

MINISTRY OF EDUCATION AND RESEARCH
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DOCTORAL THESIS
~ Summary ~

**The predictive modelling and the spatial data
visualization in the risks management**

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1. INTRODUCTION

In the recent years, the predictive modelling has become important in various fields of activity.

Thus, in medicine, the evolution of diseases can be anticipated by forecasting, and the necessary measures can be taken to stop or to reduce their negative effects.

By modeling, it can be made simulations regarding to the evolution of different diseases or it can be made 3D models of different organs of the human body, with the help of which to study the impact in their functioning, caused by diseases.

In meteorology, there can anticipate by prediction the climate changes, for to prevent or to reduce the damages caused by floods, forest fires in the dry months or hurricanes. With the help of the Geographical Information Systems, there can be created complex models, through which to highlight the necessary resources and the areas where they are located. This is necessary for the fast intervention in order to evacuate the population from areas that are estimated to be affected by disasters.

In archeology, the prediction is used to detect areas where archaeological sites can be located. This requires knowledge of the structure of soils, because depending on certain characteristics of them, there is a higher probability that to exist archaeological sites.

The models, made by 3D scanning, used in archeology, have the role of highlighting the structure of sediments in the soil and the place where the archaeological remains are found.

In geodesy, forecasting can be used to prevent the settlements of the buildings, the break of the bridges, for the monitor of the seismic activities or to prevent the soils erosion.

Thus, in the areas with soils settlements there are located leveling landmarks. Through repeated measurements there are followed the evolution of land movement. In those areas where, following

the measurements carried out, it is estimated that settlements may occur, measures there can be taken measures of consolidation of the buildings that can be affected, by placing concrete in their foundations.

In the case of the bridges, leveling landmarks are located in their vicinity, in the areas which are not affected by vibrations. Through repeated measurements are follow the deformations produced in the structure of the bridges, in order to avoid their rupture. At the same time, 3D simulations with the behavior of the bridges in case of earthquake and for their different intensities, there can be made.

For the monitor of the seismic activities there are made leveling measurements. In this way, there can be identified the areas where quota fluctuations take place, a sign that in those regions the seismic activity is intensifying.

In order to follow the soils erosion in the coastal areas, there are installed leveling landmarks in the stable areas and leveling marks in the points for which we want to determine the elevations. Through repeated measurements, the elevations of the points of interest in the coastal areas there are determined. Based on the existing measurements, there can be made predictions regarding to the change of the quotas. Thus, there can be taken measures to stop soils erosion in coastal areas, such as the construction of dams for protection.

2. THE PREDICTION

According to [9], the notion of prediction is synonymous with that of prevision. Thus, through prevision there means the possibility of anticipating of “the evolution of the future events”. This anticipation is based on the analysis of data for which there are known the values recorded in the past. Within [16] Goleț refers to the notion of prevision, which is a “process” in the author’s acception. Through this process, there are made “assessments or estimates with a probable character on the future”.

According to [8], the prediction represents “the evolution estimate on short-term of the evolution of certain phenomena”.

In [7] Cave brings into question the term prediction, defining it as a “statement of probability of the outcome of a future event”. Specifically, the prediction represents a “conditionated probability statement”. This means that the result obtained from the forecast is conditioned by the information used for the calculation of the probability. Therefore, the prediction will be more accurate if there are used more information to condition the probability statement.

In [1] there is made reference to the notion of prediction in the case of the algorithm testing. The prediction is used, in this case, to check the algorithms when the parameter values of the functions are determined empirically. However, there is not indicated an estimate of the parameters of the functions only by empirical determinations, due to the low accuracy of their determination.

The prediction can be made by the extrapolation method or by the interpolation method.

According to [3], the extrapolation can be used for short-term and long-term prediction.

Through extrapolation there is realizing the prolongation of the evolution of a phenomenon, for which there are known the values registered in the past and there are estimated the values that the respective phenomenon could register in the future.

There can be used several extrapolation methods. These methods depend on the specifics of the problem and on the data which we have available. Thus, there can be used analytical extrapolation, phenomenological extrapolation or winding curve extrapolation.

In the case of analytical extrapolation we want to determine the parameters of a function, so as to obtain the smallest estimation errors.

Examples in this case are time series or correlation functions.

In the case of the analytical extrapolation with the help of the time series, there is determined the tendency of a variable.

To determine the trend, there must first eliminate the seasonal variation, if it exists.

In the case of the analytical extrapolation with the help of the correlation functions, there is projected the dependent variable, noted by “y”. This dependent variable is correlated with the evolution of one or more independent variables.

In the case of the phenomenological extrapolation, it is followed the evolution of a phenomenon, according to [22]. The aim is to establish the meaning of the future evolution of the followed phenomenon. From this analysis there can observe certain “laws” of variation of the phenomenon. These laws are represented graphically by a “**point cloud**”. With the help of the point cloud, there is drawn the curve of the dominant trend. This curve passes through the middle of the point cloud, as can be seen in the **figure no. 1**.

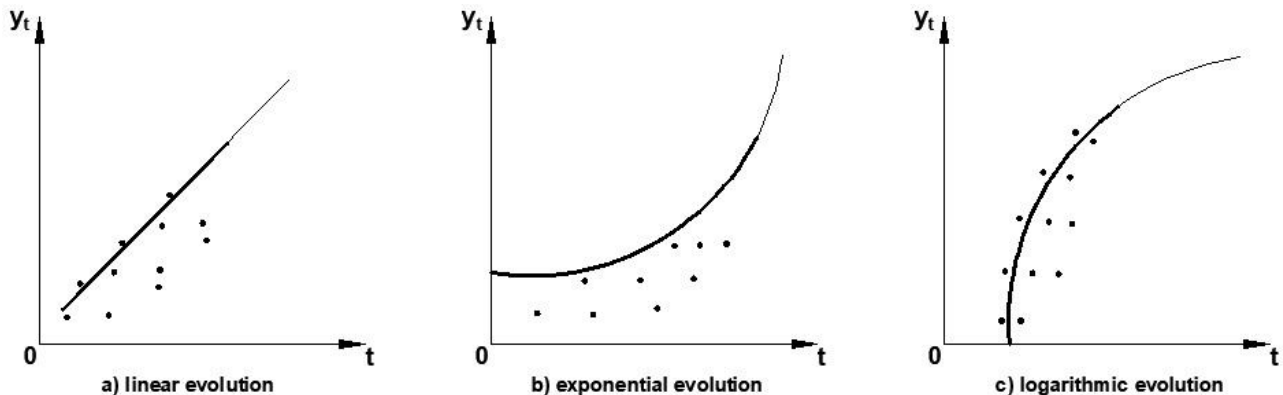


Figure no. 1. Examples of dominant trend curves

(Source: Nicolae, Valentin and others, 2002)

According to [22], this type of extrapolation describes the dynamics of complex processes. These processes consist of several elements. These elements intervene successively in the evolution of the same process. The Extrapolation by winding curve consists in the adjusting of sequential curves, by winding, as can be seen in **the figure no. 2**.

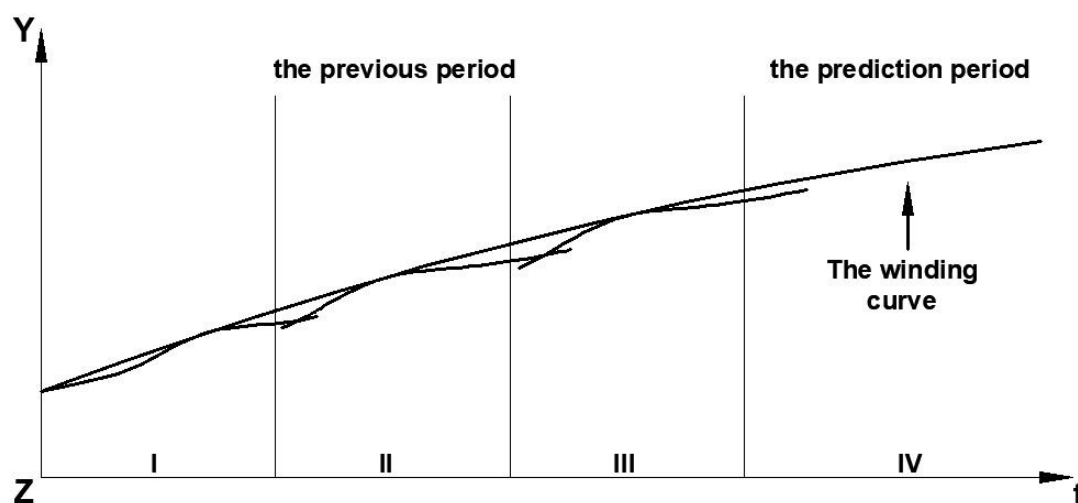


Figure no. 2. The graphical representation of the extrapolation by winding curve

(Source: Nicolae, Valentin and others, 2002)

The interpolation method consists in the establishing of the intermediate values between two given variables. These variables are represented by the initial time and the end time of the forecast period, according to [2].

Li specifies that the prediction methods are used more and more in order to generate predictions in various domains. In this sense, the accuracy of the forecasts is essential. Accuracy is important because the subsequent decisions are made based on estimates.

According to [19], there are 9 major components of the spatial predictive modelling, namely:

- ✓ the sampling design, the sample quality control and spatial reference systems;
- ✓ the choice of the spatial prediction methods;
- ✓ the preselection of the predictive variables;
- ✓ the exploratory analysis for the selection of the variables;
- ✓ the selection of the parameters for the relevant methods;
- ✓ the selection of the variables;
- ✓ accuracy and error measurements for the predictive models;
- ✓ the model validation;
- ✓ spatial predictions, the uncertainty of the predictions and their visualization.

3. THE CURRENT STAGE OF THE PREDICTIVE MODELLING

According to [9], the modeling is “a method that consists in the reproduction of a phenomenon on a smaller scale, in order to study of the characteristics of that phenomenon”.

On the other hand, the term of prediction is defined in [9] as “the operation of anticipation of the evolution of a phenomenon”.

From the two definitions presented above, in the author's opinion, the predictive modelling can be defined as being the reproduction of the evolution of a phenomenon, based on the prediction of the evolution of the characteristics of that phenomenon.

According to [10], through predictive modelling there is understood a collection of mathematical techniques. These procedures have in common the finding of mathematical relationships between a target variable, “dependent” variables and “independent” variables. The purpose is that to estimate the future values of these variables and to introduce them in the mathematical relationship, for the prediction of the future values of the target variable. Because the mathematical relationships are not perfect in practice, there is considered a certain measure of uncertainty for prediction. Usually, the confidence level for prediction is 95%.

In [34] the predictive modelling is defined as being “a process by which the future results are estimated based on past and current data available”. The predictive modelling is a technique of statistical analysis, which involves the evaluation and the calculation of the probability of the estimated results, using applications of probabilistic calculation and prediction of results.

In [15] Duncan defines the predictive modelling as being “a process by which there are estimated the values of variables, according to their relative risk”.

At the national level, examples of usage of the predictive modelling which are given in this doctoral thesis there are in medicine and aviation.

According to [28], the predictive medicine have as objective the research of the genetic risks which presented by a certain person to get sick during of the life. At the same time, there are been considered the preventive side, also, by taking of measures to prevent the occurrence of the diseases or to reduce the effects of the possible diseases, if they occur.

According to [25], the prevention in medicine must cover all the periods of the life, namely: the prenatal and the immediate after birth period, the childhood period, the adolescence and the young adulthood period, respectively the middle and the late life period.

In our country, in the field of the medicine, there is used the 3D computer modelling, according to [23]. The purpose of the 3D computer modelling is the making of the models of the real bodies. The models thus created are used for study, in order to find solutions for the restoration of the damaged organs. The prevention in this case consists in the detection in due time of the medical problems that may occur.

The forecasts which are made in Romania in the aviation domain are defined as being “descriptions of the weather conditions”. These predictions are made “for a certain time or a certain time interval and for a certain area or a certain portion of airspace”.

The forecasts in the aviation domain are made by an aeronautical meteorological unit. By forecasting there are obtained the most probable values of the elements.

In the aviation domain, there can be used several types of forecasts, namely: aerodrome forecasts, landing forecasts, take-off forecasts and nationally issued area and route forecasts.

Internationally, examples of usage of the predictive modelling which are given in this doctoral thesis there are in archeology, medicine and geodesy.

Thus, in [21] there is referred to the fact that as it has developed, archeology has moved from a descriptive discipline to one that attempts to explain aspects of the human behavior. These aspects refer to independent events and variables, known in the past.

The reason for which there is desired the making of a predictive model for archeology is one of a practical nature. When time and money do not allow a complete archaeological research on an area, a predictive model can serve as a tool for choosing the areas where there are most likely archaeological phenomena of interest. The research will then focus on these areas. Thus, there will be obtained a maximum return of the investment, according to [27].

In archeology, a model of predictive localization is defined as being “a simplified set of testable hypotheses”. These hypotheses can be based either on behavioral assumptions or on empirical correlations. This tries to predict the places where there are tooked place human activities in the past, which led to the deposition of artifacts.

The making of the predictive models in archeology supposes the classification of the independent variables, the classification of the dependent variables and the determination of the relationship between them. For example, the dependent variable could be the presence or the absence of the archeological site in a certain area. Independent variables are represented by the environmental variables. In an unknown region, the selection of variables is based on taking into account of the characteristics of the environment.

In [17] there is presented the application of the predictive modelling in the medicine domain in Africa for the detection and the control of the malaria cases.

Thus, the institutions in the health domain from Nigeria have started to use the Geographic Information Systems (the GISs) for the management and the monitoring of the problems and the better making of the decisions. This is due to the recognition of the ability of the Geographic Information Systems (the GISs) to integrate the data in the health domain, which come from different sources. Also, the GISs used in the medicine domain helps to the displaying of this data on maps, to provide a more expressive visual representation. The recognition of the power of the GISs efficiency has led to an increasing number of studies and projects, developed by academic teams and specialists in the health services domain, which include the usage of the GISs as tools for analysis and decisions making.

In order to develop a surveillance system of the malaria, there has been proposed a data model based on the Geographic Information Systems (the GISs). By usage of the GISs in the disease surveillance, and especially in the malaria control, Nigeria can reduce the infections and the deaths due to the malaria, through the usage of the analysis and the prediction.

The application used for the prediction of the malaria is based on the variations of the geographical, the seasonal, the meteorological and the socio-economic factors. Through this aims to establish a causal relationship between these factors and the occurrence of the malaria. For the making of the prediction model there was used the theory of neural networks and there was followed the following steps:

- i. the grouping of the data concerning the malaria on classes;
- ii. the determination of the classes which represent outbreaks of malaria;
- iii. the development of the models on the basis of the results from the first two stages.

The prediction model allows of the application to predict the future occurrence of the malaria, on the basis of the collected data in connection with the past and the current events. This is mainly based on users-supplied data (which has been stored in the database), as well as on the data concerning to the

climate. The model can be modified to be able to make predictions about the malaria epidemics a few months in advance. However, as much the prediction is done earlier, with that the accuracy is less exactly.

This prediction model is developed on the basis of an artificial neural network. The inputs in this network are numerically coded and represent the factors that can determine the appearance of the malaria, such as: the temperature, the presence of the water areas and of the population of the studied area. This has as result a numerically coded representation of the possibility of the malaria occurrence. În domeniul geodeziei, exemple de utilizare ale modelării predictive sunt în cazul metodei colocației prin cele mai mici pătrate și în cazul estimării stării unui sistem cu ajutorul filtrului Kalman. In the geodesy domain, examples of the usage of the predictive modelling are in the case of the least-squares collocation method and in the case of the estimation of the state of a system with the help of the Kalman filter.

According to [18], the least-squares collocation is a method of the data processing, through which there are performed simultaneously the regression (the determination of the parameters of the dominant surface), the filtering (the noise elimination) and the spatial prediction.

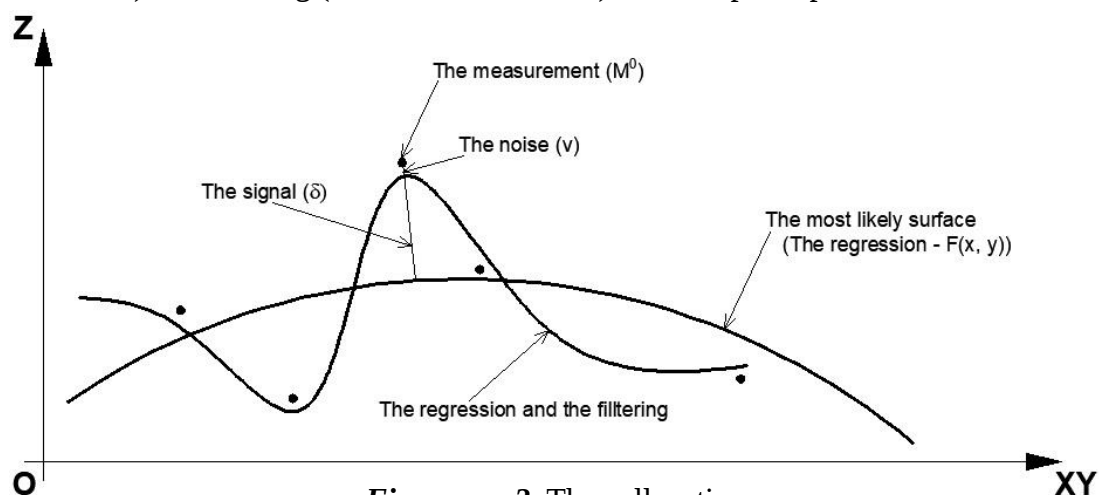


Figure no. 3. The collocation

(Source: Ilie, Andrei-Șerban, 2014)

As can be seen in **the figure no. 3**, the collocation method assumes that the measurements consist of two components, namely:

- the systematic component (the dominant surface);
- the random component, represented by signal (determined by local factors) and noise (caused by measurement errors).

According to [5], the Kalman model is based on the definition of the weighting function, namely what weight should be given to the input data to ensure the best estimate of the quantities currently desired. This is presented in **the figure no. 4**.

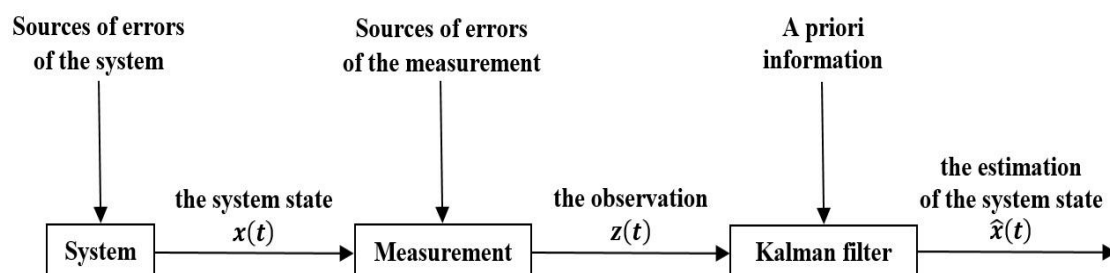


Figure no. 4. The appearance of the block diagram for system, measurement and estimator

(Source: Bogatin, Sonja and others, 2006)

According with [9], there is assumed that the observations, z , consist of l measurements. In their turn, these measurements can be expressed as a linear combination of n elements of estimators, x , and measurement errors, v .

$$z = f(x) + v = Hx + v \quad (3.1)$$

where: H - represents the design matrix.

The H matrix is given by the partial derivatives of the measurements, as in the (3.2) relationship:

$$H = \frac{\partial f(x)}{\partial x^T} \quad (3.2)$$

The principle of operation of the Kalman filter involves two steps, respectively:

- the phase of the prediction of the system state;
- the phase of the adaptation of the system.

For the mitigation of the negative effects of natural disasters, the predictive modelling can be used for the monitoring of the forest fires and by making of the flood risk maps.

Thus, for the monitoring of the forest fires, there have become important the decision-making systems, based on planning and the real-time decision-making, as it is specified in [20]. In this sense, the integration of the Geographic Information Systems (the GISs) has become increasingly important for the realistic modelling of the danger represented by the forest fires and for the prediction of the evolution mode of them.

In the case of the applications for the management of the forest fires, there are used, in real-time, basic maps, topographic data, data concerning to the forest inventory, forest fuel data and meteorological data.

According to [12], the floods are defined as “the temporary cover with water of a land that is not normally covered with water”. The floods are the effect of some complex factors, difficult to assess. The floods are natural phenomena, but their effects are amplified by man, by placing of the socio-economic objectives (human settlements, economic objectives, roads, railways, bridges, etc.) in the meadows of the rivers.

In many countries, the floods represent the most important natural hazards.

Within [12], the floods risk is defined as being “the combination between of the probability of the flooding occurrence and the potential adverse effects for the human health, environment, cultural heritage and the economic activity associated of the occurrence of a flooding”.

In [24], with examples from 19 European countries, U.S.A. and Japan, the floods maps are divided into two categories, namely:

- ✓ the floods danger maps or the floods hazard maps, which cover those areas that could be flooded depending on different scenarios;
- ✓ the floods risk maps, which present the possible negative consequences associated of the floods within these scenarios.

According to [9], the term of “mitigation” is synonymous with “modelling, sweetening”. In the context from here, “the strategy of the mitigation of the risks” means “the strategy of reduction of the negative effects of the risks”.

The planning, the implementation and the monitoring of the process of the risks reduction are presented in **the figure no. 5**. The process presented in the figure below is an iterative one, as it is specified in [32]. The risks tracking makes possible the record of the results of the analysis of prioritization of the risks (*The 3th stage of the process*), which helps both at the mitigation of the risks (*The 4th stage of the process*) and at the assessment of the impact at risk (*The 2th stage of the process*).

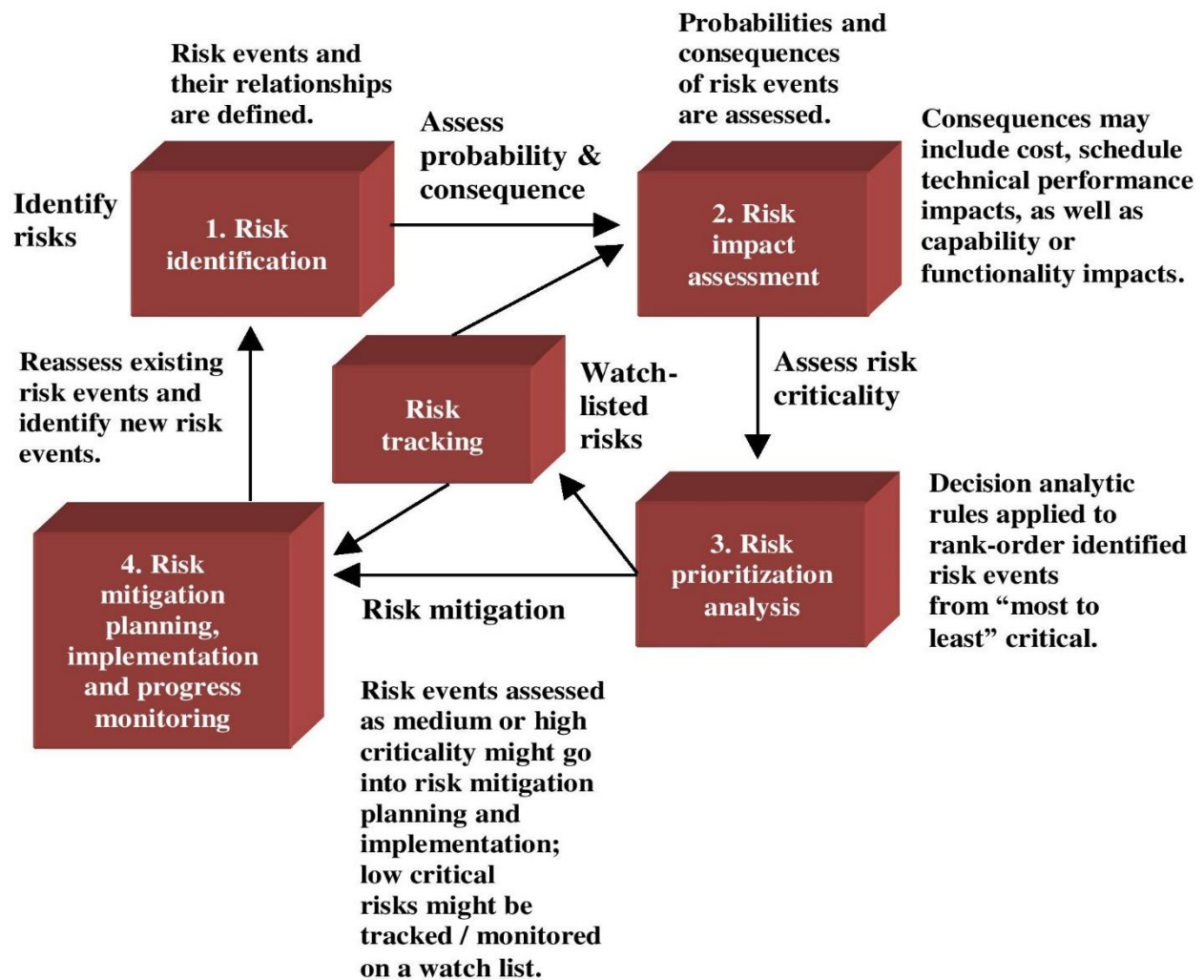


Figure no. 5. The risks management: Fundamental stages

(Source: [31])

The general rules for the application of the options for the risks reduction are presented in **the figure no. 6**. These options are based on the assessed combination between the probability of occurrence (appearance) and the severity of the consequence (degree of impact) for an identified risk, as it is presented within [31].

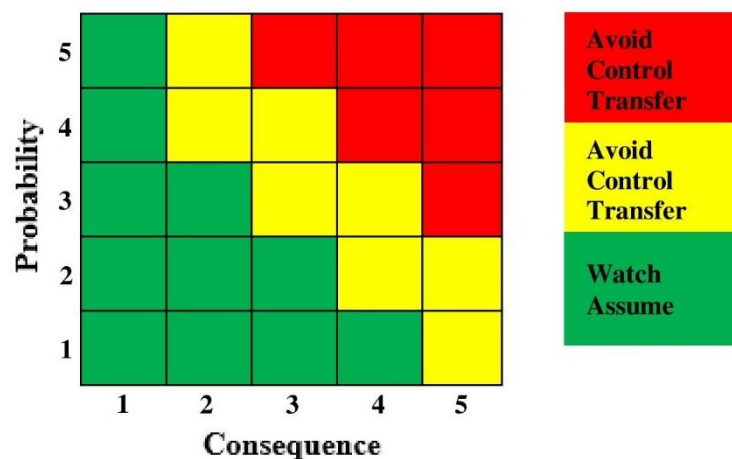


Figure no. 6. The options for the risks mitigation

(Source: [31])

As it is specified within [30], the expert systems represent computer programs, that simulate the judgment and the behavior of a man or an organization, that has knowledge and speciality experience in a particular domain. In other words, the expert systems analyze the human behavior and help at the decisions making.

According to [29], an expert system has 4 main architectural components, namely: the knowledge base, the inference engine, the knowledge acquisition module and the user interface for input / output, as can be seen in **the figure no. 7**.

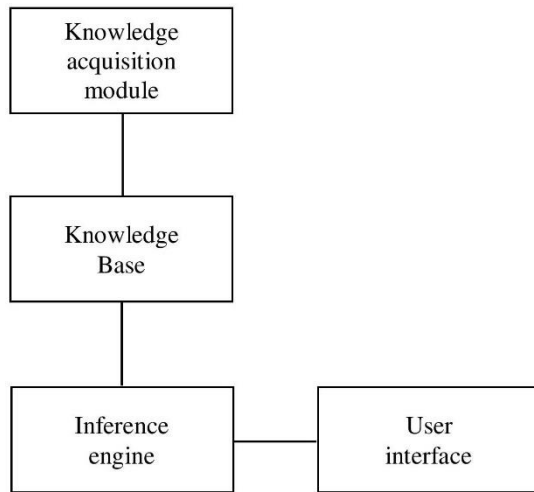


Figure no. 7. The architecture of an expert system of decisions making
(Source: [29])

4. THE SPATIAL DATA AND THE VIZUALIZATION METHODS OF THE SPATIAL DATA

According to [11], the spatial data means any data with direct or indirect reference to a specific location or geographical area.

In [6] the spatial data are defined as being those that have a spatial component. This means that the date is related to a place on Earth.

In [13] it is specified that the visualization can be described as the process of transformation of the data into representations accessible to human thinking.

According to [9], through the term of visualization there is understood “the action by which there becomes possible the visual observation of a researched phenomenon”.

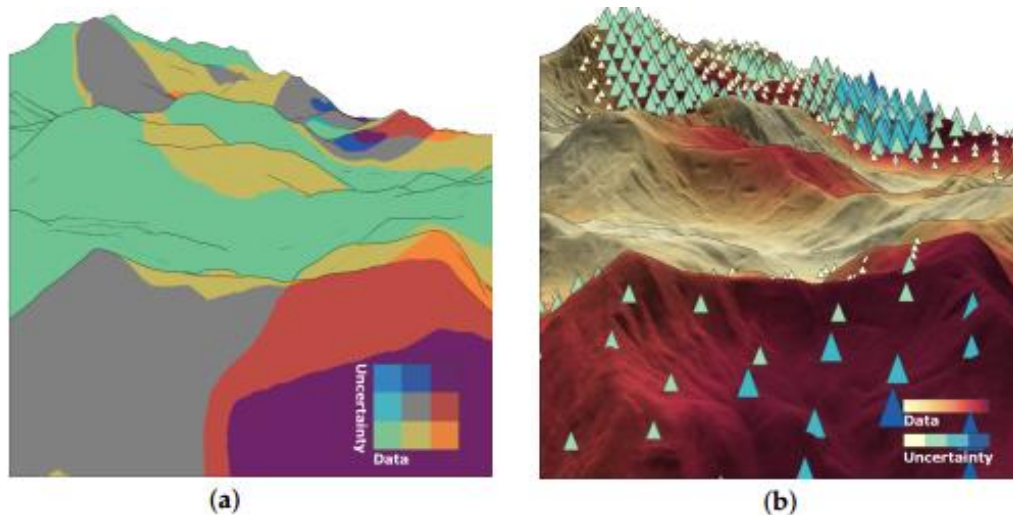


Figura nr. 8. The visualization, through a 3D model of the terrain, of the data regarding to the wind speed forecast and the uncertainty of the forecast.

(Source: Dübel, Steve and others, 2017)

In **the figure no. 14.a** the terrain is represented abstractly, using level lines, and a bivariate color scale is used to encode the data (from green to red) and the uncertainty (from green to blue).

In **the figure no. 14.b** the land is represented faithfully, by shading its surface; a continuous scale of colors (from yellow to red) is used for data and the uncertainty is represented in form of triangular, colored coded pictographs (from yellow to blue).

Another definition of the notion of visualization, according to [33], is that this represents “the process of transmission of the information through means that we can see”.

The analysis of the geospatial data requires the visualization of both the data and their reference system, as it is specified in [14]. The visualization can usually be done through a 2D map, but for many applications, which include the geology, the oceanography or the applied avionics, there is required a 3D representation of the terrain.

According to [26], for the spatial data visualization there can be used *thematic maps* for the representation of the different quantitative phenomena.

Among the methods of making of the thematic maps, which allow the visualization of the spatial data of interest to users in an attractive way, can be listed:

- the choropleths method;
- the heat mapping method;
- the network of regular hexagons method;
- the dots method;
- the clusters method;
- the proportional symbols method;
- the isolines method;
- the lines of motion method;
- the catograms method; and
- the diagrams method.

5. THE EVOLUTION PREDICTING OF THE YEARLY AVERAGE TEMPERATURES, OF THE YEARLY AVERAGE PRECIPITATION AND OF THE FORESTS SURFACES FROM ROMANIA UNTIL IN THE 2050 YEAR. THE POSSIBLE RISKS AND THE MEASURES FOR THE MITIGATION OF THE NEGATIVE EFFECTS.

In this chapter, starting from the statistical data concerning to the evolution of the monthly average temperatures and the monthly average precipitation from 1961 to 2013, and to the evolution of the forests areas, from 1990 to 2017, I done the prevision of the evolution of the annual average temperatures and of the annual average precipitation and the prevision of the forests areas until in the 2050 year.

The method used for prediction within this chapter involves the calculation of the variability index. The purpose is that to be obtained the variation of the trend of the predicted values.

Based on the predicted values, I tried to highlight the possible risks that may occur, as well as the measures to mitigate the negative effects of these risks.

In the following figures there are presented the main risks identified as a result of the estimated evolution of the considered indicators.

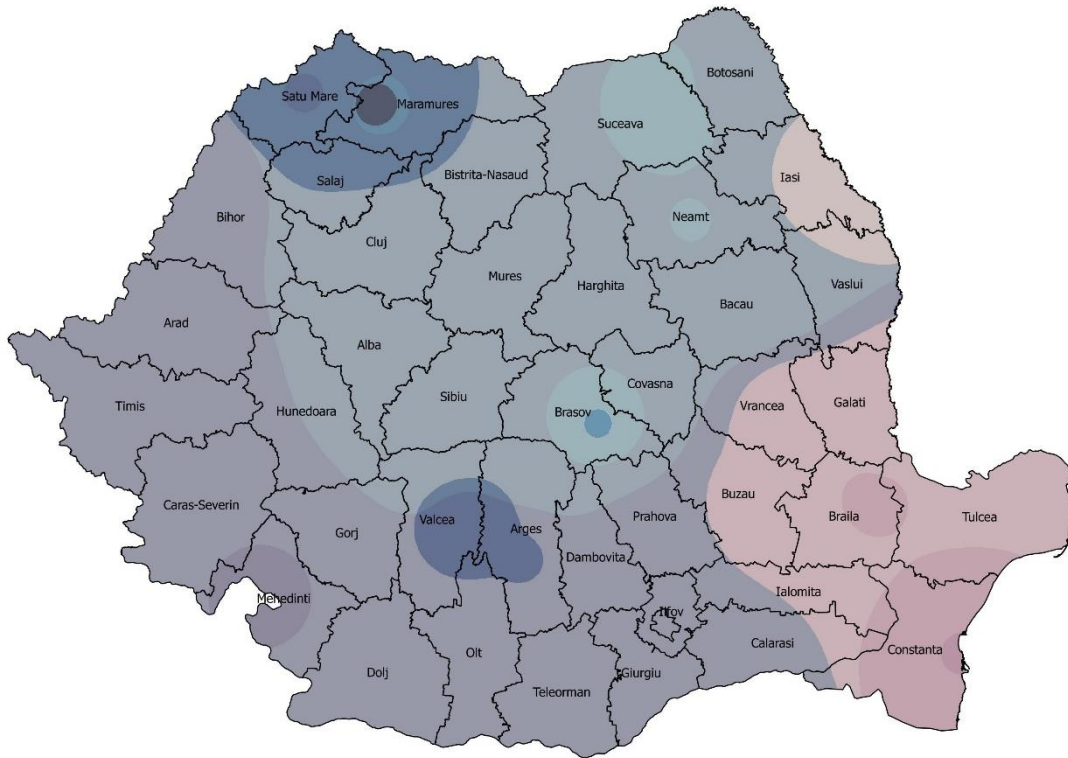


Figure no. 9. The estimation of the areas affected by drought in the 2050 year

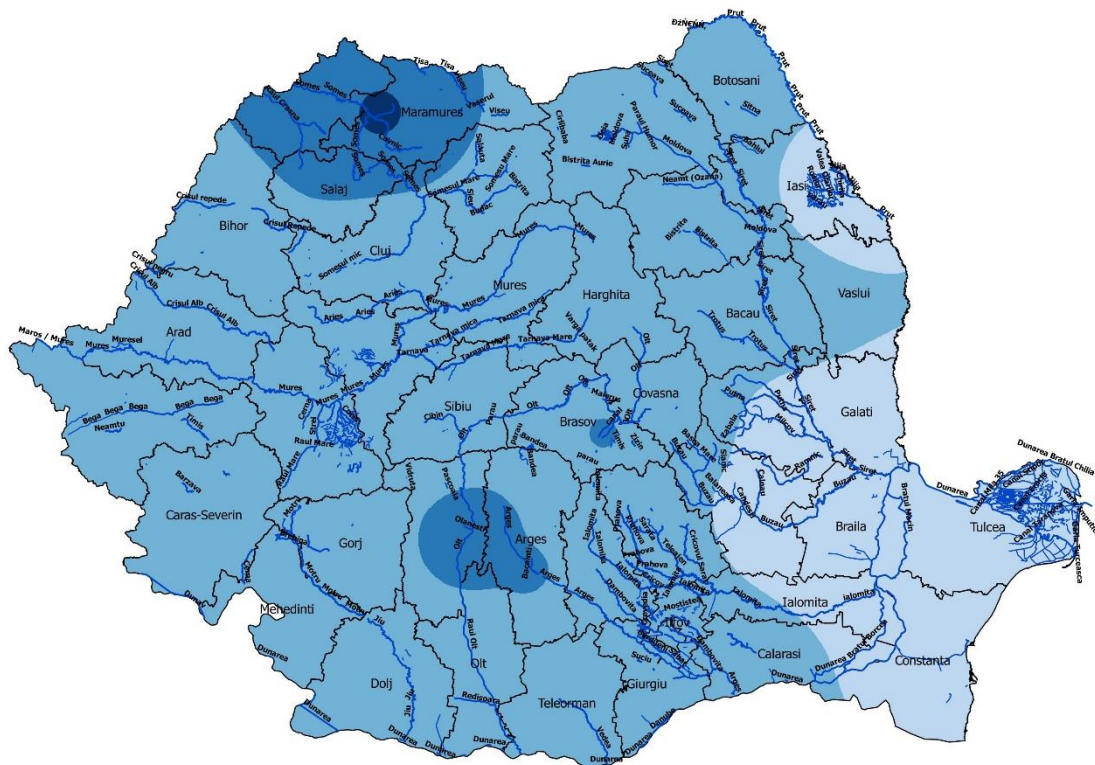


Figure no. 10. The estimation of the floods risk for the 2050 year

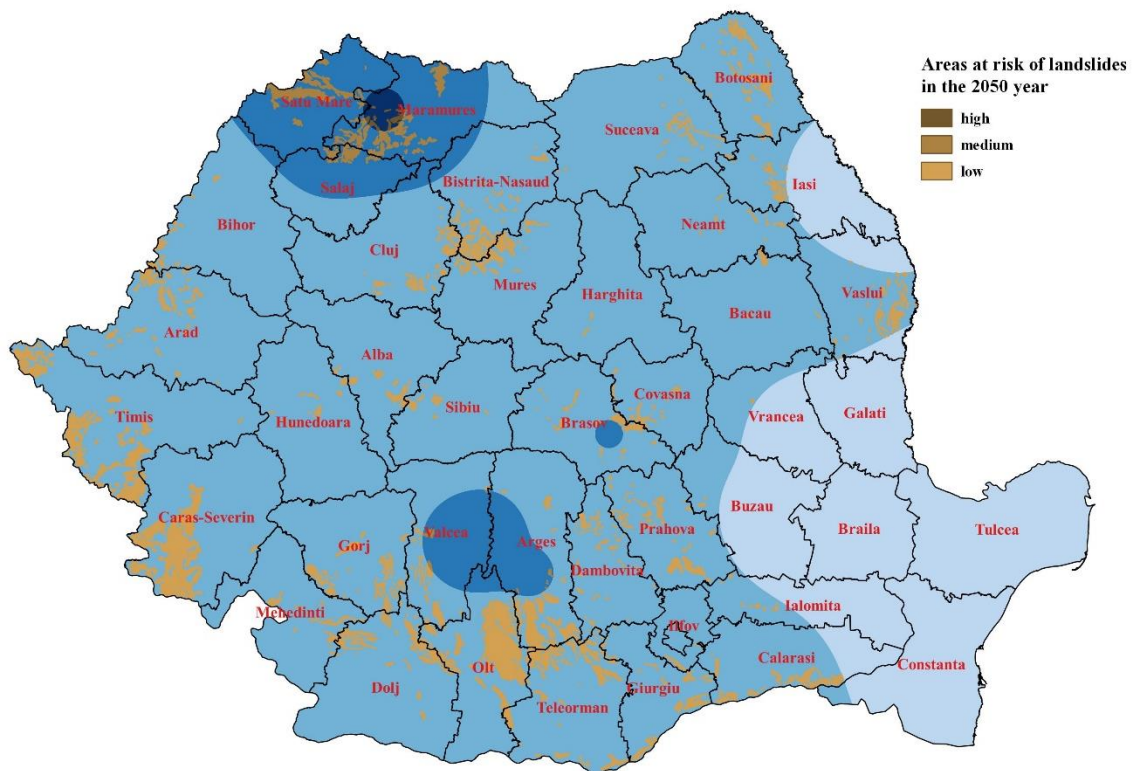


Figure no. 11. The estimation of the areas with risk of landslides in the 2050 year

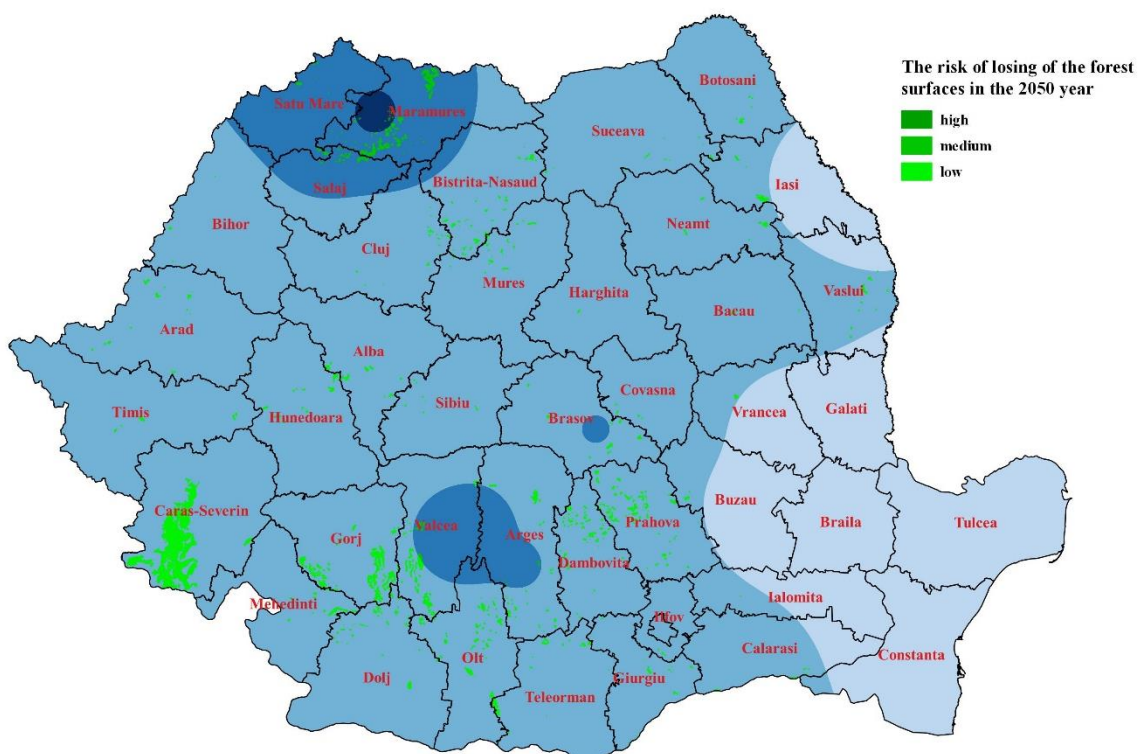


Figure no. 12. The estimation of the forests surfaces losses in the 2050 year as a result of the landslides

6. THE EVOLUTION PREDICTING OF THE AVERAGE NUMBER OF THE RETIREES AND OF THE NUMBER OF THE HEALTH UNITS FROM ROMANIA UNTIL IN THE 2050 YEAR. THE POSSIBLE RISKS AND THE MEASURES FOR THE MITIGATION OF THE NEGATIVE EFFECTS.

Within this chapter we used the statistical data related to the average number of retirees and the number of health units in Romania, available until in the 2017 year. Having these data available, I predicted the evolution of the average number of retirees and the number of health units until in the 2050 year. Following the estimated evolution of the indicators, I identified the main risks in their evolution and I tried to highlight some of the measures that can be taken for the mitigation of the negative effects.

Compared to the previous chapter, in which for the prediction of the values there was calculated the variability index, in order to be obtained the variation of the trend of the estimated indicators, in this chapter there was used a prediction method in which it was not taken into account the variability of the indicators values.

In the following there are presented the comparative situations between the average number of pensioners and the number of health units, estimated to be registered in the 2050 year.

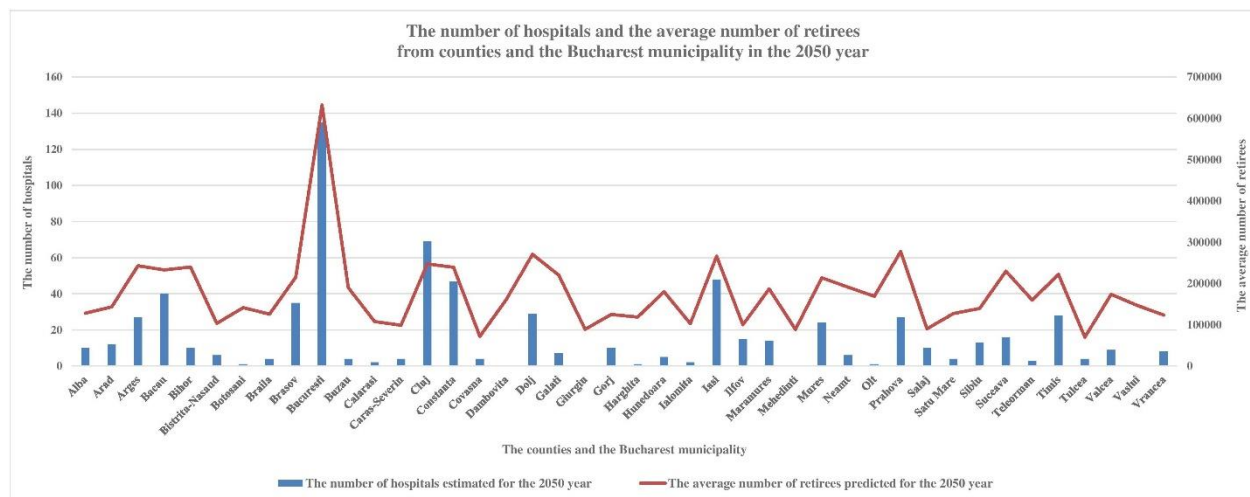


Figure no. 13. The comparative situation between the average number of retirees and the number of the hospitals in the 2050 year

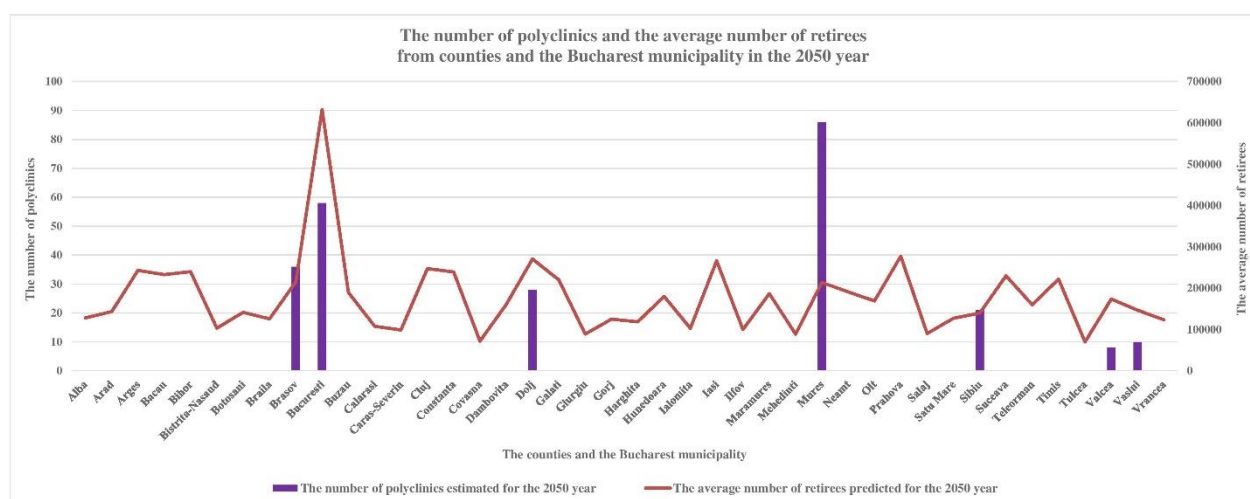


Figure no. 14. The comparative situation between the average number of retirees and the number of the polyclinics in the 2050 year

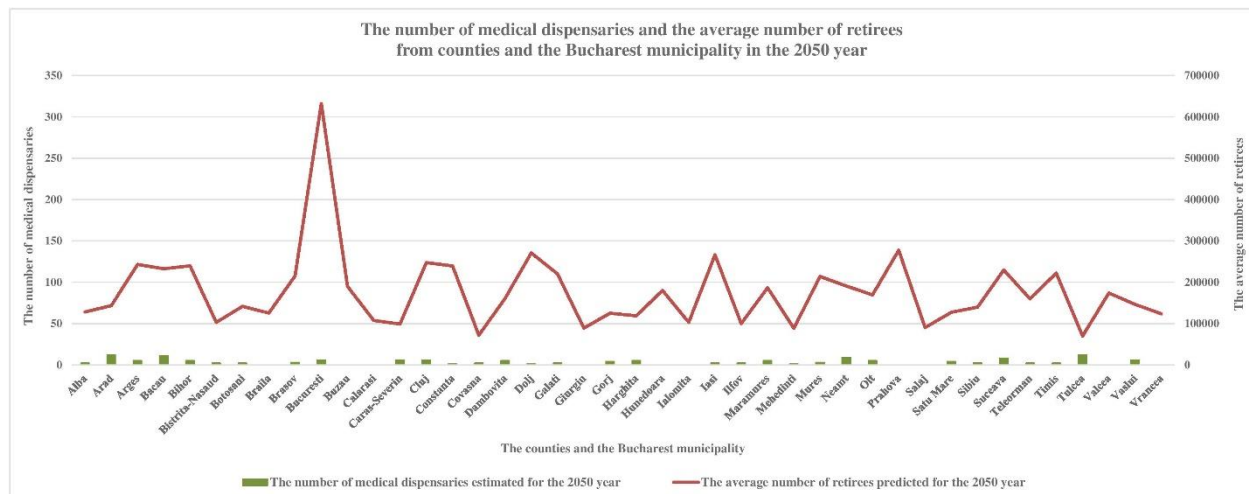


Figure no. 15. The comparative situation between the average number of retirees and the number of the medical dispensaries in the 2050 year

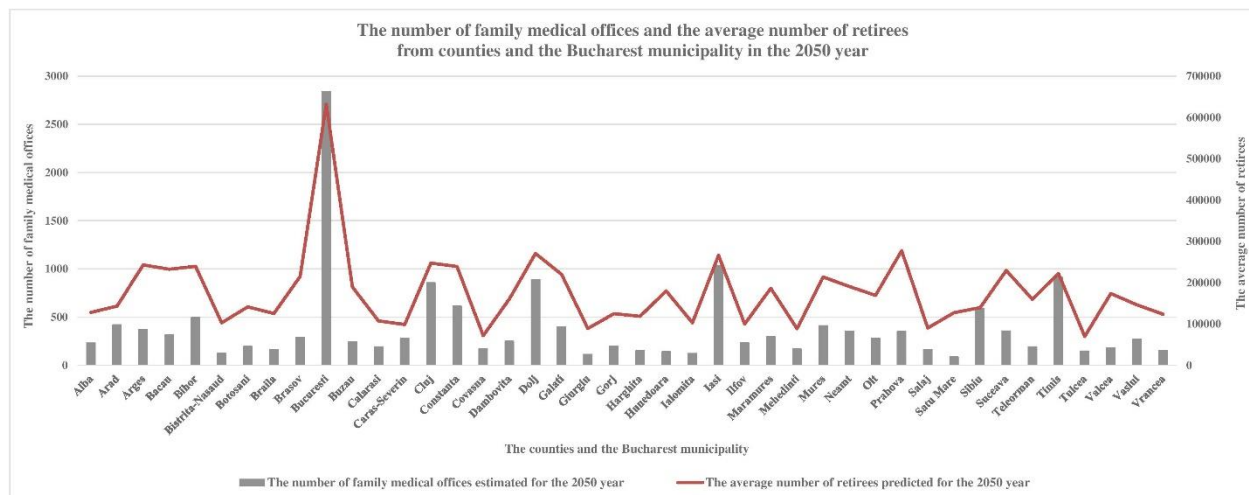


Figure no. 16. The comparative situation between the average number of retirees and the number of the family medical offices in the 2050 year

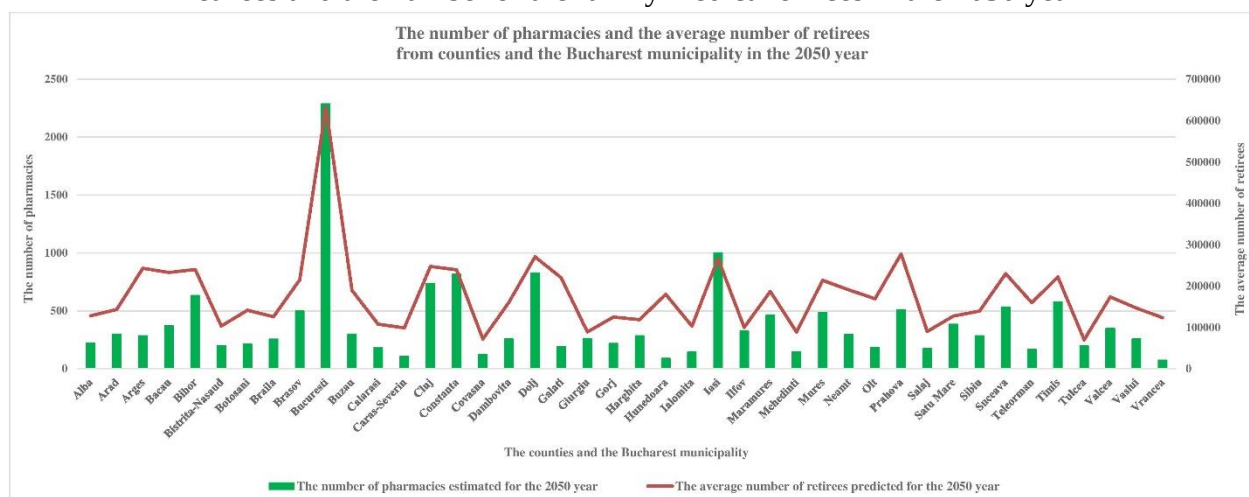


Figure no. 17. The comparative situation between the average number of retirees and the number of the pharmacies in the 2050 year

A more favorable situation can be obtained if for the determination of the average number of retirees there is used the prediction method by taking into account the variability index, applied within **the Chapter 5** of this doctoral thesis.

The differences regarding the average number of pensioners estimated for the 2050 year by the two prediction methods are presented in **the figure no. 18**.

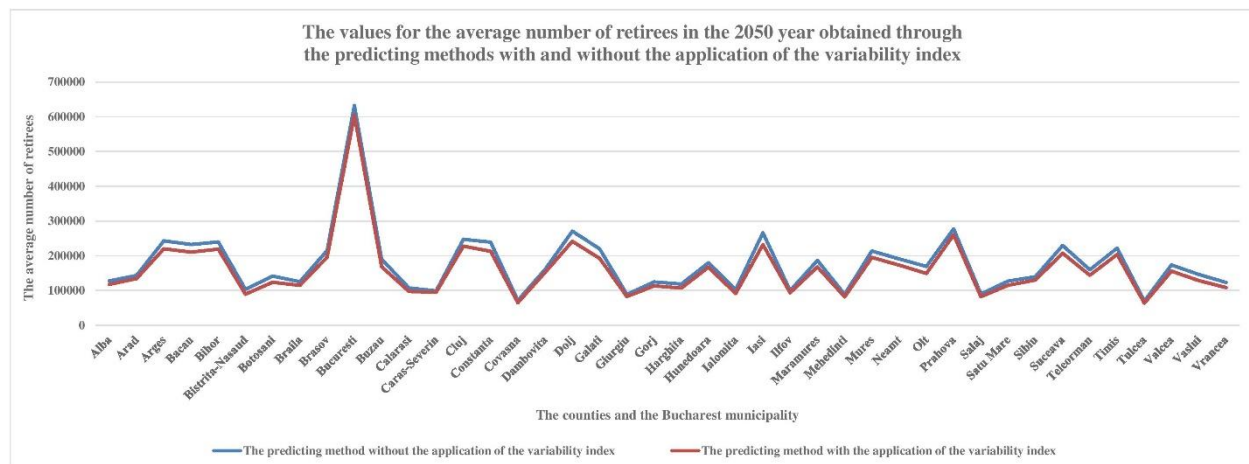


Figure no. 18. The average number of retirees estimated for the 2050 year, by the methods of prediction without variability index and with variability index

7. CONCLUSIONS, PERSONAL CONTRIBUTIONS AND PERSPECTIVES IN RESEARCH

Through this doctoral thesis, the author aims to present some ways concerning to the mode of achievement of the predictive modelling of the spatial data, starting from the data collection, the processing of them and the prediction making.

The complexity of the approached topic within the doctoral thesis involved the study of scientific papers in various domains of activity, given the fact that the predictive modelling can be applied in a very wide range of domains.

Among the personal contributions to the doctoral thesis can be listed:

- The chosen topic for the doctoral thesis is approached in the faculties in our country, but at the decision level there does not count always enough emphasis on the anticipation of the evolution mode of the phenomena;
- The case studies, within which there are approaching two current issues;
- The geostatistical analysis of the phenomena;
- The graphs presented in the doctoral thesis, through which there is desired the making of a better image of the evolution of the phenomena;
- The presentation of the possible risks as a result of the predicted evolution of the indicators, as well as the measures needed to mitigate the adverse effects of the damages;
- The proposals concerning to the future directions of research;
- Sursele bibliografice variate utilizate pentru realizarea lucrării. The various bibliographic sources used for the scientific paper making.

This scientific paper is desired to be a useful starting point for those who want to study the issue of the predictive modelling. Also, this doctoral thesis can be useful for the making of new scientific papers, starting from the approached topic.

The following can be mentioned as future research directions:

- The expert systems using, to reduce the risk of obtaining large errors following the forecasting process;
- The improving of the case study relating to the the evolution of the yearly average temperatures and of the yearly average precipitation, by using as many weather stations as possible, for a better spatial dimensioning of the yearly average temperatures and of the yearly average precipitation recorded at this stations, and to increase the quality of the forecast results;
- The improving of the case study relating to the evolution of the average number of pensioners and of the health units, by taking into account their number at the locality level, in order to increase the quality of the forecast results;
- The adapting of the forecasting method by using the variability index, in order to be able to give results in case of the existence of both positive and negative values of the indicators to be estimated.

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