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# Importance of software support in crisis situations decision-making

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**Summary:** The COVID-19 pandemic caused by the Sars-Cov2 coronavirus has affected all spheres of business like no crisis before, forcing business systems to adapt their business processes to the newly emerged business conditions. Rapid development in the field of information technologies has given rise to the development of new intelligent solutions that strongly support real-time monitoring, and decision-making based on accurate and timely information. The importance of fast data collection and their processing in real time is becoming increasingly important in modern business, as a factor that contributes to a timely response to changes in the business environment. In crisis situations, such as the global COVID-19 pandemic, the application of software tools, based on modern intelligent technological solutions, to support decision-making is an imperative. The aim of this paper is to show the importance and role of software support in crisis situations decision-making with emphasis on the COVID-19 pandemic. The paper is structured as follows: the first chapter discussed the importance of business decision-making, importance of software support in such decision-making, and the characteristics of decision support systems. The paper will also present the analysis of emergency situations and examples of information systems in different emergency systems.

**Key terms:** : information technologies, software tools, crisis situations, decision support systems, dimensional model

## 1. Introduction

The pandemic caused by the COVID-19 virus came out of nowhere and caused major disruptions in various sectors, reduced demand for goods, and increased operating costs. With over 299 million infected, and five million deaths globally (at the time of writing) [1], many governments around the world had to rely on decision support systems [2]. The rapid development of information technologies in the last few decades, both in the field of mobile technologies and in the field of intelligent devices, has enabled the collection of large amounts of data (structured, semi-structured and unstructured), and business decisions based on accurate and timely data [3], [4].

Even before the outbreak of the COVID-19 pandemic, the contemporary business environment was characterized by instability, strong competition, constant changes in market conditions, and a relatively short product life. In such conditions, business success is largely influenced by the speed and reliability of decision-making, and decision implementation to achieve defined goals. In decision-making, some important facts often remain unknown, as well as the consequences of one's decisions. Hence, the need for the application of management tools and technologies that can provide comprehensive, fast and efficient use of all available data and information in business and non-business systems, which are necessary for successful business performance. One of these systems that enable the use of comprehensive information is Business Intelligence (BI). It is a system that enables users to use technology to access data, analyze and manage them for the purpose of making business decisions. BI comprises: "Data Warehouse, Decision support systems, Executive information systems, online analytical processing (OLAP), and implementation" [5]. Business intelligence systems are increasingly shifting toward web applications in order to enable users to perform research from remote locations via web browsers.

Emergency situations are situations that arise suddenly. They are either accompanied by conflicting information, or no information at all, and they occur in a very short period, which only further impairs the decision-making process. In emergencies, decision-makers must have all the relevant observations and information available so as to be able to make decisions appropriate to the situation. "In addition, literature mentions various documents arguing that the chances of defect decision-making in a group, such as group thinking, are greater than in stressful situations when the group is very cohesive or socially isolated" [6]. "Those involved in decision-making are mentally overwhelmed and the group fails to adequately define its goals and alternatives, does not explore all possibilities, nor does it assess the risks associated with the group's decision" [6].

The paper covers general topics related to decision-making in the first section of the second chapter. The other half of the chapter analyzes the dimensional model as a way of warehousing data in decision-making. The third part of the said chapter describes the importance of decision-making in emergencies, and presents examples of emergency decision-making systems.

## 2. Decision support systems

### *2.1 Decision support systems and business decision support systems*

Decision theory is used in individual and collective decision-making, especially in uncertain situations. The aim of decision theory is to make quick, optimal and rational decisions. Contemporary decision theory emerged in the 20th century by studying different aspects of decision-making in the field of economics, statistics, psychology, philosophy, political and social science [7]. Modern business is characterized by an increased internal and external organizational complexity, unstable environment, strong competition, constant changes in market conditions, relatively short product life, and large amounts of information in the business environment. In such conditions, business success is largely influenced by the speed and reliability of decision-making and decision implementation to achieve defined goals. Computers and specialized software that process data and provide information through reports based on which accurate, timely and quality decisions can be made are increasingly used to speed up and facilitate the business decision-making process.

Software support in decision-making facilitates management of a company, and enables better business results. Given that decision-making has become a complex and highly responsible process in the modern world, it now requires the involvement of whole teams of people. Data are raw facts, and their analysis yields information. Knowledge is an accumulated set of information that has a significant role in making correct decisions [7]. Problems that can be represented by mathematical instruments are called structured or programmed problems. Such problems have standard solving mechanisms which facilitate decision-making [5]. Unstructured or unprogrammed problems cannot be expressed by standard mathematical instruments, therefore the methods for solving such problems are not known in advance, so decision-makers must use their intuition [5]. Semi-structured or semi-programmed problems have partially structured parts, and unstructured parts, so the solution depends on the part of the problem which is being solved [5].

Data Mining techniques and machine learning algorithms are used for working with unstructured data. Data mining techniques include the decision tree, artificial neural networks and genetic algorithms. Machine learning algorithms are suitable for working with large amounts of data, and are applied in situations when it is necessary to find patterns among data [5]. Data warehouses and the dimensional model are used for working with semi-structured data. The decision support system generates better information, which allows for greater choice and consequence analysis in decision-making, thus positively influencing the quality of decision-making [5].

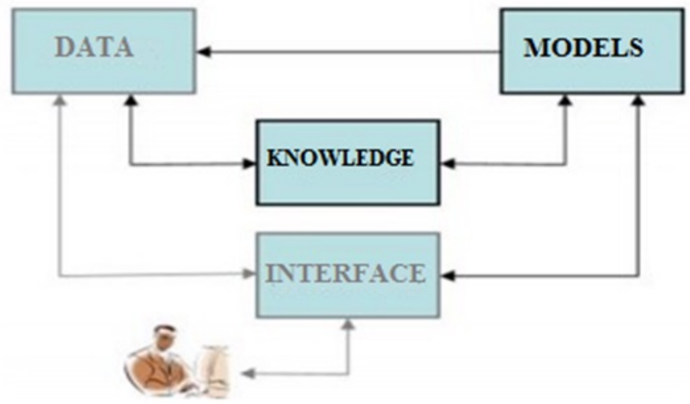


**Figure 1. Decision support system elements [12].**

The advantage of decision support systems is that they facilitate decision-making, provide more information, and provide an overview of potential consequences of decision-making [5].

Examples of Decision Support System or DSS are [5]:

- Production management system;
- Human resource management system;
- Traffic management system;
- Public transport timetable, routes and flight schedule design system;
- Accounting system;
- Cost estimation system.

Components of the decision support system (Figure 2) are [5]:

- Data-management subsystem;
- Model management sub-system;
- Knowledge-based subsystem;
- User interface;
- User.

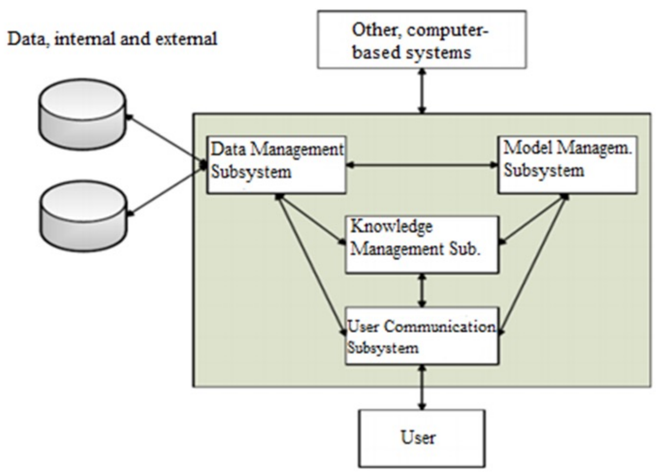


**Figure 2. Decision support system – components [13].**

In order for a decision support system to work, it needs data entry. Data can be collected from the decision-making system, i.e. from inside the company, and they are internal data, and from the environment, i.e. external data. The most important components of the data are the parameters based on which it is possible to simulate the behavior of the system in different circumstances. The collected data are stored in databases, or data warehouses. The components of a data management system are: databases, data management subsystem, and queries. The decision support system established connection with the database during data entry. In addition, the Internet can also be an external data source, and the data can be entered directly, i.e. through an application [5].

Components of the model management subsystem are [5]:

» model databases;
» model database management subsystem;
» language for set modeling;
» command processor.

The decision support system comprises a decision support model. Each DSS may contain different decision-making models, depending on the purpose and needs of the DSS. For example, there are models for: production planning, sales forecasting, vehicle scheduling, sales venue positioning [5]. Decision support models use simulation techniques, optimization techniques, and heuristic algorithms. By applying simulation techniques, we simulate the behavior of an actual system by changing environmental parameters, thus obtaining potential the possible behavior of a real-system model [5]. Optimization techniques allow us to generate the best possible solution to the problem based on the specified criteria. Optimization techniques include application of linear programming, dynamic programming, etc. The optimization technique has its drawbacks, for example, increasing problem dimensions slows down the computer, and it is not possible to incorporate all of them into a model, so the solution does not correspond to the actual system. Heuristic algorithms are used for solving problems with a large number of constraints and large-dimension models. Heuristics is capable of finding good solutions in a short period, but it is not completely reliable, because we cannot know if the solution will be close to optimal or not [5]. For making decisions in real time using DSS, the basic requirement is response speed, i.e. it is expected that the obtained solutions are fast and high-quality. The combination of optimization and heuristic techniques, and the decision-maker's experience that describes different parts of an actual system provides a comprehensive instrument for obtaining satisfactory solutions to real-life problems [5].

The knowledge management subsystem can survive on its own, or be incorporated into another subsystem. What makes it special is the connection with the knowledge base, which enables the expertise of the problem being solved. The subsystem may incorporate expert systems, neural networks, intelligent systems, etc. Decision support systems that have a built-in knowledge management subsystem are known as "Knowledge Based – DSS", "Intelligent decision support systems – IDSS" or "DSS/ES – as a combination" [5].

This subsystem is in charge of the communication between DSS and the user. The user accessed the DSS through the user interface to obtain information necessary for decision-making. In order to use the interface as efficiently as possible, it is necessary to define display standards, use standardized and comprehensible terms and labels, enable interface parameters modification, easy navigation, etc. The user interface enables data entry, model creation and data display [5].

### *2.2 Data warehouse and dimensional model*

The need for storing large amounts of data has made it necessary to store these data in a form that allows quick access. Relational databases in which data are organized into tables of interconnected relations are used most often. However, storing data in relational databases has certain limitations that are reflected in the impossibility to obtain quality and timely information for decision-making. Data are represented differently in different databases, the same data are sometimes labeled differently, so it is difficult to define queries for such databases. In addition, data is collected from different databases, which prolongs their processing and response time, and complicates the calculations, which in turn, slows down the decision-making process. Relational databases are frequently updated, so only the latest data is saved, and sometimes decision-making requires older data. For that reason, interesting data is collected and integrated into a unified system known as a data warehouse [7].

The so-called dimensional model is used for storing and structuring data in data warehouses. The dimensional model is a data model suitable for data analysis in decision-making. Data in the dimensional model are not normalized, i.e. they contain redundancies. In consequence, they occupy more memory, but also provide greater opportunities to use data for analytical purposes, and faster data access [7].

Data in a data warehouse can be represented in the form of a multidimensional structure known as the cube. There is also a new cube-based way of analyzing, easy and selective reporting and reviewing data known as OLAP (Online Analytical Processing, Figure 3) [7]. Software solutions that integrate all the main components necessary for data analysis are called Business Intelligence Platforms, Figure 3) [7].

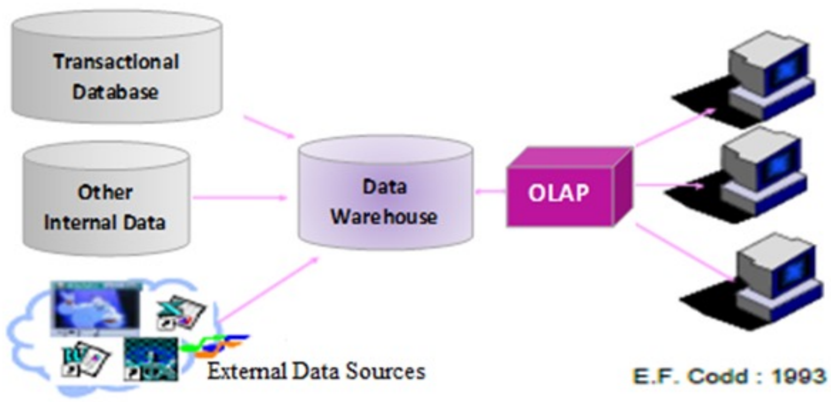


**Figure 3. Business Intelligence [14]**

The data storing procedure involves the following stages [7]:

- Extraction, transformation and loading (ETL);
- Data storage;
- Use of data for decision-making purposes.

The most comprehensive and significant part is the extraction, transformation and loading process. The importance of this process involves the identification of data sources, and extraction of interesting data. This process takes the longest. These data are then consolidated, transformed and loaded into a data warehouse as needed. When storing data, things that should be taken into account are the possibility of fast and efficient access to data, as well as data security and durability [7]. The use of data is realized through queries on the data warehouse, report preparation, graphs, data analysis and identification of patterns in the data. There is a special technique for storing and manipulating data in the data warehouse optimized for analytical use thanks to a special query language, OLAP (Online Analytical Processing. This technique makes use of a crosstab query by rows and columns [7]. The technique of data mining is used for finding hidden, previously unknown facts within the data warehouse, which enable the discovery of future behaviors [7]. Relational databases have certain limitations that make it impossible to obtain sufficiently accurate data for decision-making, so database designers presented an easier-to-understand model, the so-called dimensional model [7]. Dimensional modeling is a technique of logical data modeling in a simple and intuitive form, which is easier to view. The dimensional model contains redundant data, because normal forms are not applied on it. Each model contains a table with a composite primary key – fact table and a group of smaller tables, i.e. the so-called dimension tables. Each dimension table contains a simple primary key that matches one of the attributes of the composite primary key of the fact table. This structure is known as a star schema (star join) (Figure 4) [7].

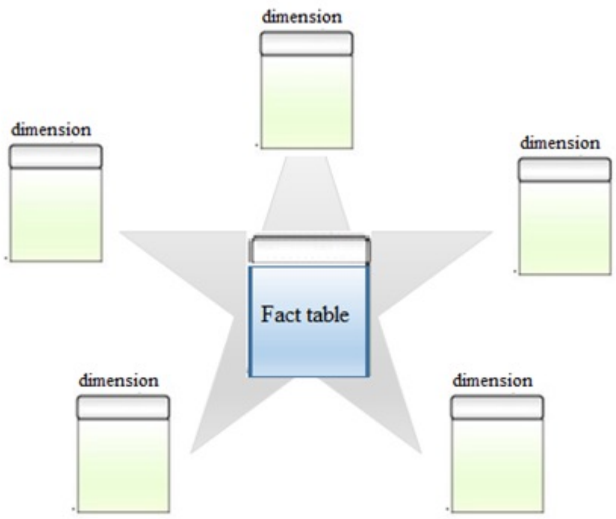


**Figure 4. Star schema [15]**

The fact table contains groups of numerical attributes:

- Keys to dimension tables;
- Dimensions.

Fact tables are normalized, or almost normalized. Dimensions are numerical attributes in a fact table, and they are added for each combination of foreign keys that define an entry; it is an assessment of the process monitored by the fact table, or measure of a phenomenon [7].

The architecture of a data warehouse is not predefined, but depends on the business itself. The following forms are the most common [7]:

- as data sources - databases or multiple databases, files, web services; k
- Data Staging Area is represented by a single database and used for data collection and transformation;
- Operational Data Store in the form of database where users update data on a daily basis;
- Data Warehouse, relational database management system;
- OLAP, non-relational database management system, speeds up queries and additional analyses;
- tools suitable for reviewing, analysis and visualization.

*2.3. Importance of software support in emergency situations*

Decision support systems have found their application in various crisis situations, because of their ability to [8]:

- provide citizens with important information in crisis situations;
- collect, store and process data from different information systems;
- ensure coordination between different decision-makers;
- predict the outcomes of the decisions made.

Emergency Medical Services - EMS, a crisis management information system was developed for the purpose of providing timely reactions in the health sector. It is a critical response database that provides real-time graphical information. Critical situations involve numerous obstacles to the integration and coordination of emergency actions in the health system [9]. The aim of this project was to develop a reliable and well-connected infrastructure. In addition, the project makes use of an intelligent, decision support system to improve business processes. The project involves: a completely computerized crisis management system; computerized system for electronic reporting on patient care, and central monitoring system – operating room [8]. EMS also enables the identification and management of patients with critical infection conditions (i.e. severe respiratory tract infections, severe infections of the central nervous system (CNS), and sepsis) to the Specialized Emergency Department (ED) for infectious diseases. EMS is based on widely available technologies and tools, such as servers, Microsoft® operating system (OS), Oracle Database Management System (DBMS), Geographic Information System (GIS), Network Analyst and Tracking Analyst [9]. EMS has four main integrated system components: infrastructure, application, data and training (Figure 5) [9].

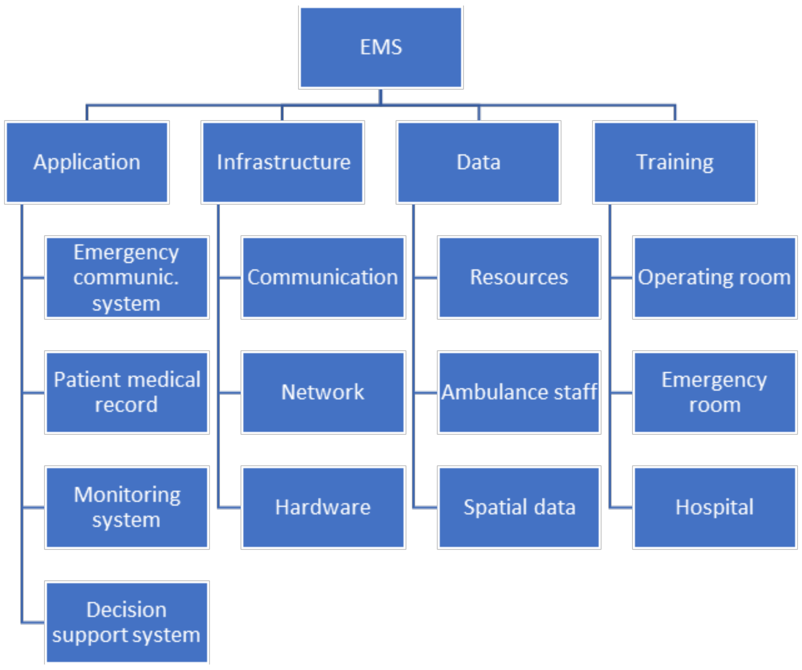


**Figure 5. Emergency Medical Services – EMS**

In the recent past, there have been several large-scale industrial catastrophes that have caused significant loss of human lives, and environmental damage. On December 3, 1984, 40 tons of toxic gas, methyl-isocyanate leaked from the chemical factory Union Carbide in Bhopal, India, killing at least 15,000 people and injuring another 150,000. A lesser known, but even more terrible incident occurred in the Chinese Henan province, where the collapse of the Banqiao and Shimantan Dams in 1975 during the typhoon Nina killed 26,000 people, while another 145,000 died as a result of the subsequent epidemics and famine. In that catastrophe, about six million buildings collapsed, and over 10 million people were affected. However, the industrial catastrophe that probably came closest to the apocalyptic visions of global devastation is the Chernobyl nuclear catastrophe that occurred in 1986 [6]. The world's largest nuclear disaster occurred on April 26, 1986 in the Chernobyl nuclear plant in Pripyat, Ukraine, which was still part of the USSR at the time. It is believed that the cause of the catastrophe was an experiment gone wrong that caused the reactor to explode. As there was no containment building on site, the radioactive content was released in the atmosphere, contaminating large areas of the USSR (especially Ukraine, Belarus and Russia), Eastern and Western Europe, Scandinavia, and the eastern seaboard of North America in the days and weeks following the accident [6].

Different, and often conflicting responses of different European countries after the Chernobyl disaster have made it clear that the European Union needed a comprehensive and unified response to nuclear emergencies. Funded by the European Commission through numerous research programs (the so-called framework programs), a group of universities and research institutions from Europe and the former USSR collaborated on the development of the Real-time Online Decision Support System or RODOS. RODOS was designed as support to emergency situations management after a nuclear disaster at all levels of society (local, regional and national) throughout Europe. RODOS aimed to [6]:

- provide a common platform or framework for the integration of the best characteristics of the existing DSS and future development;
- provides greater transparency in the decision-making process as one of the inputs aimed at improving public understanding and acceptance of emergency measures;
- facilitate and improve communication between countries, as well as data monitoring, consequence prediction, etc. in case of a future disaster;
- promote a more coherent, consistent and coordinated response to any future disaster that may affect Europe through system development and application.

RODOS DSS comprises three different subsystems, where each contains a series of modules [6]:

- Analyzing Subsystem (ASY) modules process incoming data and process the location and quantity of contamination, including temporal variation. These modules contain meteorological, atmospheric and hydrological dispersions, precipitation and absorption, effects on health and other models. ASY modules predict situation development in line with the best scientific understanding of the processes involved;
- Countermeasure Subsystem - CSI modules suggest possible countermeasures, check them for feasibility, and calculate their expected benefit in terms of a number of attributes;
- Evaluation Subsystem - ESY modules rank countermeasure strategies according to their potential benefit and preference weights provided by decision-makers.

The correlation of all software modules, data entry, data transmission and exchange, result display and modes of operations (interactive and automatic) is controlled by the RODOS operating system, a layer built under the UNIX operating system of the mainframe. Interaction with users and data presentation occurs through a graphics subsystem which includes a purpose-built geographic information system (RoGIS). It displays demographic, topographic, economic and agricultural data, together with the contours of the measured and predicted radiological data. These outputs are there to ensure that results can be used and understood by different users [6].

RODOS is a real-time network system connected to meteorological and radiological data networks, meaning that it comprises several communication modules. All data required by information processing modules are stored in databases, and RODOS includes three main categories [6]:

» programs database that includes input and output data required or produced by different modules, intermediate and final results, provisional data, etc.;
» real-time database that includes information from the regional or national radiological and meteorological networks;
» geographical database that stores geographical and statistical data for the whole of Europe.

The system is designed to be flexible, so as to function equally well in different circumstances. Hence, the content of the subsystems and databases differ depending on the particular system application, i.e. nature and characteristics of any potential nuclear accident, different monitoring data, national regulations, etc. RODOS models and databases can be adapted to different site characteristics, as well as geographical, climatic and environmental variations throughout Europe. The current version of the RODOS system is installed in national emergency centers of Germany, Finland, SPain, Portugal, Austria, The Netherlands, Poland, Hungary, Slovakia, Ukraine, Slovenia and the Czech Republic. Other countries, such as Romania, Bulgaria, Russia, Greece, and Switzerland are considering the installation. As a result, RODOS is nowadays almost a centralized resource for all relevant information that may be needed in any potential nuclear crisis in the European Union [6].

ReliefWeb (http://www.reliefweb.int) is the world's leading network for information on humanitarian emergencies and disasters. The Office for the Coordination of Humanitarian Affairs (OCHA) provides information on emergency situations and natural disasters around the world from over 1,000 sources, including the UN, governments, non-governmental organizations (NGOs), academic community and media on ReliefWeb. This network publishes final reports, documents and reports from humanitarian partners, providing a global repository of information on emergency reactions in one place [9]. Regional Information Networks (IRIN) collects information from various humanitarian and other sources, providing context and reporting on emergency situations and countries at risk [6]. Information Management Units (IMU) and Humanitarian Information Centers (HIC) collect, manage and disseminate operational data and information from the field, providing geographic information products and a collection of operational databases and related content to decision-makers both in the field, and at headquarters [6]. VISTA is an example of a new web-based visualization tool, which not only provides information about the situation, but allows humanitarian analysis of the situation as well [6].

Sahana is a web-based collaboration platform that addresses common coordination problems during catastrophes related to missing persons, aid management, volunteer management, relocation monitoring, etc. between government groups, civil society (NGOs) and victims themselves. Sahana is a web-based, integrated set of applications for catastrophe management that provides solutions for major humanitarian problems following a disaster. The main applications and problems they address are the following [6]:

» Register of missing persons: Helping to reduce trauma by efficiently finding missing persons;
» Register of organizations: Coordinating and balancing the distribution of aid organizations in the affected areas, connecting relief groups and helping them to act in coordination;
» Request management system: Registering and monitoring all incoming requests for aid until fulfillment, and aiding donors to respond to requests for aid;
» Register of camps: Monitoring the location and number of victims in various camps and temporary shelters throughout the affected area.

The development of Sahana, a free open-source code for disaster management was triggered by the 2004 tsunami, to help coordinate aid efforts in the affected Sri Lanka. It was originally developed by a group of volunteers from the IT industry of Sri Lanka, led by Lanka Software Foundation. The application of Sahana was approved and implemented by CNO (the main Sri Lankan government body for coordinating relief efforts) to help coordinate all data collected. For the purposes of global implementation and adequate response to large-scale catastrophes, the work aimed at improving the Sahana system is still ongoing. Sahana was successfully used after several other natural disasters, for example the major earthquake in Pakistan in 2005, storm in the Philippines and the earthquake in Yogyakarta, both in 2006. Sahana's long-term goals are to develop into a comprehensive disaster management system, including mitigation, preparation, aid and recovery [6].

## 5. Conclusion

Uncertainty and rapid changes in the environment are among the main features of any crisis situation. As such, crisis situations create discontinuity in the functioning of business systems, pose a threat to human lives and disrupt development, both on a local and global level [10].

Making timely decisions in such situations is directly related to the ability to access real data. Innovations in the field of information and communication technologies have led to the development of decision support systems that enable us to collect, process and spatially present data related to the given crisis situation, which allows decision-makers to consider and monitor the situation in real-time, as well as to react in a timely manner [11].

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