\,3}$**	…	**$x_{21\,j}$**	…	**$x_{21\,n}$**
…		…	…	…	…	…	…	…
i. Response, **a_{i1}**	**K_{i1}**	**$x_{i1\,1}$**	**$x_{i1\,2}$**	**$x_{i1\,3}$**	…	**$x_{i1\,j}$**	…	**$x_{i1\,n}$**
…		…	…	…	…	…	…	…
c. Disaster, **a_{cp}**	**K_{cp}**	**$x_{cp\,1}$**	**$x_{cp\,2}$**	**$x_{cp\,3}$**	…	**$x_{cp\,j}$**	…	**$x_{cp\,n}$**
…	…	**…**	**…**	**…**	.	**…**	.	**…**
Information related to life cycle of the last (K) built environment resilience management								
1. Preparedness, **a_{1p}**	**K_{1p}**	**$x_{1p\,1}$**	**$x_{1p\,2}$**	**$x_{1p\,3}$**	…	**$x_{1p\,j}$**	…	**$x_{1p\,n}$**
2. Preparedness variants, **a_{2p}**	**K_{2p}**	**$x_{2p\,1}$**	**$x_{2p\,2}$**	**$x_{2p\,3}$**	…	**$x_{2p\,j}$**	…	**$x_{2p\,n}$**
…		…	…	…	…	…	…	…
i. Response, **a_{ip}**	**K_{ip}**	**$x_{ip\,1}$**	**$x_{ip\,2}$**	**$x_{ip\,3}$**	…	**$x_{ip\,j}$**	…	**$x_{ip\,n}$**
…		…	…	…	…	…	…	…
c. Disaster, **a_{cp}**	**K_{cp}**	**$x_{cp\,1}$**	**$x_{cp\,2}$**	**$x_{cp\,3}$**	…	**$x_{cp\,j}$**	…	**$x_{cp\,n}$**

Table 2.8. Summary Decision Making Table of all Built Environment Resilience Management Life Cycle Versions Obtained and Overall Related Conceptual and Quantitative Information

Information related to built environment resilience management life cycle versions								
Built environment resilience management life cycle (BLC) versions obtained	Conceptual	Quantitative						
		Recovery costs, **X_1**	Risk, **X_2**	Stress, **X_3**	…	**X_j**	…	Facilities management costs, **X_n**
1 BLC version	**K_1**	**x_{11}**	**x_{12}**	**x_{13}**	…	**x_{1j}**	…	**x_{1n}**
2 BLC version	**K_2**	**x_{21}**	**x_{22}**	**x_{23}**	…	**x_{2j}**	…	**x_{2n}**
3 BLC version	**K_3**	**x_{31}**	**x_{32}**	**x_{33}**	…	**x_{3j}**	…	**x_{3n}**
…		…	…	…	…	…	…	…
i BLC version	**K_i**	**x_{i1}**	**x_{i2}**	**x_{i3}**	…	**x_{ij}**	…	**x_{in}**
…		…	…	…	…	…	…	…
K BLC version	**K_K**	**x_{K1}**	**x_{K2}**	**x_{K3}**	…	**x_{Kj}**	…	**x_{Kn}**
Weights of criteria		q_1	q_2	q_3	…	q_j	…	q_n
Measuring units of criteria		Lt	Points	Points	…	…	…	Points

Therefore, the maximum number of the resilience management projects obtained may be determined from the following expression:

$$K = \prod_{i=1}^{c} p, \tag{2.23}$$

where c is the number of solutions used in determining a human resource management in emergency situations versions; p is the number of the best variants of every solution used in developing a human resource management in emergency situations.

While in Table 2.6 the development of human resource management in emergency situations alternatives was based on codes of solution alternatives, Table 2.7 presents conceptual and quantitative information about the variants instead of the codes. When a particular human resource management in emergency situations project is being considered the values relating to various solutions but based on the same criterion are recalculated into a single reduced value.

The reduction of the same criterion (e.g. cost, risk) values of various solutions (mitigation, preparedness, response, disaster) to a single one it is necessary to appraise significances of these solutions. The above significances of the solutions are determined by using expert, financial analysis and other methods. The significances should be made compatible in two directions: horizontally (among criteria) and vertically (among solutions). In this way, Table 2.7 may be transformed into a summary decision making table (see Table 2.8) containing all human resource management in emergency situations versions and overall related information.

2.4. Methods Used for Stress Recognition

Ordered logit model

In statistics, the ordered logit model (also ordered logistic regression or proportional odds model), is a regression model for ordinal dependent variables. For example, if one question on a survey is to be answered by a choice among "poor", "fair", "good", "very good", and "excellent", and the purpose of the analysis is to see how well that response can be predicted by the responses to other questions, some of which may be quantitative, then ordered logistic regression may be used. It can be thought of as an extension of the logistic regression model that applies to dichotomous dependent variables, allowing for more than two (ordered) response categories.

The model only applies to data that meet the *proportional odds assumption*, the meaning of which can be exemplified as follows. Suppose the proportions of members of the statistical population who would answer "poor", "fair", "good", "very good", and "excellent" are respectively p_1, p_2, p_3, p_4, p_5. Then the logarithms of the odds (not the logarithms of the probabilities) of answering in certain ways are:

$$\text{poor (0), } log\frac{p_1}{p_2+p_3+p_4+p_5}, \tag{2.24}$$

$$\text{poor or fair (1), } log\frac{p_1+p_2}{p_3+p_4+p_5}, \tag{2.25}$$

$$\text{poor, fair or good (2), } log\frac{p_1+p_2+p_3}{p_4+p_5}, \tag{2.26}$$

$$\text{poor, fair, good or very good (3), } log\frac{p_1+p_2+p_3+p_4}{p_5}, \tag{2.27}$$

The proportional odds assumption is that the number added to each of these logarithms to get the next is the same in every case. In other words, these logarithms form an arithmetic sequence (Institute for… 2014). The model states that the number in the last column of the table – the number of times that that logarithm must be added – is some linear combination of the other observed variables.

The coefficients in the linear combination cannot be consistently estimated using ordinary least squares. They are usually estimated using maximum likelihood. The maximum-likelihood estimates are computed by using iteratively reweighted least squares.

Examples of multiple ordered response categories include bond ratings, opinion surveys with responses ranging from “strongly agree” to “strongly disagree”, levels of state spending on government programs (high, medium, or low), the level of insurance coverage chosen (none, partial, or full), and employment status (not employed, employed part-time, or fully employed) (Greene 2003).

Suppose the underlying process to be characterized is:

$$y^* = x'\beta + \varepsilon, \tag{2.28}$$

where y^* is the exact but unobserved dependent variable (perhaps the exact level of agreement with the statement proposed by the pollster); x is the vector of independent variables, and β is the vector of regression coefficients which we wish to estimate. Further suppose that while we cannot observe y^*, we instead can only observe the categories of response:

$$y = \begin{cases} 0 \; if \; y^* \leq \mu_1; \\ 1 \; if \; \mu_1 < y^* \leq \mu_2; \\ 2 \; if \; \mu_2 < y^* \leq \mu_3; \\ \vdots \\ N \; if \; \mu_N > y^*. \end{cases} \tag{2.29}$$

Then the ordered logit technique will use the observations on y, which are a form of censored data on y^*, to fit the parameter vector β.

k-Nearest Neighbor Algorithm

k-Nearest Neighbor Algorithm (KNN) used two data sets:

- training data set (to learn the patterns);
- test data set (to verify the validity of learned patterns).

The training data set contained instances of heart rate, systolic and diastolic blood pressure, skin humidity and conductivity values and the corresponding stress level in the first case and the training data set contained instances of skin temperature (forehead, nose, left and right cheeks, chin, left hand palm, left hand finger temperatures) values and the corresponding user's postdisaster stress level in the second case. The test data set was similar to the training data set, except that it did not have the emotion information. In order to classify an instance of a test data into an emotion, KNN calculated the distance between the test data and each instance of the training data set. Let an arbitrary instance x be described by the feature vector $\langle a_1(x), a_2(x), \ldots, a_n(x)\rangle$, where $a_r(x)$ is the rth feature of instance x. The distance between instances x_i and x_j was defined as $d(x_i, x_j)$ where (Nasoz *et al.* 2010):

$$d(x_i, x_j) = \sqrt{\sum_{r=1}^{n}(a_r(x_i) - a_r(x_j))^2}. \quad (2.30)$$

The algorithm then found the k closest training instances to the test instance. The probabilities of the test instance belonging to each emotion group were calculated by dividing the number of instances from each emotion group by k: (Nasoz *et al.* 2010):

$$P(\#i) = \frac{\#\, of\ ins. from\ group\ i\ among\ k\ ins.}{k}. \quad (2.31)$$

$P(\#i)$ indicated the probability of the test instance belonging to group i. Then a random number in (0.1) was generated and the emotion group whose probability range covered this random number was mapped to the test data.

For example if k=5 and there were three (3) groups and if among the 5 closest instances 3 of them belonged to group 1, 1 of them belonged to group 2, and 1 of them belonged to group 3 then $P(\#1)=0.6$, $P(\#2)=0.2$, and $P(\#3)=0.2$. Accordingly, the first group's probability range was [0, 0.6), the second group's probability range was [0.6, 0.8), and the third group's probability range was [0.8, 1). If the randomly generated number was 0.5 then the first emotion group was mapped to the test instance, if it was 0.9 then the third group was mapped to the test instance.

KNN was chosen to be implemented to test the feasibility of performing pattern recognition on physiological signals that were associated with emotions.

Marquardt Backpropagation Algorithm

The third algorithm used was a derivation of a backpropagation algorithm with Marquardt–Levenberg modification called Marquardt Backpropagation (MBP). In this technique, first the Jacobian matrix, which contains first derivatives of the network errors with respect to the weights and biases, is computed. Then the gradient vector is computed as a product of the Jacobian matrix $J(x)$ and the vector of errors $e(x)$ and the Hessian approximation is computed as the product of the Jacobian matrix $J(x)$ and the transpose of the Jacobian matrix $J^T(x)$ (Hagan, Menhaj 1994).

Then the Marquardt–Levenberg Modification to the Gauss–Newton method is given by the following equation:

$$\Delta\underline{x} = [J^T(\underline{x})J(\underline{x}) + \mu I]^{-1} J^T(\underline{x})\underline{e}(\underline{x}). \qquad (2.32)$$

When μ is 0 or a small value, then this becomes the Gauss–Newton method that uses the Hessian approximation. When μ is a large value, then this equation is a gradient descent with a small step size (1/μ). The aim is to make μ converge to 0 as fast as possible, and this is achieved by decreasing μ when there is a decrease in the error function and increasing it when there is no decrease in the error function. And the algorithm converges when the gradient value reaches below a previously determined value (Hagan, Menhaj 1994). This algorithm was chosen to be implemented due to its fast converging nature.

Resilient Backpropagation Algorithm

Resilient Backpropagation Algorithm is a derivation of a backpropagation algorithm, where the magnitude of the derivative of the performance function has no effect on the weight update and only the sign of the derivative is used to determine the direction of the weight update. When the derivative of the performance function has the same sign for two consecutive iterations, the update value for each weight is increased and when the derivative of the performance function changes sign from the previous iteration, the update value is decreased. No change is made when the derivative is equal to 0.

Each weight and bias value X is adjusted according to the following formula (Nasoz 2004):

$$dX = \Delta X \cdot sign(gX), \qquad (2.33)$$

where the elements of ΔX are all initialized to the initial Δ and gX is the gradient value. The elements of ΔX are modified after each iteration. If gX has the same sign with the previous iteration then corresponding ΔX is incremented and if gX changes sign from the previous iteration, then the corresponding ΔX is decremented.

2.5. Conclusions of Chapter 2

1. An original model has been developed, which performs a complex analysis of a human resource management in emergency situations and enables a user to analyse a built environment's resilience management life cycle and its stages, the parties involved in the project as well as its micro, meso and macro environments as an integral entity.
2. Researchers considering multiple criteria analysis methods did not address the topic of possibly extending them to the research object defined by this author, i.e. a human resource management in emergency situations, the stakeholders involved in the project and micro, meso and macro environmental factors affecting it as an integral entity.
3. A method was applied for a complex determination of human resource management in emergency situations criteria weights while taking into account their quantitative and qualitative characteristics. This method allows calculating and coordinating the weights of the quantitative and qualitative criteria according to the above characteristics.
4. A method was adapted for a multiple criteria, complex, proportional evaluation of the human resource management in emergency situations enabling the user to obtain a reduced criterion determining the complex (overall) efficiency of the alternative versions. This generalized criterion is directly proportional to the relative effect of the values and weights of the criteria considered for the efficiency of the alternative versions.
5. A method was used to determine the utility degrees and market values of human resource management in emergency situations alternative versions based on a complex analysis of all their benefits and drawbacks to find, what price will make an alternative under evaluation competitive on the market. Accordingly the utility degree of such alternative versions and the market value of an alternative under evaluation are directly proportional to the system of the criteria adequately describing them and the values and weights of these criteria.
6. A method was applied of a multiple criteria, multivariant design of a human resource management in emergency situations enabling a user to make computer-aided designs of up to 100,000 alternative management versions. Any human resource management in emergency situations variant obtained in this way is based on quantitative and conceptual information.
7. Ordered logit model, *k*-Nearest Neighbour Algorithm, Marquardt Backpropagation Algorithm and Resilient Backpropagation Algorithm were applied to analyse physiological parameters dependencies on stress.

3

Intelligent Decision Support System for the Human Resource Management in Emergency Situations

The developed Intelligent Decision Support System for the Human Resource Management in Emergency Situations consists of four parts:

- Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management;
- Text Analytics for Human Resource Management in Emergency Situations in ANDROID Project;
- Recommender Thermometer for Measuring the Preparedness for Disasters;
- Subsystem of Integrated Virtual and Intelligent Technologies.

In this Chapter the above mentioned subsystems and their application are described in more detail.

On the thematic of this chapter 7 publications (Kaklauskas *et al.* 2011a, 2011b, 2013a, 2013b, 2014a, 2014b; Paliskiene, Peciure 2014) were published.

3.1. Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management

Based on the analysis of existing neural networks (Eisenbies *et al.* 2007; Kong-A-Siou *et al.* 2013; Liu *et al.* 2014a), early warning (Krzhizhanovskaya *et al.* 2011; Alfieri *et al.* 2012; Borga *et al.* 2014; Van Veen 2014), fuzzy (Royston *et al.* 2013) expert (Karnib *et al.* 2002; Kou *et al.* 2014) and decision support (Hubbard *et al.* 2014) systems, Impact of Event Scale (Shooshtary *et al.* 2008; Heir *et al.* 2010; Chen *et al.* 2011; Dancause *et al.* 2011; Keskinen-Rosenqvist *et al.* 2011; Arnberg *et al.* 2014, Kaklauskas 1999; Kaklauskas *et al.* 2010; 2011 etc.) and in order to determine most efficient tips of stress resilience a Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management consisting of an equipment subsystem, database, database management subsystem, model-base, model-base management subsystem and user interface was developed (see Figure 3.1). The Physiological Advisory Subsystem was developed and fine-tuned in the course of the ANDROID (Academic Network for Disaster Resilience to Optimise educational Development) project. ANDROID project is being carried out with the financial assistance of the European Union Life Long Learning programme, under the Erasmus networks action. ANDROID is concerned with what resilience is, what it means to society, and how society might achieve greater resilience in the face of increasing threats from natural and human induced hazards.

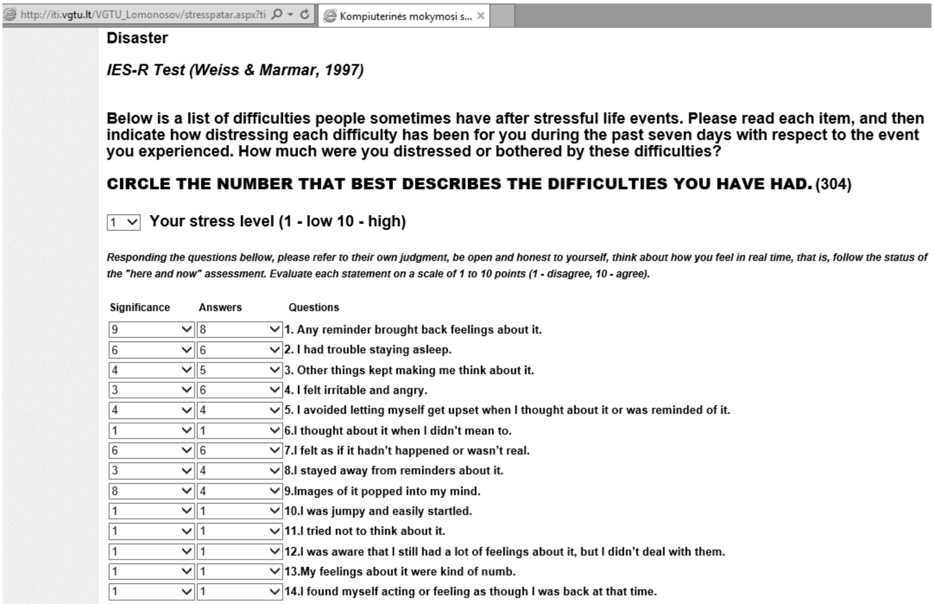
The presentation of information needed for decision making in Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management may be in conceptual (digital (numerical), textual, graphical (diagrams, graphs, drawing, etc.), augmented reality, photographical, sound, visual (video)) and quantitative forms. Thus, quantitative information presentation involves criteria systems and subsystems, units of measurement, values and initial weights fully defining the recommendations provided. Conceptual information means a conceptual description of the alternative tips, the criteria and ways of determining their values and weights, etc.

In this way, Physiological Advisory (PA) subsystem enables the decision maker to get various conceptual and quantitative information on user's post-disaster stress management from a database and a model-base allowing him to analyse the above factors and make an efficient solution.

PA subsystem has a relational database structure when the information is stored in the form of tables. These tables contain quantitative and conceptual information. Each table is given a name and is saved in the computer external memory as a separate file. Logically linked parts of the table make a relational model.

The following tables make PA subsystem database:

- initial data tables containing general facts about the user's post-disaster stress;
- physiological data tables (see Appendix A and Appendix B);
- tables assessing a user's post-disaster stress management solutions;
- tables assessing a user's post-disaster stress management tips;
- tables of multiple stress management solutions design;
- tables of multi-tips design;
- correlation tables between the user's posttraumatic stress and the parameters of the user's physiological parameters (heart rate, blood pressure, pupil, skin conductance and humidity; body, forehead, nose, left and right cheek, chin, left palm and left middle finger temperatures, etc.);
- user's physiological database (see Figure 3.2);
- recommendations tables.


http://iti.vgtu.lt/VGTU_Lomonosov/stresspatar.aspx?ti
Kompiuterinės mokymosi s...

Disaster

IES-R Test (Weiss & Marmar, 1997)

Below is a list of difficulties people sometimes have after stressful life events. Please read each item, and then indicate how distressing each difficulty has been for you during the past seven days with respect to the event you experienced. How much were you distressed or bothered by these difficulties?

CIRCLE THE NUMBER THAT BEST DESCRIBES THE DIFFICULTIES YOU HAVE HAD. (304)

1 **Your stress level (1 - low 10 - high)**

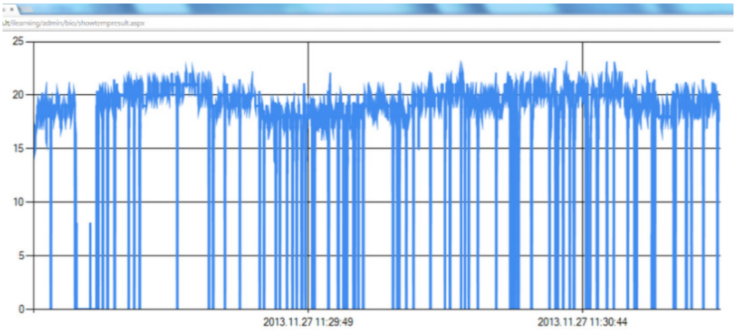
Responding the questions bellow, please refer to their own judgment, be open and honest to yourself, think about how you feel in real time, that is, follow the status of the "here and now" assessment. Evaluate each statement on a scale of 1 to 10 points (1 - disagree, 10 - agree).

Significance	Answers	Questions
9	8	1. Any reminder brought back feelings about it.
6	6	2. I had trouble staying asleep.
4	5	3. Other things kept making me think about it.
3	6	4. I felt irritable and angry.
4	4	5. I avoided letting myself get upset when I thought about it or was reminded of it.
1	1	6.I thought about it when I didn't mean to.
6	6	7.I felt as if it hadn't happened or wasn't real.
3	4	8.I stayed away from reminders about it.
8	4	9.Images of it popped into my mind.
1	1	10.I was jumpy and easily startled.
1	1	11.I tried not to think about it.
1	1	12.I was aware that I still had a lot of feelings about it, but I didn't deal with them.
1	1	13.My feelings about it were kind of numb.
1	1	14.I found myself acting or feeling as though I was back at that time.

Fig. 3.1. Fragment of Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management

A sufficient amount of studies worldwide prove an interrelation between a person's pupil size, eye blink frequency and emotional stress. Stress and anxiety tend to increase a person's pupil size and blink rate. Therefore, the temporal increase in eye blink frequency and pupil size can already be used as a measure of post-disaster stress (see Figure 3.2a).

a)



b)

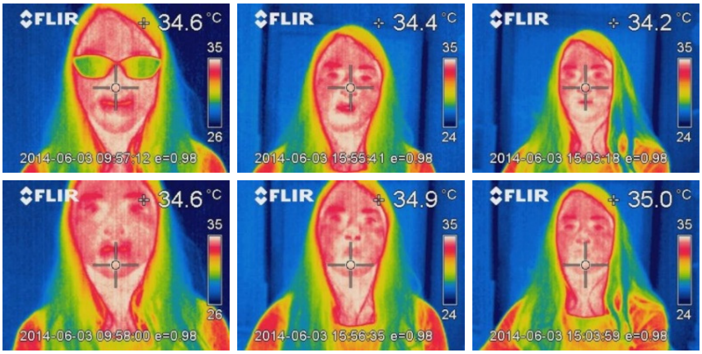


Fig. 3.2. Fragment of User's Physiological Database: a) a Person's Pupil Size, Eye Blink Frequency; b) a Person's Face Temperature

Figure 3.3 illustrates the precision of a subject's post-disaster stress level prediction by applying Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management. Blue colour represents the correctly predicted post-disaster stress level (41%), green colour represents those post-disaster stress level predictions, that had an error of one point (44%), red color represents the post-disaster stress level predictions, that had an error of two or greater points (15%).

The collection, processing and presentation of information for a database in the computer acceptable form is a complicated time-consuming process. The information collected in a database should be reliable, fully describing user's post-disaster stress management as well as enabling PA subsystem to perform an efficient user's post-disaster stress multi-tips and management solutions (social, ethical, psychological, emotional, religious, ethnic, technical, technological, economic, legal/regulatory, integrated, etc.) design and multiple criteria analysis.

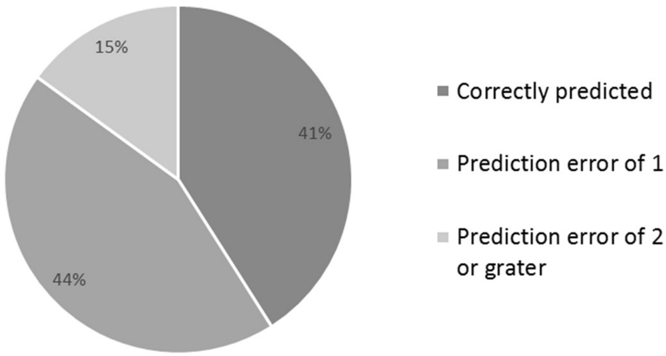


Fig. 3.3. Precision of a Subject's Post-Disaster Stress Level Prediction

A lot of data had to be processed and evaluated in carrying out multiva-riant design of a disaster stress management life cycle (emergency response (rescue efforts, fire fighting, emergency medical assistance and an evacuation procedure, stress management for emergency response), recovery (rehabilitation and disaster-resilient reconstruction, land use planning, industrial rehabilitation planning and livelihood support, stress management for recovery), prevention/mitigation (utilisation of seismic resistant technology for rebuilding or retrofitting, the construction of dikes, replanting of mangroves, forestation and the construction and operation of meteorological observation systems to help prevent and mitigate damage in the event of an earthquake, flood, landslide or storm) and preparedness/readiness (hazard maps, food and material stockpiling as well as the preparation of emergency kits, all vital factors that help to minimise the impact of a disaster, stress management for preparedness/readiness). The number of feasible alternatives can be as large as million. Each of the alternatives may be described from various perspectives (social, cultural, ethical, psychological, emotional, religious, ethnic, technical, technological, economic, legal/regulatory and other aspects), e.g. by conceptual and quantitative information. The problem arises how to perform computer-aided design of the alternative variants based on this enormous amount of information. To solve this problem a method of multiple criteria multivariant project (disaster stress management) life cycle design was developed (Kaklauskas 1999). According to the above method multiple criteria multivariant design is carried out in 5 stages.

The users seeking the efficient post-disaster stress management should provide in tables of initial data exact information about post-disaster stress, resilience aims and significance as well as about micro, meso and macro environment.

Based on various sources of information the recommendations presenting some interest to the user as well as some general facts, a system of criteria, their types (quantitative and qualitative), units of measurement and the range of value estimation are determined. The wider the range of estimating the values and weights of the criteria the more accurate analysis may be done.

Uniform types of relational tables have been chosen to facilitate entering of appropriate data into the database. Such unified database also make it possible easily correct and introduce new information as well as efficiently carrying out computation.

The above tables are used as a basis for working out the matrices of decision making. These matrices, along with the use of a model-base and models, make it possible to perform multi-tips design and multiple criteria evaluation resulting in the selection of most beneficial recommendations.

In order to design and realise an effective user's post-disaster stress management tips the alternatives available should be analysed.

Based on the above tables of multi-tips design possible user's post-disaster stress management variants are being developed. When using a method of multi-tips design suggested by the author until million alternative user's post-disaster stress management tips may be obtained. These tips are checked for their capacity to meet various requirements. Those which can not satisfy these requirements raised are excluded from further consideration. In designing a number of variants of user's post-disaster stress management the problem of significance compatibility of the criteria arises. In this case, when a complex evaluation of the alternatives is carried out the value of a criterion significance is dependent on the overall criteria being assessed as well as on their values and initial weights.

The model-base consists of the following models:

- model to determine the correlation between the user's posttraumatic stress and the parameters of the user's physiological parameters (heart rate, blood pressure, pupil, skin conductance and humidity; body, forehead, nose, left and right cheek, chin, left palm and left middle finger temperatures, etc.) (model for dependence analysis);

- model to evaluate the user's posttraumatic stress;
- model to determine initial criteria weights (data and user characteristics and recommendations) using expert evaluation methods;
- model to determine criteria weights;
- module to develop the model of a user's posttraumatic stress state;
- model to design multivariant recommendations;
- model to design multivariant stress management solutions;
- model to analyse multiple criteria and to prioritize recommendations and stress management solutions;
- model to determine the utility degree of recommendations and stress management solutions;
- model to deliver the recommendations and stress management solutions.

3.1.1. User's Post-Disaster Stress and His Physiological Data Dependencies Analysis

The study includes nine users post-disaster. These users' post-disaster physiological parameters (heart rate, systolic and diastolic blood pressure, humidity and skin conductivity) dependencies on stress were analysed using Logit, *k*-Nearest neighbor algorithm, Marquardt backpropagation and resilient backpropagation algorithms. As an example of the calculations will be based on data from a single user post-disaster. This user's post-disaster physiological measurements are presented in Appendix A. In this case, stress is the dependent variable, and user's post-disaster physiological parameters – independent variables. The independent variables – physiological indicators, which were not statistically significant, were rejected.

Calculation results obtained using the Logit method presented in Table 3.1. Predicted probability of being assigned to a second group of stress (stress-affected) for eight different measurements presented in Table 3.2.

Projected Logit (stress) = 24.989 + 0.098 x Systolic blood pressure + 0.144 x Heart rate.

With test data sample of 32 (1 stress level – 29, 2 stres level – 3) was obtained 87.5% correct prediction.

User's post-disaster stress as determined by its physiological data using *k*-Nearest neighbor method with test data sample of 32 (1 stress level – 29.2, 2 level of stress – 3) were obtained at 97% correct classification.

Table 3.1. Calculation Results Obtained Using the Logit Method

Exogenous variable	*	Coefficient	Standard error	z	*p*-value
Systolic blood pressure	b_1	0.0977705	0.0321322	3.0428	0.00234
Heart rate	b_2	0.144038	0.0274875	5.2401	<0.00001
1 path		24.989	4.03428	6.1942	<0.00001
The average of the dependent variable		1.119497		Standard deviation of dependent variable	0.324883
Log-likelihood		-84.78862		Akaike criterion	175.5772
Schwarz criterion		186.8634		Hannan-Quinn criterion	180.0850
Maximum likelihood ratio results: $\chi2$ (Chi-square criterion) (2) = 90.7011 [0.0000]					

* Marking.

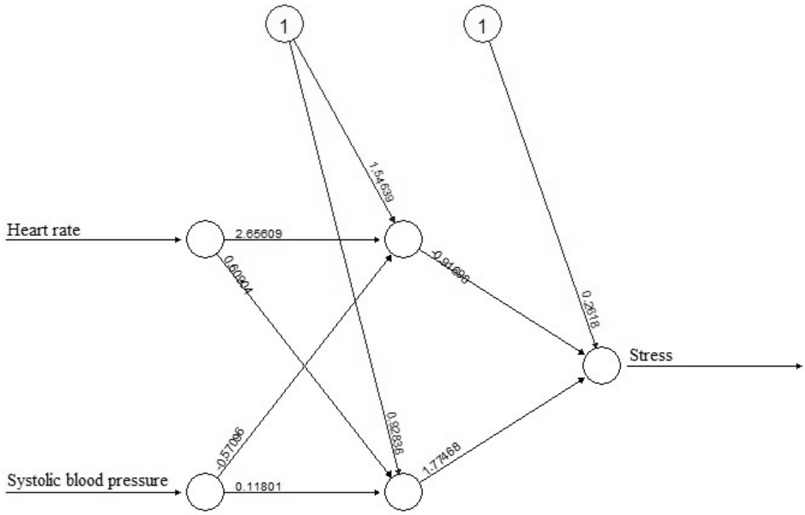
Table 3.2. Predicted Probability of Being Assigned to a Second Group of Stress (Stress-Affected) for Eight Different Measurements

Nr.	Systolic blood pressure, Beta = 0.0977705	Heart rate, Beta = 0.144038	Intercept = 24.989	Predicted probability of being assigned to a second group of stress	Fair value, 1 = yes, 0 = no
1	115	76	24.989	0.057	0
2	102	88	24.989	0.088	0
3	105	74	24.989	0.017	0
4	101	74	24.989	0.011	0
5	117	99	24.989	0.670	1
6	112	83	24.989	0.110	0
7	120	93	24.989	0.535	1
8	118	75	24.989	0.066	0

Correctly classified all the first stress level values, incorrectly classified one second stress level value.

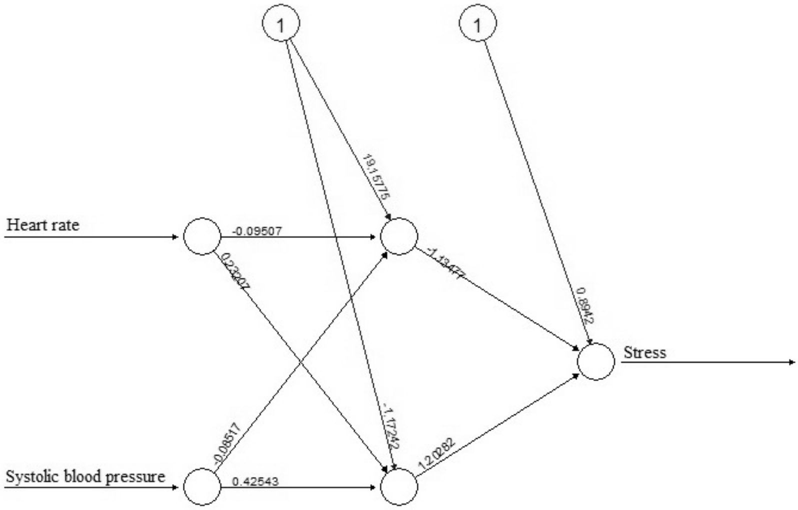
User’s post-disaster stress and his physiological data dependence model using Marquardt Backpropagation Algorithm (see Figure 3.4) was created using the systolic blood pressure and heart rate data.

After 41 steps it was achieved 16.73 error and reached 0.00098 threshold.



Error: 16.72956; Steps: 41

Fig. 3.4. User's Post-Disaster Stress and His Physiological Data Dependence Using Marquardt Backpropagation Algorithm



Error: 12.772542; Steps: 16748

Fig. 3.5. User's Post-Disaster Stress and His Physiological Data Dependence Using Resilient Backpropagation Algorithm

With test data sample of 32 (1 stress level – 29, 2 stress level – 3) were obtained 91% correct prediction.

27 of 29 first stress group observations and 2 of 3 second stress group observations were correctly categorized.

User's post-disaster stress and his physiological data dependence model using resilient backpropagation algorithm (see Figure 3.5) was created using systolic blood pressure and heart rate. After 16748 steps it was achieved 12.77 error and reached 0.0091 threshold.

3.1.2. User's Post-Disaster Stress and His Temperature Data Dependencies Analysis

The study included six users post-disaster. These users' post-disaster skin surface temperatures at different zones using a thermal imaging were measured and their dependence on stress were investigated. The following parameters were measured:

- forehead temperature;
- nose temperature;
- left cheek temperature;
- right cheek temperature;
- chin temperature;
- left hand palm temperature;
- left hand middle finger tip temperature.

Table 3.3. Calculation Results Obtained Using the Logit Method

Exogenous variable	*	Coefficient	Standard error	*z*	*p*-value
Nose temperature	b_1	–0.2679	0.1228	–2.182	0.0291
Left cheek temperature	b_2	0.9234	0.3557	2.596	0.0094
Chin temperature	b_3	–0.5593	0.3215	–1.740	0.0819
Palm temperature	b_4	0.5656	0.1751	3.231	0.0012
1 strip		22.4179	9.4301	2.3772	0.0174
The average of the dependent variable		2.4046	Standard deviation of dependent variable		0.4927
Log-likelihood		–79.6597	Akaike criterion		169.3193
Schwarz criterion		183.6953	Hannan-Quinn criterion		175.1609
Maximum likelihood ratio results: $\chi 2$ (Chi-square criterion) (4) = 18.1531 [0,0012]					

* Marking.

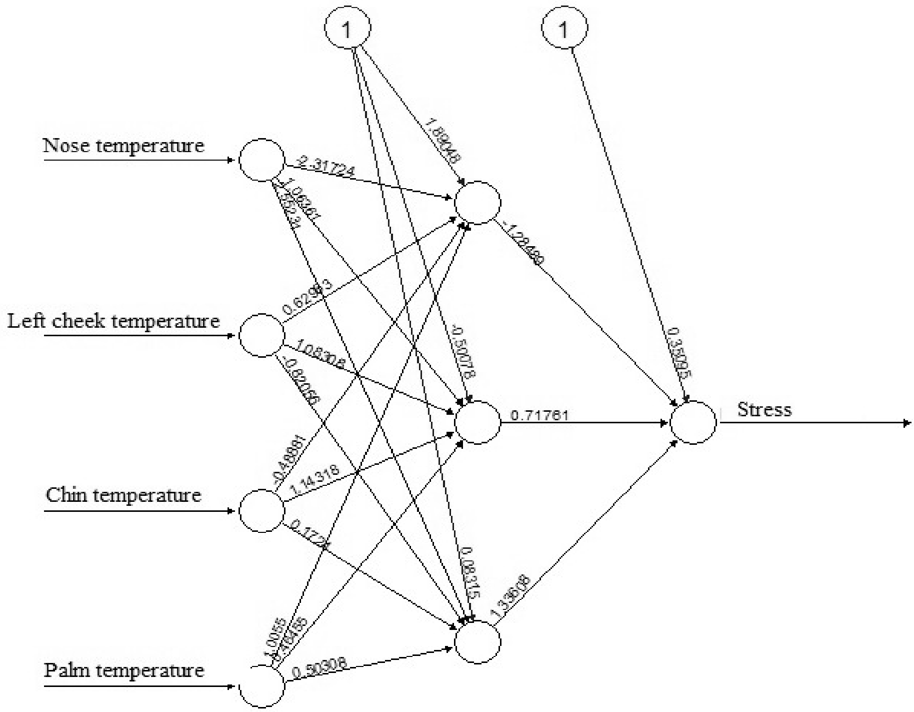
These users' post-disaster temperature data (forehead, nose, left and right cheeks, chin, left hand and left hand middle finger tip temperatures) dependencies on stress were analysed using Logit, *k*-Nearest neighbor algorithm, Marquardt backpropagation and resilient backpropagation algorithms. As an example of the calculations will be based on data from a single user post-disaster. This user's post-disaster temperature measurements are presented in Appendix B. In this case, stress is the dependent variable, and user‘s post-disaster temperature parameters – independent variables. The independent variables –temperature indicators, which were not statistically significant, were rejected.

Table 3.4. Predicted Probability of Being Assigned to the Second Stress Group (Productive) for 14 Different Measurements

No.	Nose temperature, beta = -0.2679	Left cheek temperature, beta = 0.9234	Chin temperature, beta = -0.5593	Palm temperature, beta = 0.5656	*z* value	Predicted probability of being assigned to the second stress group	Stress group
1	28.4	32.6	32.8	31	-0.7335	0.3244	1
2	32.9	32.6	33.5	33.5	-0.9163	0.2857	1
3	27.2	31.9	30.9	31	0.0043	0.5011	1
4	28.1	32.9	33.1	32.4	0.248	0.5617	1
5	26	32.2	32.3	31.2	-0.0672	0.4832	1
6	27.4	33.4	33.6	30.4	-0.5138	0.3743	1
7	25.9	32.7	32	28.9	-0.7119	0.3292	1
8	25.1	32.5	31.8	29.3	-0.3442	0.4148	1
9	29.8	32.9	33.4	31.8	-0.7146	0.3286	1
10	30.1	33.2	33.4	32.5	-0.122	0.4695	1
11	29.1	33.1	33.5	32	-0.2852	0.4292	2
12	24.2	32.9	30.9	28.5	0.3172	0.5786	2
13	30.2	32.8	32	31.1	-0.527	0.3712	2
14	28.1	33.3	32.1	29.7	-0.3506	0.4132	2

Calculation results obtained using the Logit method presented in Table 3.3. Predicted probability of being assigned to the second stress group (productive) for 14 different measurements presented in Table 3.4.

The probability of being assigned to the second stress group decreases by $1 - e^{1-0.2679} * 100\% = 23.5\%$ when nose temperature increases 1 degree and other parameters do not change. The probability of being assigned to the second stress group analogically increases by 42.84% and 76.05%, when cheek and palm temperature increases 1 degree and other parameters do not change and decreases by 151.78% when the chin temperature changes 1 degree and other parameters do not change.



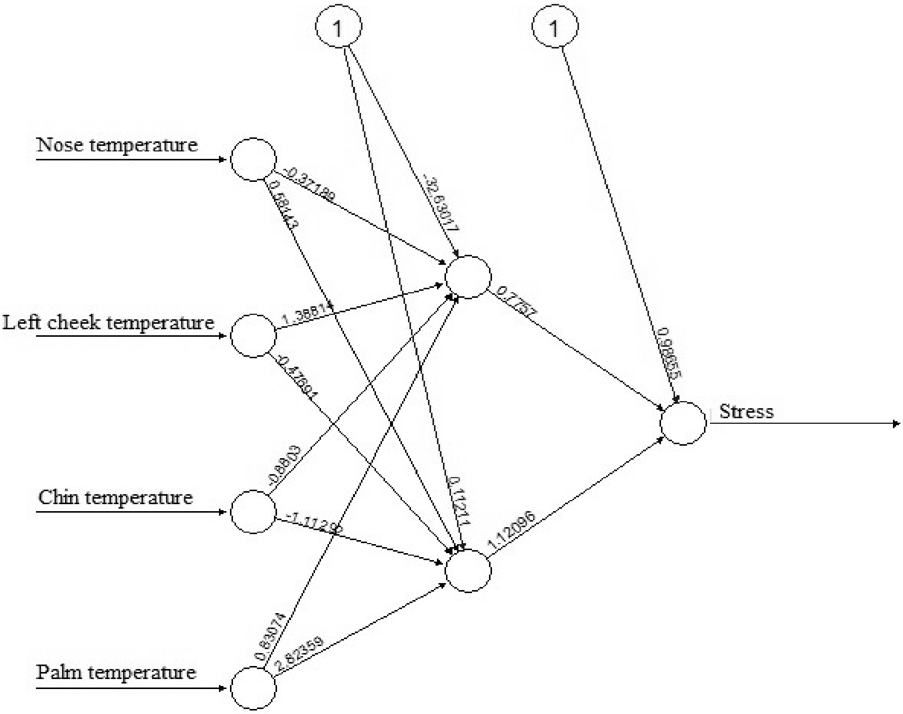
Error: 15.778626; Steps: 29

Fig. 3.6. User's Post-Disaster Stress and His Temperature Data Dependence Using Marquardt Backpropagation Algorithm

User's post-disaster stress as determined by its temperature data using *k*-Nearest neighbor method with test data sample of 14 (1st stress group – 10 observations, 2nd stress group – 4 observations) and *k* = 3 were obtained at 78.6% correct classification.

Incorrectly classified one second stress and two third stress level values.

Two values of first stress group and one value of second stress group were incorrectly classified.



Error: 13.821955; Steps: 66418

Fig. 3.7. User's Post-Disaster Stress and His Temperature Data Dependence Using Resilient Backpropagation Algorithm

User's post-disaster stress and his temperature data dependence using Marquardt Backpropagation Algorithm Model (see Figure 3.6) was created using nose, left cheek, chin and palm temperatures data.

After 29 steps it was achieved 15.79 error and reached 0.00805 threshold.

With test data sample of 14 (1st stress group – 10 observations, 2nd stress – 4 observations) were obtained 71.4% correct prediction.

User's post-disaster stress and his temperature data dependence model using resilient backpropagation algorithm (see Figure 3.7) was created using nose, left cheek, chin and palm temperatures data. After 66418 steps it was achieved 13.82 error and reached 0.0099 threshold.

Table 3.5. Predicted Probability of Being Assigned to the First or Second Stress Group (Productive) for 14 Different Measurements

No.	Nose temperature	Left cheek temperature	Chin temperature	Palm temperature	Predicted value	Stress group
1	28.4	32.6	32.8	31	1.3072	1
2	32.9	32.6	33.5	33.5	1.2773	1
3	27.2	31.9	30.9	31	1.5123	1
4	28.1	32.9	33.1	32.4	1.5658	1
5	26	32.2	32.3	31.2	1.4729	1
6	27.4	33.4	33.6	30.4	1.3513	1
7	25.9	32.7	32	28.9	1.3114	1
8	25.1	32.5	31.8	29.3	1.4	1
9	29.8	32.9	33.4	31.8	1.312	1
10	30.1	33.2	33.4	32.5	1.4681	1
11	29.1	33.1	33.5	32	1.4167	2
12	24.2	32.9	30.9	28.5	1.593	2
13	30.2	32.8	32	31.1	1.3711	2
14	28.1	33.3	32.1	29.7	1.4114	2

Achieved network was tested with the test data sample of 14 (1st stress group – 10 observations, 2nd stress group – 4 observations). Predicted probability of being assigned to the first or second stress group (productive) for 14 different measurements presented in Table 3.5.

3.2. Text Analytics for Human Resource Management in Emergency Situations in ANDROID Project

The purpose of this research was to develop a Text Analytics for ANDROID project that would be more flexible and more informative in selecting out and integrating rational electronic information by the desired area as much as by coverage and that would allow the actual users to participate and have an influence during the operation by automatically designing, evaluating and selecting the most suitable information for themselves according to different aspects (popularity of a text (citation index of papers (Scopus, ScienceDirect, Google Scholar, etc.) and authors (Scopus, ScienceDirect, Google Scholar, etc.), Top 25 papers, impact factor of journals, supporting phrases, document name and contents, density of keywords). The developed Subsystem is also practically used in two distance MSc study programmes of Vilnius Gediminas Technical University (Real Estate Management; Construction Economics and Business).

Already existing text analytics and text mining (Kamel Boulos *et al.* 2010; He 2013; Mostafa 2013; He *et al.* 2013; Anholt *et al.* 2014; Fagan 2014; Liew *et al.* 2014; Marwick 2014; Nguyen 2014; Truyens, Van Eecke 2014) cannot develop text material alternatives (perform a multivariant design), perform multiple criteria analysis, automatically select the most effective variant according to different aspects (popularity of a text (citation index of papers (Scopus, ScienceDirect, Google Scholar, etc.) and authors (Scopus, ScienceDirect, Google Scholar, etc.), Top 25 papers, impact factor of journals, supporting phrases, document name and contents, density of keywords), calculate utility degree and market value. However, the Text Analytics for ANDROID Project can perform the aforementioned functions. To the best of the knowledge herein, these functions have not been previously implemented.

The essence of this research involves the Text Analytics Model that is designated to select the most rational, integrated text material from a library of documents. It covers the inputting of bag of concepts space; selecting, processing and indexing information in accordance with the inputted bag of concepts space and User Model; formulating the results of the retrieval and finally showing them to the user. Further, after selecting, processing and indexing documents, it covers the selecting out of composite parts (chapters/sections/paragraphs) of the documents under analysis and, after that, performing the multicriteria analysis of the composite parts. This is followed by the designing of alternative variants of the selected information and performing a multicriteria analysis of the summarised integrated alternatives of the text by which the retrieval results are then formulated.

Once the selecting, processing and indexing of information has been completed, the selecting out of the composite parts of the documents and their multicriteria analysis are performed. Further alternative variants are designed, these are analysed and the most rational alternative is selected. All this makes the retrieval system more flexible and more informative, since it selects out electronic information as much by area as by coverage.

The multicriteria analysis of the most rational text materials from a library of documents under analysis covers the complex determination of criteria weights taking into account their quantitative and qualitative characteristics. It includes a multicriteria evaluation of the text materials defining the utility and market value of the text materials.

Text Analytics Model permits selecting the maximally rational information in the coverage that the user desires. The designing of alternative variants provides the user with an opportunity to supplement and/or correct the already inputted bag of concepts space, modify the weights and then repeat the search. In other words, the user by using User Model is provided an opportunity to intervene in the occurring retrieval and to redirect it; thus the retrieval takes into account the user-selected priorities and the existing situation.

The designing of alternative variants from the selected text materials contained in a library of documents covers the following stages: a) development of a table of codes of text materials from a library of documents, b) rejection of inefficient versions, c) computer-aided development of summarised, integrated text alternatives based on the codes compiled during Stage a), d) development of summarised, integrated text alternatives and the conceptual and quantitative information describing them and e) development of a summary decision-making table of all the obtained summarised, integrated text alternatives and relavent conceptual and quantitative information overall.

A brief analysis of several major parts of the Model and Subsystem follows, as an example:

- initial requirements for a search;
- user Model: Search for initial requirements, refining the search requirements and the Agent subsystem;
- rational text selection: Module for the multiple criteria analysis of the composite parts (chapters/sections/paragraphs).

3.2.1. Initial Requirements for a Search

At the beginning of a search, a user is able to submit the following kinds of search requirements:

1. The user indicates the goal or goals for the search – research, practical or cognitive. The user notes the possibilities of interest to him/her while conducting the search: research literature (books, academic articles and the like), practical literature or popular literature.
2. The user requests or selects bag of concepts space (see Figure 3.8).
3. The user establishes various limitations (volume of the material under search by pages, desired time for reading a lecture by minutes and the like).

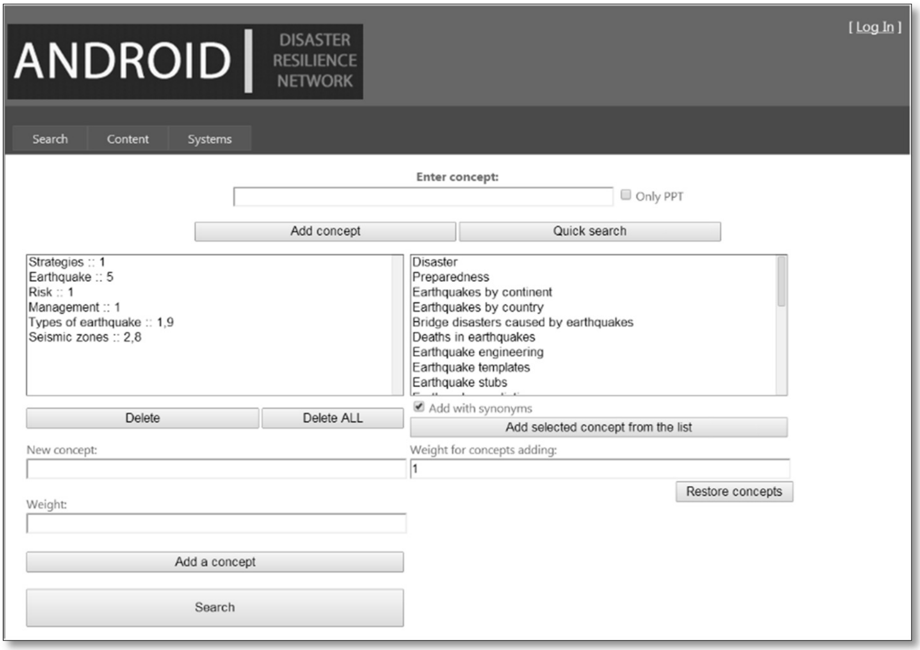


Fig. 3.8. User Window of the Text Analytics for the ANDROID Project

To limit the amount of search results showing the pages that include the concepts in question (or to restrict the search by the duration of reading), user has to tick the option Advanced search options below the button Search. Additional fields appear: aproximately ... pages and approximately for: ... minutes. The user will also see round buttons to choose search either by the number of pages (default) or by the duration of reading.

3.2.2. User Model: Initial Search Requirements, Refining the Search Requirements and the Agent Subsystem

The Agent subsystem accumulates information about a user and stores his/her individual data. This information can be explicit (year of birth or university graduation) or implicit. The main skills of a user are implicit. They consist of informal and unregistered knowledge, practical experiences and skills. Such data are very important because they describe a user's experience. Information about a user's existing education, needs and the like accumulate in the Agent subsystem.

As a user's historical search information is being analysed, his/her initial search requirements can be refined (or made more specific). In this case, the user's behavior is under analysis; for example, which documents the user does or does not select for review, how often a document is viewed and how much time is spent looking at it along with use of the drag function are all under observation. This may partially be called the analysis of user conducted searches, the agent function. The Agent subsystem accumulates statistical information about the previous searches conducted by a user in a matrix form:

- bag of concepts space of a search;
- results of a search;
- how many times a user modified the initial search before suitable results were gained;
- the most popular resources and Internet website addresses employed by the user;
- how many times did a user read the selected material and how much time was spent doing so.

This way the automatic search is actually personalized by applying the historical information gathered by the Agent subsystem:

- bag of concepts space under search is refined (or made more specific);
- information about the user's education, work experience and search needs are considered;
- the user's most frequently employed resources, Internet website addresses and authors are considered;
- the user's opinion regarding the significance of the documents gained by the results of a search are considered.

3.2.3. Rational Text Selection: Module for the Multiple Criteria Analysis of the Composite Parts (Chaters/Sections/Paragraphs)

The following factors determine a rational text:

- citation index of papers (Scopus, ScienceDirect, Google Scholar);
- citation of authors (Scopus, ScienceDirect, Google Scholar, etc.);
- top 25 papers;
- impact factor of journals;
- popularity of a text (citation index, number of readers, time spent reading);

- reputation of the documents;
- supporting phrases;
- document name and contents;
- density of keywords.

These factors are briefly discussed below.

Popularity of a text

The citation index, number of readers and time spent reading determine the popularity of a text. Citations in full-text articles, books and bibliographical information contained in databases serve as a very useful foundation for indexing potentially useful text interrelationships. Nearly everyone writing a course report, not even to mention serious researchers, look for citations in documents applicable to the research undertaken in order to discover other documents of interest. Essentially each directive for a citation leads to an older document by means of a citation in a newer document thereby generating a sequential accumulation of material. Today the Science Citation Index (SCI), Social Sciences Citation Index (SSCI), Arts and Humanities Citation Index (AHCI) and others become standard tools allowing the tracking of a citation from an existing document to other documents that appear later.

There can be a considerable number of internal or external Internet website addresses used within a text that are interrelated with a specific term to be searched. This is one of the most important factors for establishing the importance priority of a text, using popularity for an objective assessment of an electronic document. Popularity is essentially equal to "votes" cast by other research works and/or websites, which substantiate the significance and popularity of your electronic document by providing links to it. For example, one of the reasons why Wikipedia is so popular in the world in numerous areas is its extremely effective system of internal and external links of this nature.

The Google Scholar (http://scholar.google.lt/), for one, can be used to establish a citation index.

The number of visiting readers and the length of time a document is read are also important descriptions about the popularity of a text.

Reputation of the documents

One of the goals for establishing the reputation of a document is to "measure" the usefulness and conditional importance of a text for researchers, practitioners and the society-at-large. For instance, a user at work may be constantly searching for information about documents on the regulations of a built environment in Lithuania. The Subsystem provides information from a document entitled Lietuvos būsto strategijos [Housing Strategy of Lithuania]. This information had satisfied the user; thus, as the Subsystem conducts its usual search on this, it gives Lietuvos būsto strategijos and other documents relevant to it greater priority than it does to other documents. Furthermore it is of utmost importance to assess how many people viewed the document under discussion how many times and how much time they spent doing so.

Supporting phrases

"Supporting phrases" are also employed for the analysis of a text, which include synonyms and other words or phrases assisting a rational selection of a text required by the user.

Document name and contents

The name and contents of a document provide a concise description of the text under discussion. Thus the applicability of words contained in a document's name or table of contents to the keywords (their synonyms) of a search show that the document is relevant. The greater priority (significance) is ascribed to such documents.

Density of keywords

When keywords comprise five percent of a text, it means that five percent of all the words on a single page are the provided keywords. One to three percent keywords is an optimal proportion. The proportion of a text comprised of keywords is calculated by the formula:

$$\frac{N_{kwr}}{T_{vw}} \cdot 100, \tag{3.1}$$

where N_{kwr} denotes the number of times a specific keyword repeats, and T_{vw} – the total number of words in the text under analysis.

Thereby the value of the proportion of keywords in a text is calculated. To calculate the proportion of a text comprised of keyword phrases, the formula used is:

$$(N_{kwr} \cdot \frac{N_f}{T_{vw}}) \cdot 100, \tag{3.2}$$

where N_f means the number of words in a phrase. In other words, as an example, when an applicable phrase is used four times within a text, and a page consists of four hundred words, the proportion of the page consisting of a keyword phrase is equal to $(4{\cdot}3/400){\cdot}100$, or three percent.

Feedback on the appropriateness of the found document

It is intriguing to consider the different goals people have for their searches. At the same time, the search process itself guides the data discovery in terms of the reaction of the searcher to the delivered results, sometimes influencing the next iterations of the search query until the content that was sought after is sufficiently "found" (Loshin 2012).

A user could be dissatisfied with the results of an initial search and desire an additional search. There can be several reasons for this. For example, it could happen that, at the time of the initial search, no documents are found that correspond to a minimal density of keywords in accordance with the search bag of concepts space the user has provided. In such a case, a modified search is undertaken to upgrade the search (i.e., by supplementing the search bag of concepts space).

The goal during the time of the search for information is a text selected for maximal satisfaction of the user's needs. At times researchers attempt to select out appropriateness, usefulness, interrelationship and other, similar concepts by appropriate types such as by appropriate topics or by the appropriateness for the user (it is claimed that a document can have an appropriate topic, thus being suitable, but a user cannot or does not want to use it: perhaps the language is incomprehensible, the user already has such a document, the document is too complicated or the like).

Feedback regarding the appropriateness of a found document relates with methods like modifying a search inquiry in accordance with the user's assessment of the appropriateness of the preliminarily found document. Generally an initial search is conducted according to the bag of concepts space that a user provides. The results of such an initial search are provided to the user along with an assessment questionnaire, wherein preliminary assessments of the appropriateness of the found documents to the needs of the user are provided. Then the initial search parameters are modified by employing the user's answers (for example, providing greater weight to the successfully used terms and lessening or eliminating the weights of less appropriate terms). Thereby a second search is conducted. Such an interaction may continue as long as a user wants it to.

The essence of the feedback on the appropriateness of a found document is taking the initial results according to the submitted questionnaire and formulating a new questionnaire in light of the appropriateness of the results.

The feedback function employed by this Method is the electronic intelligent analysis function.

Once the questionnaire parameters are filled out (the feedback regarding the appropriateness of the found document), other, more suitable documents are found during a search, which had been surpassed during the initial search; thusly overall effectiveness betters. Naturally the effect of such feedback depends very much on the quality of the terms selected to supplement the search and their weights. Besides, if the words submitted with the initial questionnaire are not related to the topic of the query or the weights attached to them are inappropriate, the quality of the search can prove poorer. Nonetheless the opposite is true also.

The results may give a user new ideas and thoughts for improving this search. The user then submits such information (desired authors, literature and Internet resources; bag of concepts space) for a repeat search.

The user can also indicate the appropriateness of the selected text directly by using a point system ranking usefulness. Usefulness is assessed on a some sort of a 10-point scale (for example, where zero points means “inappropriate”, four points means “somewhat appropriate, six points – “appropriate” or ten points “very appropriate”. Information about the reaction regarding appropriateness needs to be included in the initial questionnaire for the search to operate more effectively.

3.3. Recommender Thermometer for Measuring the Preparedness for Resilience

Based on the analysis of the thermometers and similar scales, neural networks (Kong-A-Siou *et al.* 2013; Liu *et al.* 2014a), early warning (Krzhizhanovskaya *et al.* 2011; Alfieri *et al.* 2012; Borga *et al.* 2014; Hissel *et al.* 2014; Van Veen 2014), fuzzy (Kou *et al.* 2014), expert (Karnib *et al.* 2002; Kou *et al.* 2014) and decision support (Hubbard *et al.* 2014; Krzhizhanovskaya *et al.* 2013, Kaklauskas 1999, Kaklauskas *et al.* 2011c) and in order to determine most efficient tips and resilience alternatives to flood adaptation in the built environment area a Recommender Thermometer for Measuring the Preparedness for Flood Resilience Management consisting of a database, database management subsystem, model-base, model-base management subsystem and user interface was developed.

The following tables make Recommender Thermometer database:

1. Initial data tables. These contain general facts about the preparedness for flood resilience management of built environment considered and the information of its deterioration and obsolescence. The reasons of refurbishing and their significance as well as the money intended to be spent on it are also given.
2. Tables assessing preparedness for flood resilience management of built environment solutions. They contain quantitative and conceptual information about alternative solutions.
3. Table of questionnaire. Each of the question leads to recommendation.
4. Tables of alternative recommendations.
5. Tables of alternative built environment refurbishment solutions. A number of options (Homeostasis, Omnivory, High flux, Flatness, Buffering, Redundancy (Wardekker *et al.* 2010)) that could be considered within a resilience approach to flood adaptation in the built environment area have been developed and successfully used in advanced industrial economies;
6. Tables of multivariant design of built environment refurbishment solutions. They provide quantitative and conceptual information on the inter-

connection of the elements of preparedness for flood resilience management of built environment to be regenerated, their compatibility and possible combinations as well as data on complex multivariant design of a of built environment.
7. Tables of multivariant design of recommendations.

The model-base consists of the following models:

- model for the criteria weight establishment;
- model for multivariant design of alternative recommendations and built environment refurbishment solutions;
- model for multiple criteria analysis and setting the priorities;
- model for determination of alternative utility degree;
- model for determination of the “temperature” of the preparedness for resilience management (Thermometer model);
- model for providing recommendations and rational built environment refurbishment solutions.

If investments to flood resilience of built environment are too high, then:

$$T_j = 36.6° + (100\% - N_j) \div 200 \cdot 36.6°, j = \overline{1,n}\,, \tag{3.3}$$

where T_j is the “temperature” of preparedness for flood resilience of built environment in the j-th alternative. N_j – the value of the preparedness for flood resilience of built environment utility degree in the j-th alternative and n – the number of alternatives compared.

If investments to flood resilience of built environment are too low, then:

$$T_j = 36.6° - (100\% - N_j) \div 200 \cdot 36.6°, j = \overline{1,n}. \tag{3.4}$$

The example considered is flood resilience management in Lithuanian built environment. Five alternatives of preparedness for flood resilience management of built environment (Homeostasis, Omnivory, High flux, Flatness, Buffering, Redundancy (see Figure 3.9 and http://iti.vgtu.lt/imitacijosmain/daugkrit.aspx?sistemid=409) have been analysed.

Rusnė is the only Lithuania’s town on an island, in the southwest of Šilutė District. A modern bridge over the Atmata connects the town to the mainland and the road then leads to Šilutė. The other bank of the Skirvytė is in Kaliningrad Oblast, Russian Federation. A modern bridge was constructed over the Atmata, but there are times when even the bridge cannot save the locals from spring floods, which usually cover over 40,000 ha of meadows with water. The residents of Rusnė are protected from floods by levees. The island has a system of polders with 20 water-pumping stations. The land at the lake of Dumblė is 1.3 m below the sea level.

Extreme floods are mostly characteristic of the areas in the lower reaches and delta of the Nemunas. The floods result from higher discharge in the Nemunas caused by snowmelt; because of ice jams the extent of submerged riverside land may often increase. Ice jams may prolong floods for extensive periods (by slowing down the receding stage). Such floods very often reach the level of a disaster.

Floods resulting from snowmelt and ice jams account for about 70–75% of cases; about 15% are caused by heavy rains. The risk of floods may increase because of ice jams frequent in the Nemunas delta. Another 15% of cases may be attributed to other reasons such as the rising sea level in the Baltic Sea, accidents in hydrotechnical facilities and so on. Spring and winter are the typical flood seasons in Lithuania; they cover about 60% and 35% of cases respectively.

Based on the calculated criteria values and weights, a decision making matrix for preparedness for flood resilience management of the town Rusnė (see Figure 3.9 and http://iti.vgtu.lt/imitacijosmain/daugkrit.aspx?sistemid=409) was developed. As can be seen from Figure 3.9, each criterion goes together with its measurement unit and weight. The magnitude of weight indicates how many times one criterion is more significant than the other one in a multiple criteria evaluation of refurbishment.

Quantitive and qualitative information pertinent to alternatives									
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives					
				Homeostasis	Omnivory	High flux	Flatness	Buffering	Redundancy
Ground subsidence	-		0.004	3	4	3	5	9	5
Water system	+		0.002	8	7	4	5	6	5
Tidal differences	-		0.005	3	4	5	4	7	6
Water barriers	+		0.021	7	6	4	7	8	9
Local ecology	+		0.013	8	7	7	8	8	8
Economical functions	+		0.012	6	9	7	8	7	5
Public spaces	+		0.017	7	8	5	5	6	7
Inland shipping	+		0.027	7	8	6	7	7	7
Port functions	+		0.023	7	8	6	7	7	7
Residential functions	+		0.008	8	8	8	7	6	7
(Para)medical facilities	+		0.029	9	9	8	9	8	8
Cooling	+		0.021	7	5	8	9	7	8
Energy supply	+		0.032	6	9	9	9	7	9
Drinking water	+		0.033	9	7	4	5	7	7
Disaster management organization	+		0.041	9	9	9	9	9	9
Electricity	+		0.035	6	9	9	9	7	8
Sewage system	+		0.028	9	6	7	6	8	9
Main roads leading in/out of the area	+		0.009	8	7	6	8	8	7
Main water barriers	+		0.024	8	7	6	8	9	7
Maeslantkering storm surge barrier	+		0.011	6	6	8	8	9	7

Fig. 3.9. Fragment of Grouped Decision Making Matrix of Flood Resilience Management in Built Environment Multiple Criteria Analysis

The following alternatives have been chosen for the calculations: Homeostasis, Omnivory, High flux, Flatness, Buffering, Redundancy. The Flatness and Redundancy could hardly be implemented in our concerned area. In contrast, the alternatives such as Homeostasis, Omnivory, High flux, and Buffering could be used in Lithuania. Those alternatives are composed to the area.

When analysing the alternative Homeostasis we have noticed that such criteria as Water system, Water barriers, Local ecology, Public spaces, Inland shipping, (Para)medical facilities, Energy supply, Drinking water, Electricity, Sewage system, Main roads leading in/out of the area, Main water barriers, Risk information, Social structure, Evacuation plans, Water damage insurance, Safety policy, Areal system management, Urban planning, Modification of areas, Temperature, Sea level rise, River discharge, Societal and governmental issues, Rapid ice-sheet melting, Extreme storm, Maeslantkering failure plus extreme storm have high significance and only need a minor improvement or none at all. The matrix of the quantitative and qualitative information related to the alternatives with certain low percentages illustrates this clearly (cf. the criteria such as Ground subsidence, Port functions, Flooding-resistant buildings, Top-heavy system prevention, Port malaria incidents).

Precipitation extremes	+		0.025	0.0044 AVG MIN	0.0038 AVG MIN	0.0044 AVG MIN	0.0044 AVG MIN	0.005 AVG MIN	0.0031 AVG MIN
Societal and governmental issues	+		0.012	0.002 AVG MIN	0.0023 AVG MIN	0.002 AVG MIN	0.0023 AVG MIN	0.0015 AVG MIN	0.0018 AVG MIN
Wildcards	-		0.021	0.0041 AVG MIN	0.0026 AVG MIN	0.002 AVG MIN	0.0036 AVG MIN	0.0046 AVG MIN	0.0041 AVG MIN
Rapid ice-sheet melting	+		0.026	0.0048 AVG MIN	0.0041 AVG MIN	0.0034 AVG MIN	0.0048 AVG MIN	0.0048 AVG MIN	0.0041 AVG MIN
Frozen port	+		0.009	0.0016 AVG MIN	0.0018 AVG MIN	0.002 AVG MIN	0.0016 AVG MIN	0.0007 AVG MIN	0.0013 AVG MIN
Port malaria incidents	+		0.026	0.0051 AVG MIN	0.0044 AVG MIN	0.0051 AVG MIN	0.0038 AVG MIN	0.0032 AVG MIN	0.0044 AVG MIN
Enduring heat and drought	+		0.025	0.0042 AVG MIN	0.0048 AVG MIN	0.0042 AVG MIN	0.0042 AVG MIN	0.0036 AVG MIN	0.0042 AVG MIN
Extreme storm	+		0.03	0.0062 AVG MIN	0.0031 AVG MIN	0.0046 AVG MIN	0.0054 AVG MIN	0.0062 AVG MIN	0.0046 AVG MIN
Maeslantkering failure plus extreme storm	+		0.032	0.0063 AVG MIN	0.0049 AVG MIN	0.0056 AVG MIN	0.0056 AVG MIN	0.0063 AVG MIN	0.0035 AVG MIN
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				0.1712	0.1555	0.1556	0.1656	0.1683	0.1452
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0.0068	0.0054	0.0044	0.006	0.0087	0.0065
Significance of the alternative				0.1768	0.1625	0.1642	0.1719	0.1727	0.151
Priority of the alternative				1	5	4	3	2	6
Utility degree of the alternative (%)				100%	91.94%	92.9%	97.25%	97.67%	85.44%

* The signs "+/-" indicates that a greater (less) criterion value corresponds to a greater significance for a user (stakeholders)

Fig. 3.10. Fragment of Flood Resilience Management in Built Environment Multiple Criteria Analysis Results

The results of the multiple criteria evaluation of the six flood resilience management versions are given in Figure 3.10 (also see http://iti.vgtu.lt/imitacijos-main/daugkrit.aspx?sistemid=409). From the numeric values it can be seen that the 1st version (Homeostasis) is the best among all the versions that were evaluated. The utility degree of it N_1 = 100%. The 5th version (Buffering) according to its priority was recognized as the second best. The utility degree of it N_5 = 97,67% (see Figure 3.10).

Using the Equation 3.3. and Figure 3.10 (also see http://iti.vgtu.lt/imitacijos-main/daugkrit.aspx?sistemid=409), when the investments to flood resilience of built environment are too high, the Recommender Thermometer determines preparedness for flood resilience "temperature" T_j of the j^{th} alternative:

$T_{Homeostasis} = 36.6° + (100\% - 100\%) \div 200 \cdot 36.6° = 36.6°$,

$T_{Omnivory} = 36.6° + (100\% - 91.94\%) \div 200 \cdot 36.6° = 38.07°$,

$T_{High\ flux} = 36.6° + (100\% - 92.9\%) \div 200 \cdot 36.6° = 37.9°$,

$T_{Buffering} = 36.6° + (100\% - 97.67) \div 200 \cdot 36.6° = 37.03°$.

Using the Equation 3.4. and Figure 3.13, when the investments to flood resilience of built environment are too low, the Recommender Thermometer determines preparedness for flood resilience "temperature" T_j of the j-th alternative:

$T_{Flatness} = 36.6° - (100\% - 97.25\%) \div 200 \cdot 36.6° = 36.10°$,

$T_{Redundancy} = 36.6° - (100\% - 85.44\%) \div 200 \cdot 36.6° = 33.94°$.

3.4. Subsystem of Integrated Virtual and Intelligent Technologies

Subsystem of Integrated Virtual and Intelligent Technologies consists of:

- locations of interest search model;
- advisory model;
- augmented reality model.

These models briefly are described below.

Locations of Interest Search Model

Information about a place (a short and detailed description of an address or GPS coordinate) is loaded into the Google Maps service system using the tool, named My Maps. Data loaded into the virtual space can be reviewed using the Google Earth program, installed both on stationary and mobile devices.

The user of the Smartphone mobile device is provided with the current locale of the user and the adjacent house while the user is viewing the information about the place. Nonetheless, this type of information display has particular disadvantages; i.e., information could by represented on the place surface (2D) and complicate the understanding in terms of cardinal points and environment. Therefore 3D virtual reality (Google Street View) and augmented reality solutions (a 360° virtual tour and Wikitude, as shown in Figure 3.14) could be used to facilitate the place search.

The Wikitude service enables data import from a "kml" file type, which could be exported from Google Maps or Google Earth. Additional data (address, reference, contacts) could be placed into Wikitude by changing the "kml" standard into the "arml" standard and loading it into the system on the Wikitude Developer site. The Wikitude customer viewing programs (Apps) are compatible, both with Android and iOS (iPad, iPhone) Smartphones.

Application of Wikitude (see Figure 3.14, centre picture) foresees verification of the current coordinates of the user, calculation of distances and directions to the built environment facility and other built environment facilities, which are shown on the Radar screen, enabling an orientation for the user within the area. The information is displayed in a Smartphone as an on-screen layer of augmented reality superimposed on real surroundings, which are captured by the phone's camera. A user first identifies the sought property and then uses the navigation system to approach the property. A list of additional information about the property can be opened in the Wikitude menu, an app for Smartphones (see the right image of Figure 3.14). The list of additional information in Wikitude includes a link to the Virtual Tour for exploring the property's interiors (see the left image of Figure 3.14).

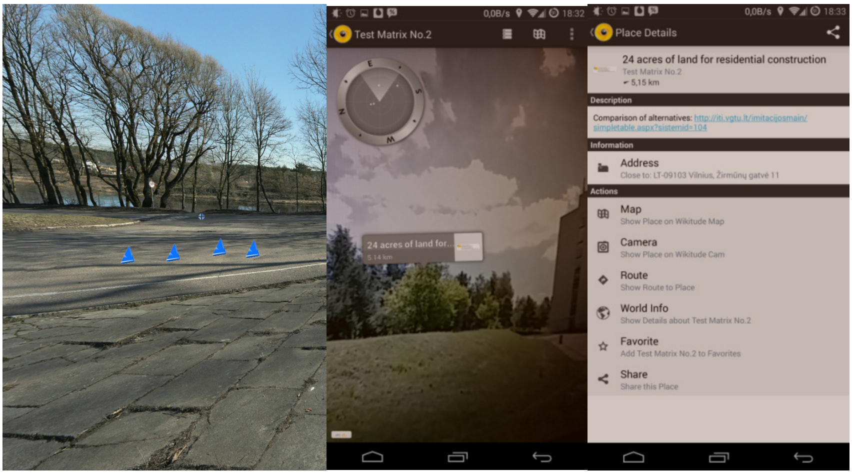


Fig. 3.14. Virtual and Augmented Reality Inside and Outside the Building

Advisory Model

The Advisory Model, which links to http://iti.vgtu.lt/ilearning/kapa-teikti.aspx, provides personalized recommendations for upgrading living conditions in the places with flood risks taken from the answers to the questions generated by the subsystem.

The title page includes 29 questions. The user answers the questions and clicks on “Show recommendations”. The subsystem will evaluate the answers and generate recommendations relevant to improving the quality of living conditions in the places with flood risks.

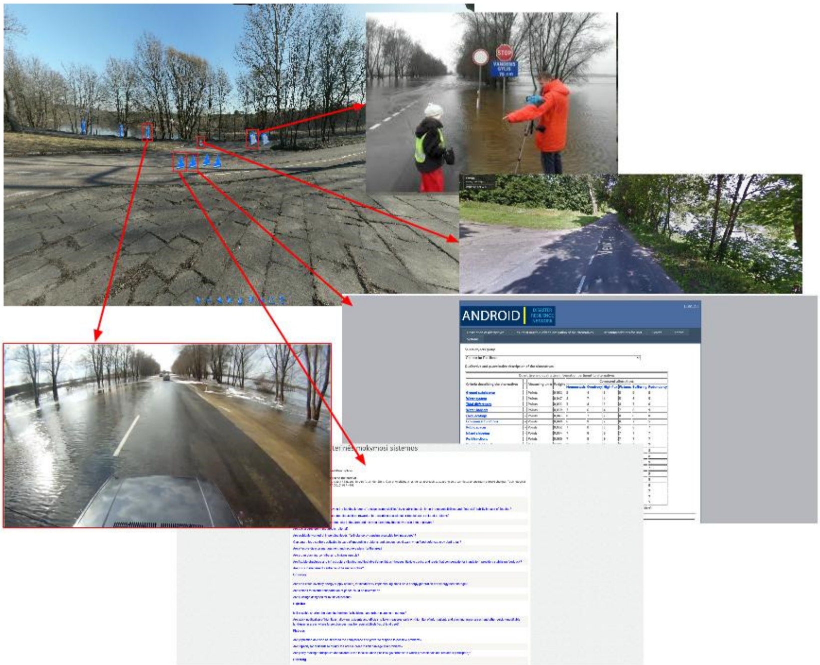
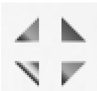


Fig. 3.15. Virtual tour for flood event example

Augmented Reality Model

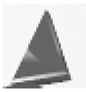
The Augmented Reality Model offers real-time additional information about the place (see Figure 3.15). The entire space around, below or above the place of interest is visible by using the keyboard buttons (◄►▲▼) (see http://iti.vgtu.lt/imitacijosmain/flood.swf). The user can zoom all required objects in or out. Further the user can go directly through view points and the entire place thereby experiencing a sense of touring it without leaving home, e.g., by going from one place to another and viewing the entire facility. The view can also be augmented with particular additional objects, i.e., by adding descriptions of objects to be incorporated into the tour or panorama (e.g., a click on the additional object installed on a wall displays information for review about materials used in construction or finishing of the building). This includes photos, sound tracks, video clips, flash or other elements of multimedia, links to recommended systems, multiplecriteria systems.

A different icon is presented to identify each kind of problem for the virtual tour. A click on the icon produces the corresponding image. The icons for identifying each problem are presented in Figure 3.16.



- Link to google maps street view

- Video clip



- Web link to systems

- Image

Fig. 3.16. The Icons for Identifying Each Problem

A click on the “triangle” icon placed at the tour, open web links. In first is Flooding Resilience Recommendation System. In second is multicriteria system. In third is stress evaluation questionnaire. In fourth can find database of several themes like earthquake, fire, flooding, tsunami and windstorm. These themes have four open source content types: calculators, design and construction guides, open source software, and video. There is also an information “i” icon (video clips) located near the element relevant to the problem appear showing information about potential problems at the precise part of the road, for example, if river flood, show how the problems are solving. Additional elements displays picture of example problem, in this time flood.

3.5. Conclusions of Chapter 3

1. The developed subsystems of the Intelligent Decision Support System for the Human Resource Management in Emergency Situations provide a comprehensive assessment of alternative versions from economic, technical, infrastructural, qualitative, technological, legislative and other perspectives. The decision support system enables a user to analyse human resource management in emergency situations quantitatively (subsystems of criteria, units of measure, values and weights) and conceptually (text, formula, schemes, graphs, diagrams, augmented reality). Such a comprehensive analysis was not used in the previous studies analysing human resource management in emergency situations.
2. The developed Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management determines the level and symptoms of post-disaster stress by performing a multivariant design of a disaster's stress management life cycle (consisting of emergency response, recovery, prevention/mitigation and preparedness/readiness stages). Next, it generates alternative recommendations applicable to a specific user on ways to reduce post-disaster stress. It also performs a multiple criteria analysis of these recommendations and selects the ten most rational ones, regarding a disaster stress management life cycle, complete with informational tips for that user. The Impact of Event Scale-Revised (IES-R) is used as a self-assessment instrument to determine the symptoms of post-disaster stress and to compile recommendations.
3. The existing text analytics and text mining cannot develop text material alternatives (perform a multivariant design), perform a multiple criteria analysis or automatically select the most effective variant by different aspects, such as by the citation index of papers (Scopus, ScienceDirect, Google Scholar), author (Scopus, ScienceDirect, Google Scholar), the Top 25 papers, impact factor of journals, supporting phrases, document name and contents or density of keywords. Furthermore it is not able to calculate utility degree and market value. However, the developed Text Analytics for the ANDROID Project can perform the aforementioned functions. These functions have not been previously implemented to the best of the knowledge herein.
4. The Recommender Thermometer for Measuring the Preparedness for Resilience, which this author developed, has several innovative aspects of global implication. Primarily it has the capacity to measure the "temperature" of the preparedness for flood resilience management automatically and to compile multiple alternative recommendations customised for a specific user involving preparedness for floods, including one's own

home; taking precautions against a threat of floods, retrofitting for flood-prone areas and checking home insurance plus the preparedness for bush fires, for cyclones, for severe storms, for heat waves etc. Furthermore it is able to perform a multiple criteria analysis of the recommendations and to select the ten most rational ones for that user. No other system in the world offers these functions yet.

5. The Subsystem of Integrated Virtual and Intelligent Technologies, which this author developed, integrates virtual reality with the Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management, Text Analytics for ANDROID Project and Recommender Thermometer for Measuring the Preparedness for Resilience.
6. The Intelligent Decision Support System for a Human Resource Management in Emergency Situations, which was developed by this author in cooperation with her colleagues, differs from other systems by the object of the investigation and the adaptation of methods in a new research field – human resource management in emergency situations.

General Conclusions

1. The analysis of literature in this field showed that there is no intelligent decision support system developed that would help to make human resource management in emergency situations more efficient and would provide a comprehensive assessment of alternative versions from economic, technical, infrastructural, qualitative, technological, legislative and other perspectives quantitatively and conceptually.
2. A model is applied for a complex analysis of a human resource management in emergency situations enables the user to analyse a built environment's resilience management life cycle and its stages, the parties involved in the project as well as its micro, meso and macro environments as an integral entity and allows to prepare for emergency situations.
3. By developing the Intelligent Decision Support System for a Human Resource Management in Emergency Situations a method for a complex determination of human resource management in emergency situations criteria weights was applied. Based on this method quantitative and qualitative characteristics of the criteria are taken into account. This method allows calculating and coordinating the weights of the quantitative and qualitative criteria according to the above characteristics.
4. A method was used for a multiple criteria complex proportional evaluation of the human resource management in emergency situations enabling

the user to obtain a reduced criterion determining the complex (overall) efficiency of the human resource management in emergency situations. This generalized criterion is directly proportional to the relative effect of the values and weights of the criteria considered for the efficiency of the human resource management in emergency situations.

5. In order to determine the utility degrees and market values of human resource management in emergency situations alternative versions based on a complex analysis of all their benefits and drawbacks to find, what price will make an alternative under evaluation competitive on the market, a method for market value determination was adapted. Accordingly the utility degree of such alternative versions and the market value of an alternative under evaluation are directly proportional to the system of the criteria adequately describing them and the values and weights of these criteria.
6. A method was applied of a multiple criteria, multivariant design of a human resource management in emergency situations enabling a user to make computer-aided designs of up to 100,000 alternative human resource management in emergency situations versions.
7. Ordered logit model, *k*-Nearest Neighbour Algorithm, Marquardt Backpropagation Algorithm and Resilient Backpropagation Algorithm were applied to analyse physiological parameters dependencies on stress.
8. The developed subsystems (Physiological Advisory Subsystem to Analyse a User's Post-Disaster Stress Management; Text Analytics for Human Resource Management in Emergency Situations in Android Project; Recommender Thermometer for Measuring the Preparedness for Resilience and Subsystem of Integrated Virtual and Intelligent Technologies) provide a comprehensive assessment of alternative versions from economic, technical, infrastructural, qualitative, technological, legislative and other perspectives. A decision support system was developed on the basis of the above-named subsystems. It enables a user to analyse human resource management in emergency situations quantitatively (subsystems of criteria, units of measure, values and weights) and conceptually (text, formula, schemes, graphs, diagrams, augmented reality).
9. The impact of emergency situations to human resource management is not sufficiently analysed in the scientific literature. The intelligent decision support systems developed by other researchers are not designed to be applied in the whole built environment's resilience management life cycle. The developed system differs from other systems by the adaptation of multiple criteria analysis and mathematical methods in a new research field – human resource management in emergency situations. This system helps to improve the management efficiency of the organisations and to reduce negative impact of the disasters to society and economics.

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Summary in Lithuanian

Įvadas

Problemos formulavimas

Daugeliui bendruomenių Europos Sąjungoje ir už jos ribų dideles problemas sukelia natūralios kilmės ir žmonių įtakotos katastrofos. Augant žmonių populiacijai ir vystantis miestų infrastruktūrai, pavojų poveikis ir įtaka gyvenimo kokybei vis didėja. Dėl kylančių potvynių ir audrų atsiranda ekonominiai nuostoliai, su oro sąlygomis susijusios nelaimės naikina infrastruktūrą. Pasaulyje galima įvardinti daug katastrofų valdymo spragų. Siekiant efektyviau valdyti katastrofų sukeliamą poveikį, katastrofos turėtų būti numatomos iš anksto ir joms turėtų būti pasiruošiama. Efektyvus pavojų mažinimas ir pasirengimas jiems gali žymiai sumažinti kylančias grėsmes. Laiku vykdomas atsistatymas po katastrofų gali sumažinti ekonominę ir socialinę žalą.

Užstatyta aplinka apima visą žmonių gyvenamąją aplinką, kurioje jie vykdo kasdienę veiklą. Pažeidus ar sugriovus užstatytos aplinkos elementus, visuomenės ekonominė ir socialinė veikla yra sutrikdomos. Skurdžiose šalyse katastrofos trikdo ekonomikos augimą ir mažina žmonių galimybes išbristi iš skurdo. Taigi, pavojų rizika turi būti vertinama ir valdoma žmones supančioje užstatytoje aplinkoje.

Darbo aktualumas

Stresą žmonėms sukelia tiek kasdienės užduotys, tiek ir nelaimės aplinkoje, t. y. įvairios ekstremalios situacijos. Šiose stresinėse situacijose žmogus negali valdyti savo emocijų. Tai keičia jo elgesį, darbo našumą ir reakciją į skirtingas aplinkybes. Šis klausimas nėra pakankamai plačiai išanalizuotas vadybos moksle, analizuojant žmogiškųjų išteklių valdymą, į šias aplinkybes dažnai neatsižvelgiama. Gebėjimas greitai atgauti jėgas reiškia įveikti iššūkius ir tapti stipresniu. Šis gebėjimas gali būti ugdomas taikant ekspertines sistemas, padedančias įvertinti katastrofų pavojų, įgyti finansų, mokymo ir kitų žinių. Tokios sistemos turi būti kuriamos bendradarbiaujant skirtingų sričių specialistams. Ekstremalių situacijų poveikio žmonėms analizė apima visą greito atsistatymo po katastrofų gyvavimo ciklą.

Šiuo metu yra 11 Europos Sąjungos (ES) politikos sričių, susijusių su katastrofų rizikos valdymu: civilinė sauga, klimato kaita, aplinka, sanglaudos politika, solidarumo fondas, sveikata, draudimas, tyrimai, pramonė ir infrastruktūra, humanitarinė pagalba ir vystymas, saugumas ir konfliktų prevencija. ES reglamentai ir direktyvos užima didžiausią šių strategijų, įstatymų ir programų, susijusių su katastrofų rizikos valdymu, dalį. ES valstybės narės (iš kurių viena yra Lietuva) turi laikytis šių dokumentų nuostatų. Reglamentas yra privalomas teisės aktas, kuris galioja visoje ES (European Union… 2015). Potencialiai pavojingi objektai Lietuvoje yra įtraukti į 2005 metų balandžio 18 dienos Lietuvos Respublikos Aplinkos ministro įsakymą Nr. D1-207 (Lietuvos Respublikos... 2005). Pilnas potencialiai pavojingų objektų Lietuvoje sąrašas pateiktas C priede. Lietuvoje yra daugybė ekstremalių situacijų valdymo tikslinių grupių, kurių sąrašas pateikiamas D priede.

Disertacijoje analizuojamos sistemos ir kuriama žmogiškųjų išteklių valdymo ekstremaliose situacijose sistema yra paremtos sprendimų priėmimo metodų ir intelektinių technologijų taikymu. Mokslinėje literatūroje teigiama, kad sprendimų paramos sistemos bei intelektinės technologijos ir sistemos suteikia papildomų privalumų ekspertinėms sistemoms vykdant sprendimų priėmimą. Šių sistemų integravimas leidžia per trumpesnį laiką išspręsti didesnį kiekį užduočių ir problemų bei padeda sumažinti protinio darbo reikalaujančių užduočių skaičių, taip padidinant darbuotojų darbo našumą. Be to, šių sistemų pagalba žinios greičiau gali būti perduodamos vartotojams, jos atrenkamos pagal atitinkamą sritį, reikiamu laiku, o tai leidžia prisitaikyti prie dinamiškos ir kompleksiškai valdomos aplinkos. Integruotos sistemos skirtos nukreipti darbuotojus sudėtingose situacijose, o intelektinės technologijos gali padidinti priimamo sprendimo kokybę ir darbo našumą (Holsapple 2003; Prelipcean, Boscoianu 2011).

Atlikti moksliniai tyrimai parodė, kad teksto analitikos sistemų, katastrofų valdymo sistemų, intelektinių sprendimų paramos sistemų ir fiziologinių parametrų integravimas padeda didinti realių problemų sprendimo mokymo ir praktinių problemų sprendimo efektyvumą.

Tyrimų objektas

Disertacijos tyrimo objektas – visas užstatytos aplinkos greito atsistatymo po katastrofų gyvavimo ciklas, įskaitant ekstremalių situacijų veikiamas suinteresuotąsias grupes.

Darbo tikslas

Pagrindinis tyrimo tikslas – pasiūlyto modelio, sukurtos sistemos ir daugiakriterių metodų pagalba padidinti žmogiškųjų išteklių valdymo ekstremaliose situacijose efektyvumą.

Darbo uždaviniai

Disertacijos tikslui pasiekti sprendžiami šie uždaviniai:

1. Sukurti žmogiškųjų išteklių valdymo ekstremaliose situacijose gyvavimo proceso kompleksinės analizės modelį.
2. Aprašyti žmogiškųjų išteklių valdymo ekstremaliose situacijose gyvavimo procesą, jame dalyvaujančias suinteresuotas grupes ir veikiančią išorinę aplinką kiekybine ir koncepcine formomis.
3. Pritaikyti kompleksinį kriterijų reikšmingumo nustatymo, atsižvelgiant į jų kokybines ir kiekybines charakteristikas, daugiakriterio kompleksinio proporcingo įvertinimo, daugiakriterį naudingumo laipsnio ir rinkos vertės nustatymo bei žmogiškųjų išteklių valdymo ekstremaliose situacijose gyvavimo proceso daugiakriterio variantinio projektavimo metodus.
4. Sukuti žmogiškųjų išteklių valdymo ekstremaliose situacijose intelektinę sprendimų paramos sistemą, susidedančią iš keturių posistemių: fiziologinės rekomendacinės posistemės, skirtos vartotojo stresui po katastrofų valdyti, žmogiškųjų išteklių valdymo ekstremaliose situacijose teksto analitikos posistemės, rekomendacinio termometro, skirto matuoti pasiruošimą greitam atsistatymui po katastrofų bei integruotų virtualių ir intelektinių technologijų posistemės.

Tyrimų metodika

Išsamiai disertacijos tyrimų objekto analizei atlikti buvo pritaikyti daugiakriterės analizės ir rekomendaciniai metodai bei fiziologinės ir intelektinės technologijos (teksto analitikos, rekomendacijų ir sprendimų priėmimo), leidžiantys vartotojams atsižvelgti į ekonominius, techninius, kokybinius, technologinius, socialinius, psichologinius, fiziologinius, etinius, emocinius, religinius, etninius, teisinius, infrastruktūros ir kitus aspektus. Vertinamų veiksnių įvairovė turi atitikti įvairiais būdais pateikiamus sprendimų priėmimui reikalingus duomenis.

Darbo mokslinis naujumas

Teorinių ir eksperimentinių žmogiškųjų išteklių valdymo ekstremaliose situacijose tyrimų mokslinio naujumo aspektai:

1. Sukurtas originalus žmogiškųjų išteklių valdymo ekstremaliose situacijose kompleksinės analizės modelis, sudarantis sąlygas kompleksiškai analizuoti žmogiškųjų išteklių valdymo ekstremaliose situacijose gyvavimo procesą, jame dalyvaujančias suinteresuotas grupes ir veikiančią išorinę mikro, mezo ir makro lygmens aplinką kaip vieną visumą.
2. Aprašytas žmogiškųjų išteklių valdymo ekstremaliose situacijose gyvavimo procesas, jame dalyvaujančios suinteresuotas grupės ir veikianti išorinė aplinka kiekybine (kriterijų sistema ir posistemės, matavimo vienetai, vertės ir svoriai) ir koncepcine (tekstas, formulės, brėžiniai, grafikai, diagramos ir papildyta realybė) formomis.
3. Pritaikyti kompleksinis kriterijų reikšmingumo nustatymo, projektų daugiakriterio kompleksinio proporcingo įvertinimo, daugiakriteris

žmogiškųjų išteklių valdymo ekstremaliose situacijose alternatyvių variantų naudingumo laipsnio ir rinkos vertės nustatymo bei žmogiškųjų išteklių valdymo ekstremaliose situacijose gyvavimo proceso daugiakriterio variantinio projektavimo metodai.

4. Sukurta originali žmogiškųjų išteklių valdymo ekstremaliose situacijose intelektinė sprendimų paramos sistema, susidedanti iš keturių posistemių. Ši sistema skirta užstatytos aplinkos greito atsistatymo po katastrofų daugiavariantiniam projektavimui ir daugiakriterei analizei sumažinimo, pasiruošimo, reagavimo ir atsigavimo etapų metu.

Darbo rezultatų praktinė reikšmė

Praktinė darbo rezultatų reikšmė – kompleksinė užstatytos aplinkos greito atsistatymo po katastrofų gyvavimo ciklo ir jo etapų analizė, panaudota intelektinės sprendimų paramos sistemos, skirtos žmogiškųjų išteklių valdymui ekstremaliose situacijose, sukūrimui. Pritaikant šią sistemą organizacijų veikloje, galima paspartinti atsistatymą po katastrofų kiekviename etape, valdyti stresą ir sumažinti su katastrofomis susijusias išlaidas.

Darbo rezultatai gali būti taikomi bet kurioje organizacijoje, susiduriančioje su ekstremaliomis situacijomis. Sukurta sistema gali naudotis organizacijų vadovai, siekiantys padidinti darbuotojų efektyvumą, taip pat valstybinių organizacijų atstovai, siekiantys kelti ekonominius rodiklius ir sumažinti katastrofų sukeliamas neigiamas pasekmes. Tinkamas pasiruošimas katastrofoms, gebėjimas greitai atsistatyti po jų gali padėti didinti valdymo efektyvumą ir mažinti neigiamą katastrofų poveikį visuomenei bei ekonomikai.

Ginamieji teiginiai

Remiantis atliktų tyrimų rezultatais, buvo iškelti tokie ginamieji teiginiai:

1. Originalus žmogiškųjų išteklių valdymo ekstremaliose situacijose kompleksinės analizės modelis objektyviau vertina užstatytos aplinkos gyvavimo ciklo greito atsistatymo po katastrofų gyvavimo procesą, jame dalyvaujančias suinteresuotas grupes ir veikiančią išorinę mikro, mezo ir makro lygmens aplinką kaip vieną visumą.
2. Intelektinėje žmogiškųjų išteklių valdymo ekstremaliose situacijose sprendimų paramos sistemoje integruota daugiakriterė analizė, rekomendaciniai metodai, fiziologinės ir intelektinės technologijos (teksto analitika, rekomendacinė ir sprendimų parama). Ši sistema objektyviau vertina užstatytos aplinkos gyvavimo ciklo greito atsistatymo po katastrofų gyvavimo procesą sumažinimo, pasiruošimo, reagavimo ir atsigavimo etapuose, juose dalyvaujančias suinteresuotąsias šalis bei mikro, mezo ir makro lygmens aplinkos faktorius. Be to, ši sistema parenka racionaliausias žmogiškųjų išteklių valdymo ekstremaliose situacijose alternatyvas.

Darbo rezultatų aprobavimas

Pagrindiniai disertacijos rezultatai buvo publikuojami vienuolikoje mokslinių straipsnių: du – mokslo žurnaluose, įtrauktuose į *ISI Web of Science* sąrašą (Kaklauskas *et al.* 2011 (5 metų *Impact* faktorius – 2,339]; Kaklauskas *et el.* 2013 (5 metų Impact faktorius – 2,339)); vienas – recenzuojamame mokslo žurnale „Mokslas – Lietuvos ateitis“ (Matuliauskaitė, Žemeckytė 2011); keturi – recenzuojamuose tarptautinių konferencijų leidiniuose (Kaklauskas *et al.* 2012; Kaklauskas *et al.* 2013; Kaklauskas *et al.* 2014; Kaklauskas *et al.* 2014) ir trys – Lietuvos jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis“ straipsnių rinkiniuose (Girkantaitė *et al.* 2011; Bartkienė *et al.* 2013; Pališkienė, Pečiūrė 2014).

Disertacinio tyrimo rezultatai buvo paskleisti penkiose mokslinėse konferencijose užsienyje ir Lietuvoje:

- tarptautinėje konferencijoje „4th International Conference on Building Resilience, Incorporating the 3rd Annual Conference of the ANDROID Disaster Resilience Network“ Salforde, Jungtinėje Karalystėje 2014 m.;
- tarptautinėje konferencijoje „International Conference Informatics in Control, Automation and Robotics (CAR 2011)“, Šendžene, Kinijoje 2011 m.;
- jaunųjų mokslininkų konferencijose „Mokslas ¬ Lietuvos ateitis“, Vilniuje, Lietuvoje 2011, 2013 ir 2014 m.

Darbo rezultatai buvo panaudoti vykdant tris tarptautinius ERASMUS programos projektus: „Atstatymo po katastrofų akademinis tinklas, skirtas aukštojo mokslo vystymo optimizavimui“ (ANDROID), „Bendra iniciatyva siekiant mokyti grėsmių prevencijos“ (CADRE) ir „Studijų programų atstatymo po katastrofų valdymo srityje atnaujinimas diegiant atviros prieigos ir papildytos realybės intelektines sistemas (RESINT).

Taip pat, darbo rezultatai buvo panaudoti studijų procese, papildant jais magistrantūros studijų programas „Internetinė ir biometrinė verslo valdymo sprendimų parama“ ir „Biometrinė ir intelektinė sprendimų parama“ Vilniaus Gedimino technikos universitete.

Disertacijos struktūra

Disertaciją sudaro įvadas, trys skyriai ir bendrosios išvados, literatūros sąrašas, autorės publikacijų sąrašas ir devyni priedai.

Darbo apimtis – 162 puslapiai be priedų, tekste pateiktos 37 numeruotos formulės, 20 paveikslų ir 17 lentelių. Rašant disertaciją buvo naudotasi 213 literatūros šaltinių.

1. Žmogiškųjų išteklių valdymas ekstremaliose situacijose: mokslinis požiūris ir problematika

Šiame skyriuje išanalizuota mokslinė literatūra, kurioje aprašomas katastrofų ir atsistatymo po jų valdymas. Taip pat išanalizuotos pasaulio mokslininkų taikomos intelektinės sprendimų paramos sistemos (intelektinės sprendimų paramos sistemos ir darbo našumas, įvadas į intelektines sprendimų paramos sistemas, teksto analitikos sistemos, neraiškiųjų skaičių teorijos intelektinė sprendimų paramos sistema, kitos sistemos, skirtos greito atsistatymo po katastrofų analizei). Išanalizuoti fiziologiniai parametrai (kraujo spaudimo ir pulso priklausomybė nuo asmens patiriamo streso ir odos temperatūros priklausomybė nuo asmens patiriamo streso), taikomi žmogiškųjų išteklių valdymui ekstremaliose situacijose. Remiantis pirmajame skyriuje atlikta analize galima konstatuoti, kad:

1. Atlikta literatūros analizė parodė, kad pasaulyje nėra sukurtų intelektinių sprendimų paramos sistemų, kuriose būtų integruotas žmogiškųjų išteklių valdymas ekstremaliose situacijose ir kurios išsamiai analizuotų alternatyvas iš ekonominės, techninės, infrastruktūros, kokybinės, technologinės, teisinės ir kitų perspektyvų. Be to, nei viena intelektinė sprendimų paramos sistema neanalizuoja alternatyvų kiekybine (kriterijų sistema ir posistemės, matavimo vienetai, vertės ir svoriai) ir koncepcine (tekstas, formulės, brėžiniai, grafikai, diagramos ir papildyta realybė) formomis.
2. Pasaulyje atlikta daugybė tyrimų, kuriuose taikomi fiziologiniai metodai, skirti žmogaus streso lygio nustatymui, sukurta nemažai tuo paremtų sistemų. Tačiau šios sistemos nenustato po katastrofų kylančio streso lygio, neatlieka užstatytos aplinkos greito atsistatymo po katastrofų gyvavimo ciklo (sumažinimo, pasiruošimo, reagavimo ir atsigavimo etapais) daugiakriterės analizės, neteikia žmogiškiesiems ištekliams ekstremaliose situacijose valdyti skirtų rekomendacijų, pritaikytų konkrečiam vartotojui, neatlieka alternatyvų analizės ir neparenka geriausios iš jų vartotojui. Vis dėlto, šios funkcijos yra labai reikalingos.
3. Patys pažangiausi teksto analitikos uždaviniai apima teksto klasifikavimą, teksto grupavimą, koncepcijos/subjekto išskyrimą, apibendrinimą, modelių išvedimą per struktūrizuotus duomenis, nuotaikų ir emocijų analizę, dokumentų santraukas, subjekto santykio modeliavimą ir rezultatų interpretavimą. Tačiau egzistuojančios teksto analitikos sistemos negali pateikti alternatyvų (atlikti daugiavariantinio projektavimo), atlikti daugiakriterės analizės ar automatizuotu būdu parinkti efektyviausio varianto pagal tam tikrus aspektus, pavyzdžiui, straipsnių citavimo indeksą (*Scopus*, *ScienceDirect*, *Google Scholar* duomenų bazės), autoriaus vertinimą, vykdyti atrankos iš daugiausiai cituojamų 25 straipsnių, vertinti žurnalų *Impact* faktorių, atrinkti pagal dokumentų pavadinimus ir turinį, ar raktinių žodžių pasikartojimų dažnumą.
4. Mokslinėje literatūroje aprašomi įvairūs termometrai ir panašios skalės, skirtos žmogiškųjų išteklių ir atsistatymo po katastrofų valdymui: distreso termometras, panikos termometras, baimės termometras, ugnies pavojaus termometras, audrų skalės, žemės drebėjimų skalės (*Richterio* ir *Mercalli*), nerimo termometras, pagalbos termometras, problemų termometras, emocijų termometras, depresijos termometras, Torino skalė (skirta prognozuoti asteroidų/kometų poveikį), per didelio karščio laikrodis ir kiti. Šie termometrai neturi galimybės automatiškai matuoti konkretaus vartotojo ir jo aplinkos pasiruošimo katastrofoms (pavyzdžiui, potvyniams), be to, jie negali atlikti daugiakriterės rekomendacijų analizės ir išrinkti vartotojui labiausiai tinkančių.
5. Atlikta analizė parodė, kad sukurtose sistemose nėra integruota papildyta realybė su kitomis streso, greito atsistatymo po katastrofų ir teksto analitikos sistemomis bei termometrais ir kitomis skalėmis.

2. Žmogiškųjų išteklių valdymo ekstremaliose situacijose modelis ir tyrimo metodai

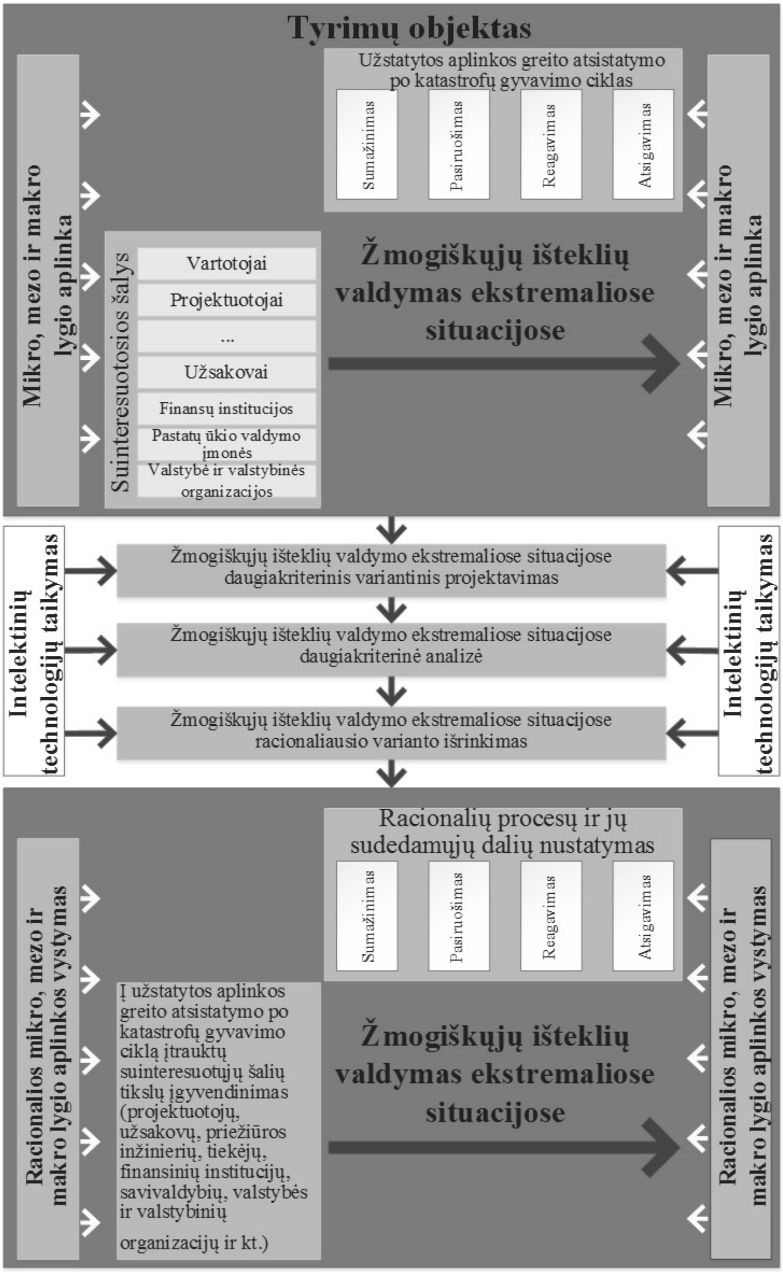
Įvairių šalių mokslininkai, savo darbuose nagrinėdami daugiakriterės analizės ir matematinius metodus, neanalizavo tokio tyrimo objekto kaip autorė: žmogiškųjų išteklių valdymo ekstremaliose situacijose, užstatytos aplinkos greito atsistatymo po katastrofų gyvavimo proceso, jame dalyvaujančių suinteresuotų grupių ir veikiančios išorinės aplinkos kaip vienos visumos. Šiai tyrimo objekto daugiakriterei analizei atlikti buvo pritaikyti daugiakriterės analizės ir matematiniai metodai bei integruotos intelektinės technologijos (S2.1 pav.).

Disertacijos rengimo metu buvo pasiūlyta kompleksinės žmogiškųjų išteklių valdymo ekstremaliose situacijose analizės modelio praktinio įgyvendinimo schema (S2.2 pav.).

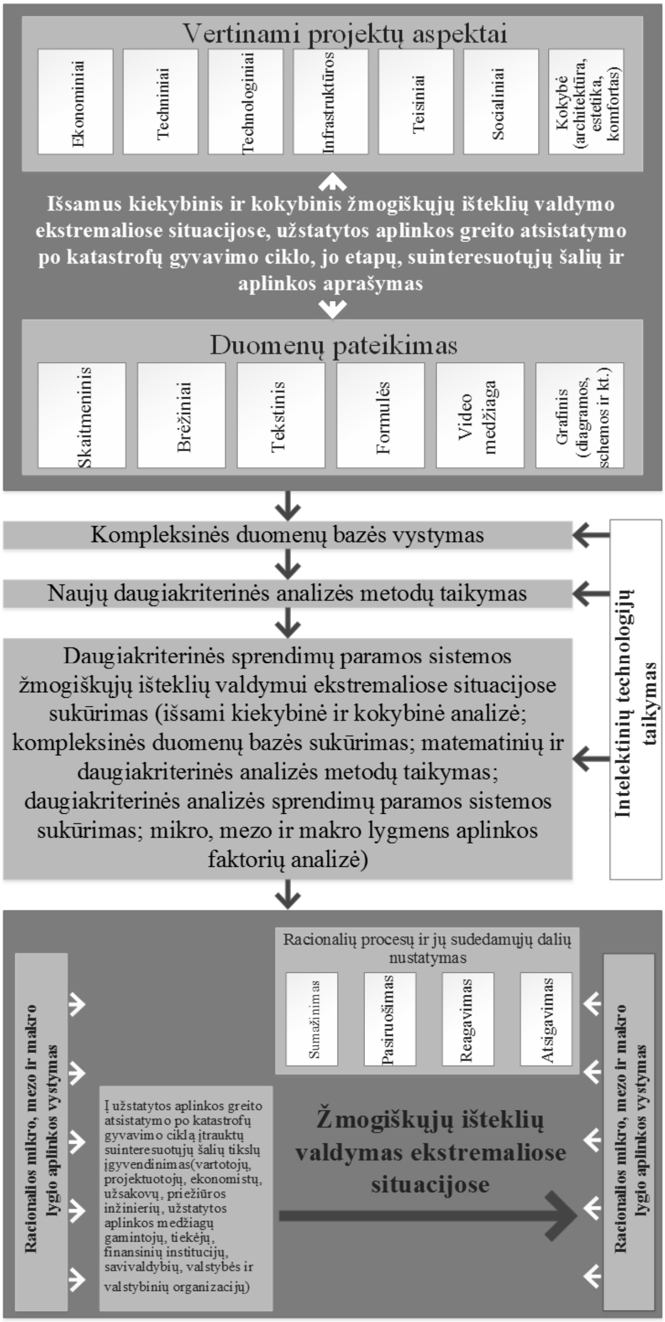
Daugiakriterinė sprendimų paramos sistema žmogiškųjų išteklių valdymui ekstremaliose situacijose sukurta taip:

- atlikta išsami kiekybinė ir kokybinė užstatytos aplinkos greito atsistatymo po katastrofų gyvavimo ciklo, jo etapų suinteresuotųjų šalių ir aplinkos analizė;
- remiantis tyrimų objekto aprašymu sukurta kompleksinė duomenų bazė;
- pritaikyti matematiniai ir daugiakriterinės analizės metodai, skirti žmogiškųjų išteklių valdymo ekstremaliose situacijose daugiakriterinei analizei, alternatyvų naudingumo laipsnio ir prioritetų nustatymui;
- sukurta daugiakriterinės analizės sprendimų paramos sistema, skirta daugiakriteriniam kompiuteriniam žmogiškųjų išteklių valdymo ekstremaliose situacijose projektavimui, lternatyvų naudingumo laipsnio ir prioritetų nustatymui;
- atlikta žmogiškųjų išteklių valdymą ekstremaliose situacijose įtakojančių mikro, mezo ir makro lygmens aplinkos faktorių analizė ir jų pakeitimas.

Atliekant daugiakriterę analizę, lyginamų metodų analizės rezultatai pateikiami sprendimų matricos pavidalu, kur stulpeliai išreiškia nagrinėjamus n alternatyvius projektus, o eilutėse pateikiama kiekybinė ir koncepcinė informacija, išsamiai apibūdinanti nagrinėjamas alternatyvas. Žmogiškųjų išteklių valdymo ekstremaliose situacijose alternatyvas aprašant kiekybine ir koncepcine formomis, pateikiama jo įvairius aspektus (ekonominius, techninius, technologinius, infrastruktūrinius, architektūrinius, estetinius, komfortinius, teisinius, socialinius) apibūdinanti informacija. Kiekybinė informacija apima kriterijų sistemas, matavimo vienetus, reikšmes ir pradinius reikšmingumus, minimizuojantį ar maksimizuojantį kriterijų, informaciją apie alternatyvių projekto variantų sudarymą. Aprašant žmogiškųjų išteklių valdymą ekstremaliose situacijose koncepcine forma, tekstu, schemomis, grafikais, diagramomis, brėžiniais ir vaizdajuostėmis pateikiama koncepcinė informacija apie variantus ir juos išsamiai apibūdinančius kriterijus.



S2.1 pav. Žmogiškųjų išteklių valdymo ekstremaliose situacijose kompleksinės analizės modelis



S2.2 pav. Praktinis modelio įgyvendinimas

Aprašant kriterijus, nurodomos priežastys ir pagrindimas, kuriais remiantis buvo nustatyti kriterijų sistema, reikšmės ir reikšmingumai, taip pat pateikiama informacija apie variantinio projektavimo galimybes. Šiuo atveju nagrinėjamos alternatyvos, jas apibūdinanti kiekybinė ir koncepcinė informacija grupuojamos tam tikra tvarka, t. y. paruošiama žmogiškųjų išteklių valdymo ekstremaliose situacijose metodų daugiakriterės analizės sugrupuota sprendimų priėmimo matrica. Norint išrinkti efektyviausią metodą, reikia, sudarius sprendimų priėmimo matricą, atlikti metodų daugiakriterę analizę. Tai atliekama lyginant nagrinėjamų projektų kriterijų reikšmes ir reikšmingumus, analizuojant koncepcinę informaciją.

Streso atpažinimui pritaikyti Logit, k-artimiausių kaimynų, Marquardto atgalinės sklaidos ir tampriosios atgalinės sklaidos metodai.

Remiantis antrajame skyriuje pasiūlytais metodais ir modeliu bei atlikta analize galime konstatuoti, kad:

1. Sukurtas naujas žmogiškųjų išteklių valdymo ekstremaliose situacijose kompleksinės analizės modelis padeda atlikti užstatytos aplinkos greito atsistatymo po katastrofų ir jo etapų, suinteresuotųjų šalių ir supančios mikro, mezo ir makro lygmens aplinkos kaip vienos visumos analizę.
2. Taikydami daugiakriterės analizės metodus, mokslininkai neanalizuoja disertacijoje pateikiamos temos, t.y. žmogiškųjų išteklių valdymo ekstremaliose situacijose, suinteresuotųjų šalių ir supančios mikro, mezo ir makro lygmens aplinkos kaip vienos visumos.
3. Pritaikytas kompleksinis kriterijų reikšmingumo nustatymo metodas, kuriuo remiantis galima apskaičiuoti ir tarpusavyje suderinti kiekybinių ir kokybinių kriterijų reikšmingumus, atsižvelgiant į jų kiekybines ir kokybines charakteristikas.
4. Panaudotas daugiakriterio kompleksinio proporcingo įvertinimo metodas, kuriuo remiantis apskaičiuojamas kompleksinį metodo efektyvumą apibūdinantis apibendrintas kriterijus. Šis apibendrintas kriterijus tiesiogiai ir proporcingai priklauso nuo lyginamų kriterijų reikšmių ir reikšmingumų santykinės įtakos žmogiškųjų išteklių valdymo ekstremaliose situacijose kompleksiniam efektyvumui.
5. Siekiant nustatyti, prie kokios žmogiškųjų išteklių valdymo ekstremaliose situacijose pasirinkto metodo rinkos vertės jis būtų vienodai konkurentabilus, kompleksiškai įvertinus alternatyvų teigiamas ir neigiamas savybes, buvo pritaikytas daugiakriteris naudingumo laipsnio ir rinkos vertės nustatymo metodas. Pagal šį metodą apskaičiuotų nagrinėjamų žmogiškųjų išteklių valdymo ekstremaliose situacijose variantų naudingumo laipsniai ir vertinamojo varianto rinkos vertė tiesiogiai ir proporcingai priklauso nuo juos adekvačiai apibūdinančių kriterijų sistemos, kriterijų reikšmių ir reikšmingumų dydžių.
6. Pritaikytas žmogiškųjų išteklių valdymo ekstremaliose situacijose gyvavimo proceso daugiakriterio variantinio projektavimo metodas, kuriuo remiantis galima automatizuotu būdu sudaryti daugelį alternatyvių

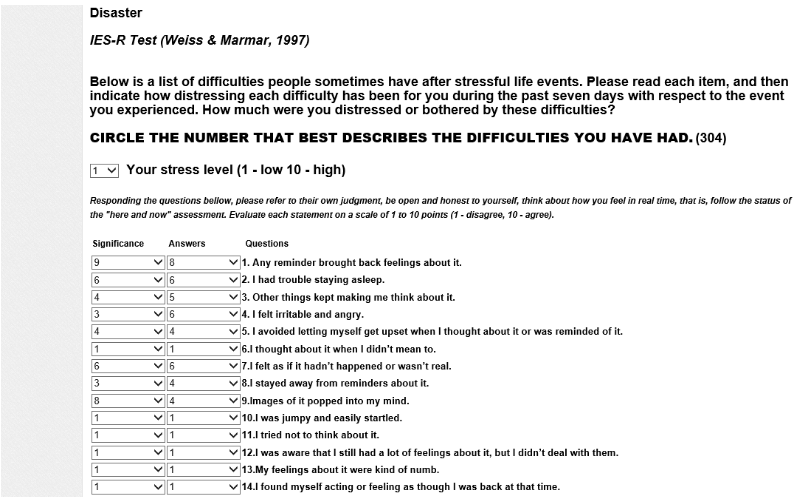
projekto variantų. Kiekvienas automatizuotu būdu sudarytas žmogiškųjų išteklių valdymo ekstremaliose situacijose gyvavimo proceso variantas apibūdinamas koncepcine ir kiekybine informacija.

7. Streso atpažinimui pritaikyti Logit, k-artimiausių kaimynų, Marquardto atgalinės sklaidos ir tampriosios atgalinės sklaidos metodai.

3. Žmogiškųjų išteklių valdymo ekstremaliose situacijose intelektinė sprendimų paramos sistema

Remiantis atlikta neuroninių tinklų, informacinių, ekspertinių ir sprendimų paramos sistemų (intelektinės sprendimų paramos sistemos, teksto analitikos sistemos, neraiškiųjų skaičių teorijos intelektinės sprendimų paramos sistemos ir kitos sistemos, skirtos greito atsistatymo po katastrofų analizei) analize, 2 skyriuje aprašytais pagrindiniais principais, metodais ir modeliu, buvo sukurta žmogiškųjų išteklių valdymo ekstremaliose situacijose sistema, susidedanti iš tokių posistemių:

- fiziologinė rekomendacinė posistemė, skirta vartotojo stresui po katastrofų valdyti,
- žmogiškųjų išteklių valdymo ekstremaliose situacijose teksto analitikos posistemė,
- rekomendacinis termometras, skirtas matuoti pasiruošimą greitam atsistatymui po katastrofų,
- integruotų virtualių ir intelektinių technologijų posistemė.



Disaster

IES-R Test (Weiss & Marmar, 1997)

Below is a list of difficulties people sometimes have after stressful life events. Please read each item, and then indicate how distressing each difficulty has been for you during the past seven days with respect to the event you experienced. How much were you distressed or bothered by these difficulties?

CIRCLE THE NUMBER THAT BEST DESCRIBES THE DIFFICULTIES YOU HAVE HAD. (304)

1 **Your stress level (1 - low 10 - high)**

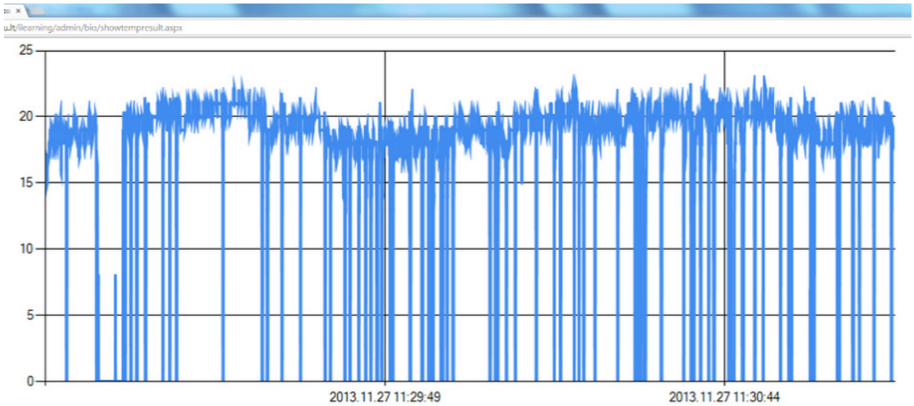
Responding the questions bellow, please refer to their own judgment, be open and honest to yourself, think about how you feel in real time, that is, follow the status of the "here and now" assessment. Evaluate each statement on a scale of 1 to 10 points (1 - disagree, 10 - agree).

Significance	Answers	Questions
9	8	1. Any reminder brought back feelings about it.
6	6	2. I had trouble staying asleep.
4	5	3. Other things kept making me think about it.
3	6	4. I felt irritable and angry.
4	4	5. I avoided letting myself get upset when I thought about it or was reminded of it.
1	1	6.I thought about it when I didn't mean to.
6	6	7.I felt as if it hadn't happened or wasn't real.
3	4	8.I stayed away from reminders about it.
8	4	9.Images of it popped into my mind.
1	1	10.I was jumpy and easily startled.
1	1	11.I tried not to think about it.
1	1	12.I was aware that I still had a lot of feelings about it, but I didn't deal with them.
1	1	13.My feelings about it were kind of numb.
1	1	14.I found myself acting or feeling as though I was back at that time.

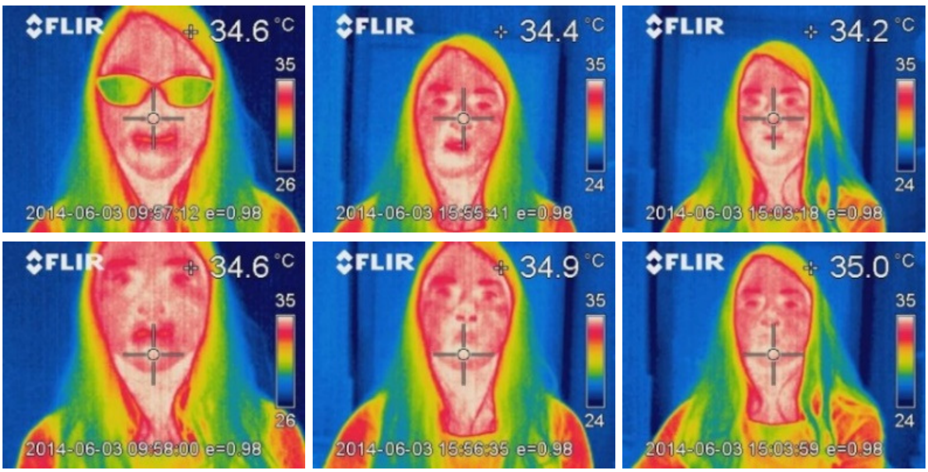
S3.1 pav. Fiziologinės rekomendacinės posistemės fragmentas

Kuriant fiziologinę rekomendacinę posistemę, skirtą vartotojo stresui po katastrofų valdyti (S3.1 pav.), buvo išanalizuota vartotojo streso po katastrofų ir jo fiziologinių duomenų priklausomybė bei vartotojo streso po katastrofų ir jo temperatūros duomenų priklausomybė (S3.2 pav. ir S3.3 pav.), panaudojant Logit, k-artimiausių kaimynų, Marquardto atgalinės sklaidos ir tampriosios atgalinės sklaidos algoritmus ir sukurtų priklausomybių patikimumo įvertinimą.

a)



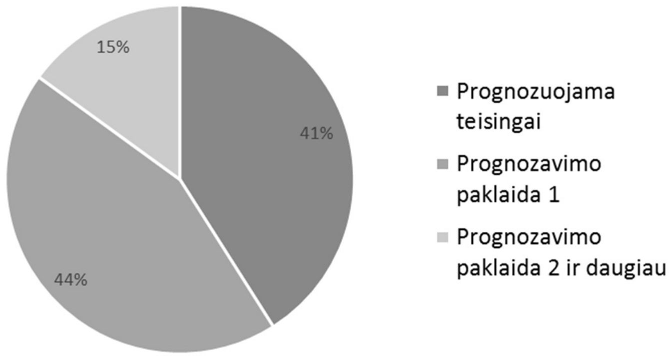
b)



S3.2 pav. Vartotojo fiziologinės duomenų bazės fragmentas: a) vartotojo akies vyzdžio dydžio kaita ir mirksėjimo dažnumas, b) asmens veido temperatūra

Žmogiškųjų išteklių valdymo ekstremaliose situacijose teksto analitikos posistemė ANDROID projektui buvo kuriama tokiais pagrindiniais etapais:

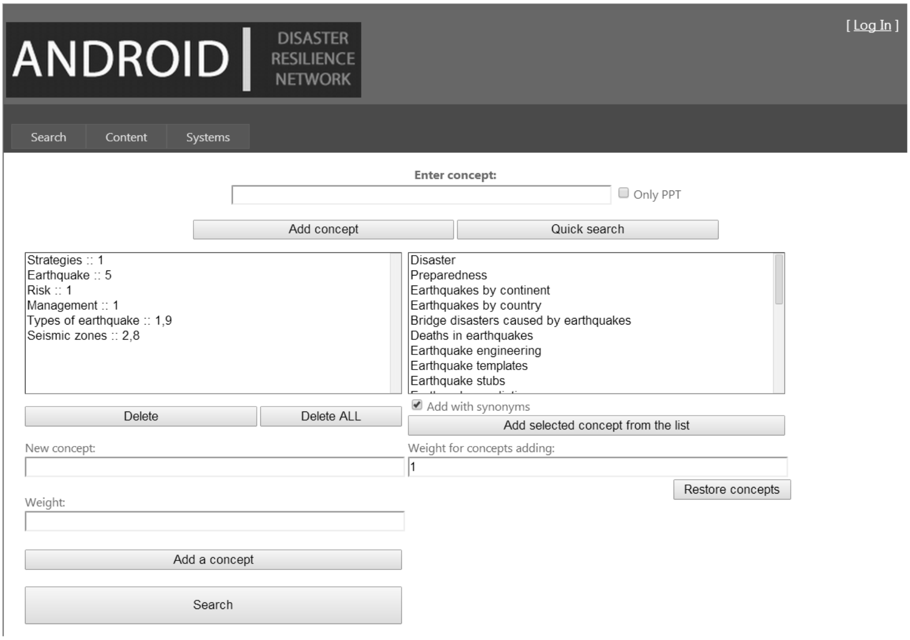
- nustatomi pradiniai reikalavimai paieškai,
- sudaromas vartotojo modelis: pradiniai reikalavimai paieškai ir agento posistemė (S3.4 pav.),
- kuriama racionalus teksto atrinkimo posistemė: atskirų dalių daugiakriterės analizės modulis (ženklų/pastraipų/skyrių).



S3.3 pav. Vartotojo streso lygio po katastrofų nustatymo tikslumas

Žmogiškųjų išteklių valdymo ekstremaliose situacijose teksto analitikos posistemėje ANDROID projektui tekstas apibrėžiamas šiais faktoriais:

- straipsnių citavimo indeksas (Scopus, ScienceDirect, Google Scholar),
- autorių citavimas (Scopus, ScienceDirect, Google Scholar),
- geriausi 25 straipsniai,
- žurnalų *Impact* faktorius,
- teksto populiarumas (citavimo indeksas, skaitytojų skaičius, laikas, praleistas skaitant),
- dokumentų patikimumas,
- pagalbinės frazės,
- dokumentų pavadinimas ir turinys,
- reikšminių žodžių pasikartojimo dažnumas.



S3.4 pav. Teksto analitikos posistemės, skirtos ANDROID projektui, vartotojo langas

Precipitation extremes	+		0.025	0.0044 AVG MIN	0.0038 AVG MIN	0.0044 AVG MIN	0.0044 AVG MIN	0.005 AVG MIN	0.0031 AVG MIN
Societal and governmental issues	+		0.012	0.002 AVG MIN	0.0023 AVG MIN	0.002 AVG MIN	0.0023 AVG MIN	0.0015 AVG MIN	0.0018 AVG MIN
Wildcards	-		0.021	0.0041 AVG MIN	0.0026 AVG MIN	0.002 AVG MIN	0.0036 AVG MIN	0.0046 AVG MIN	0.0041 AVG MIN
Rapid ice-sheet melting	+		0.026	0.0048 AVG MIN	0.0041 AVG MIN	0.0034 AVG MIN	0.0048 AVG MIN	0.0048 AVG MIN	0.0041 AVG MIN
Frozen port	+		0.009	0.0016 AVG MIN	0.0018 AVG MIN	0.002 AVG MIN	0.0016 AVG MIN	0.0007 AVG MIN	0.0013 AVG MIN
Port malaria incidents	+		0.026	0.0051 AVG MIN	0.0044 AVG MIN	0.0051 AVG MIN	0.0038 AVG MIN	0.0032 AVG MIN	0.0044 AVG MIN
Enduring heat and drought	+		0.025	0.0042 AVG MIN	0.0048 AVG MIN	0.0042 AVG MIN	0.0042 AVG MIN	0.0036 AVG MIN	0.0042 AVG MIN
Extreme storm	+		0.03	0.0062 AVG MIN	0.0031 AVG MIN	0.0046 AVG MIN	0.0054 AVG MIN	0.0062 AVG MIN	0.0046 AVG MIN
Maeslantkering failure plus extreme storm	+		0.032	0.0063 AVG MIN	0.0049 AVG MIN	0.0056 AVG MIN	0.0056 AVG MIN	0.0063 AVG MIN	0.0035 AVG MIN
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				0.1712	0.1555	0.1556	0.1656	0.1683	0.1452
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0.0068	0.0054	0.0044	0.006	0.0087	0.0065
Significance of the alternative				0.1768	0.1625	0.1642	0.1719	0.1727	0.151
Priority of the alternative				1	5	4	3	2	6
Utility degree of the alternative (%)				100%	91.94%	92.9%	97.25%	97.67%	85.44%

S3.5 pav. Potvynių valdymo užstatytoje aplinkoje daugiakriterės analizės rezultatų fragmentas

Disertacijoje pateikiamas sukurtas rekomendacinis termometras, skirtas matuoti pasiruošimą greitam atsistatymui po katastrofų, susidedantis iš duomenų bazės, duomenų bazės valdymo posistemės, modelių bazės, modelių bazės valdymo posistemės ir vartotojo sąsajos. Panaudojant šį termometrą, gali būti skaičiuojamas investicijų į pasiruošimą katastrofoms ir atsistatymui po jų dydis bei jų naudingumas. Pavyzdžiui, 3.5 paveiksle pateiktas pasiruošimo potvynių valdymui užstatytoje aplinkoje daugiakriterės analizės rezultatų fragmentas.

Integruotų virtualių ir intelektinių technologijų posistemė susideda iš dominančių vietų paieškos modulio, rekomendacinio modulio ir papildytos realybės modulio.

Remiantis trečiajame skyriuje sukurta žmogiškųjų išteklių valdymo ekstremaliose situacijose sistema ir posistemėmis bei atlikta analize galime konstatuoti, kad:

1. Sukurta sistema gali išsamiai įvertinti alternatyvius variantus iš ekonominės, techninės, infrastruktūros, kokybinės, technologinės, teisinės ir kitų perspektyvų. Ši sistema leidžia išanalizuoti žmogiškųjų išteklių valdymo ekstremaliose situacijose metodus kiekybiškai (kriterijų posistemė, matavimo vienetai, vertės ir svoriai) ir konceptualiai (tekstas, formulės, schemos, grafikai, diagramos, papildyta realybė). Tokia išsami analizė anksčiau nebuvo naudojama nagrinėjant žmogiškųjų išteklių valdymą ekstremaliose situacijose.
2. Fiziologinė rekomendacinė posistemė, skirta vartotojo stresui po katastrofų valdyti skirta vartotojo stresui po katastrofų mažinti, panaudojant daugiakriterį projektavimą ir parenkant konkrečiam vartotojui skirtas rekomendacijas. Šiam tikslui naudojama patikslinta įvykio poveikio skalė (IES-R), kurios pagalba vartotojas pats įvertina savo būklę, yra nustatomi simptomai, jų reikšmingumas ir sudaromos rekomendacijos.
3. Pasaulyje egzistuojančios teksto analitikos sistemos negali pateikti tekstinės medžiagos alternatyvų (atlikti daugiavariantinio projektavimo), atlikti daugiakriterės analizės ar automatiškai parinkti efektyviausio varianto (pagal straipsnių citavimo indeksą (Scopus, ScienceDirect, Google Scholar), autorių vertinimą (Scopus, ScienceDirect, Google Scholar), geriausių 25 straipsnių analizę, žurnalų *Impact* faktorių, dokumento pavadinimą ir raktinių žodžių pasikartojimo intensyvumą). Sukurta žmogiškųjų išteklių valdymo ekstremaliose situacijose teksto analitikos posistemė gali vykdyti šias funkcijas ir pateikti geriausius variantus.
4. Rekomendacinis termometras, skirtas matuoti pasiruošimą greitam atsistatymui po katastrofų turi keletą inovacinių aspektų. Jis automatiškai gali nustatyti pasiruošimą greitam atsistatymui po katastrofų (potvynių), parinkti alternatyvias rekomendacijas, atlikti šių rekomendacijų daugiakriterę analizę ir parinkti reikšmingiausias konkrečiam vartotojui. Jokia kita sistema pasaulyje neturi šių funkcijų.
5. Integruotų virtualių ir intelektinių technologijų posistemė yra integruota su fiziologine rekomendacine posisteme, skirta vartotojo stresui po katastrofų valdyti, žmogiškųjų išteklių valdymo ekstremaliose situacijose

teksto analitikos posisteme, rekomendaciniu termometru, skirtu matuoti pasiruošimą greitam atsistatymui po katastrofų.

6. Autorės kartu su kolegomis sukurta žmogiškųjų išteklių valdymo ekstremaliose situacijose intelektinė sprendimų paramos sistema nuo kitų pasaulyje egzistuojančių sistemų skiriasi tyrimo objektu ir esamų metodų pritaikymu naujoje tyrimų srityje – žmogiškųjų išteklių valdymui ekstremaliose situacijose.

Bendrosios išvados

1. Atlikus literatūros analizę nepavyko rasti intelektinių sprendimų paramos sistemų, kurių pagalba būtų galima efektyvinti žmogiškųjų išteklių valdymą ekstremaliose situacijose ir kurios išsamiai vertintų projektų alternatyvas iš ekonominės, techninės, infrastruktūros, kokybinės, technologinės, teisinės ir kitų perspektyvų kokybine ir kiekybine formomis.
2. Pritaikytas žmogiškųjų išteklių valdymo ekstremaliose situacijose kompleksinės analizės modelis padeda atlikti užstatytos aplinkos greito atsistatymo po katastrofų ir jo etapų, suinteresuotųjų šalių ir supančios mikro, mezo ir makro lygmens aplinkos kaip vienos visumos analizę ir taip pasiruošti ekstremalioms situacijoms.
3. Kuriant intelektinę žmogiškųjų išteklių valdymo ekstremaliose situacijose sprendimų paramos sistemą, buvo pritaikytas kompleksinis kriterijų reikšmingumo nustatymo metodas, kuriuo remiantis sistemos pagalba galima apskaičiuoti ir tarpusavyje suderinti kiekybinių ir kokybinių kriterijų reikšmingumus, atsižvelgiant į jų kiekybines ir kokybines charakteristikas.
4. Taikant daugiakriterio kompleksinio proporcingo įvertinimo metodą apskaičiuojamas kompleksinį žmogiškųjų išteklių valdymo ekstremaliose situacijose efektyvumą apibūdinantis apibendrintas (redukuotas) kriterijus. Šis apibendrintas kriterijus tiesiogiai ir proporcingai priklauso nuo lyginamų kriterijų reikšmių ir reikšmingumų santykinės įtakos žmogiškųjų išteklių valdymo ekstremaliose situacijose kompleksiniam efektyvumui.
5. Siekiant nustatyti, prie kokios vertinamojo žmogiškųjų išteklių valdymo ekstremaliose situacijose varianto rinkos vertės jis būtų vienodai konkurentabilus rinkoje, kompleksiškai įvertinus visų alternatyvų teigiamas ir neigiamas savybes, buvo pritaikytas daugiakriteris alternatyvų naudingumo laipsnio ir rinkos vertės nustatymo metodas. Panaudojus šį metodą ir apskaičiavus nagrinėjamų žmogiškųjų išteklių valdymo ekstremaliose situacijose variantų naudingumo laipsnius, galima išrinkti kainos ir efektyvumo požiūriu geriausią alternatyvą.

6. Panaudojant daugiakriterio variantinio projektavimo metodą, galima automatizuotu būdu sudaryti daugelį alternatyvių žmogiškųjų išteklių valdymo ekstremaliose situacijose variantų, iš kurių sistema išrenka efektyviausią.
7. Streso atpažinimui pritaikyti Logit, k-artimiausių kaimynų, Marquardto atgalinės sklaidos ir tampriosios atgalinės sklaidos metodai, kurių pagalba nustatytas ryšys tarp patirto streso ir žmogaus fiziologinių parametrų.
8. Sukurtos keturios posistemės (fiziologinė rekomendacinė posistemė, skirta vartotojo stresui po katastrofų valdyti; žmogiškųjų išteklių valdymo ekstremaliose situacijose teksto analitikos posistemė; rekomendacinis termometras, skirtas matuoti pasiruošimą greitam atsistatymui po katastrofų; integruotų virtualių ir intelektinių technologijų posistemė) leidžia įvertinti žmogiškųjų išteklių valdymo ekstremaliose situacijose alternatyvas iš ekonominės, techninės, infrastruktūros, kokybinės, technologinės, teisinės ir kitų aspektų. Šios keturios posistemės sudaro žmogiškųjų išteklių valdymo ekstremaliose situacijose intelektualią sprendimų paramos sistemą, kuri analizuoja alternatyvas tiek kiekybiškai, tiek konceptualiai.
9. Mokslinėje literatūroje nėra pakankamai išanalizuotas ekstremalių situacijų poveikis žmogiškųjų išteklių valdymui, o pasaulyje sukurtos intelektinės sprendimų paramos sistemos nėra skirtos taikyti visame užstatytos aplinkos greito atsistatymo po katastrofų gyvavimo cikle. Taigi, sukurta sistema nuo kitų panašių sistemų skiriasi tyrimų objekto naujumu, ir naujai tyrimų sričiai pritaikytais daugiakriterės analizės ir matematiniais metodais ir padeda didinti organizacijų valdymo efektyvumą ir mažinti neigiamą katastrofų poveikį visuomenei bei ekonomikai.

Appendices[1]

Appendix A. Physiological Data Table
Appendix B. Temperature Data Table
Appendix C. List of Potentially Dangerous Objects
Appendix D. The Target Groups
Appendix E. EU Policies contributing to Disaster Risk Management
Appendix F. Resilience Management Stages
Appendix G. List of Journals in the Field of Operations Research and Management Science
Appendix H. The Co-authors‘ Agreements to Present Publications Material in the Dissertation
Appendix I. Copies of Scientific Publications by the Author on the Topic of the Dissertation

[1]The appendices are supplied in the enclosed compact disc

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