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IT in the logistics of crisis situations: a review of selected systems and technologies

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IT systems are an indispensable element supporting logistics processes. Commercial organisations have been investing in this kind of tools for years, as they are absolutely necessary to ensure seamless operations in a reality where pressure on profits requires speed, effectiveness and high efficiency. This kind of solutions, along with all their advantages, can successfully be transferred and applied to decision-making in the logistics of crisis management. The first part of the article outlines and provides an analysis of available technologies and information systems that are (or can be) used in the area in question. Further, we formulate the requirements that a dedicated support system for the logistics of crisis situations must meet.

Słowa kluczowe: information systems, decision support, logistics of crisis situations.

Introduction

A modern state with a strong economy relies both on the material resources it has and on information that is crucial for creating conditions for growth and smooth decision making. With modern technologies, enhanced by the contribution of other areas of science such as logistics, security engineering or economic sciences, fast and efficient response to adverse phenomena caused by crisis situations is possible. On the other hand, any disruptions to sending, storing or processing information in dedicated IT systems will cause problems.

At a time when technology plays the key role in almost all areas of life, it becomes a must to have (implement) reliable tools supporting the national security system. This also applies to logistics projects in crisis situations. The business environment has long ago appreciated the advantages of IT support for management and logistics. For instance, the ERP solutions that are classified as solutions creating integrated logistics systems are widely used by western companies and institutions. One of the advantages brought by the modern ERP systems is an increased number of successful IT projects[1]. Taking this into account, along with the increasing experience of specialised IT platform providers, and as they are forced to focus on constant improvement, one can conclude with high likelihood that if requirements regarding the desired functionalities are properly formulated (adequately matching the needs) and features such as reliability and user-oriented architecture are treated as a priority, a dedicated IT system will not only be successfully implemented but will also be widely used.

The Polish market still lags behind the others in the above areas, therefore, it has a large upside potential[2]. It should also be made clear that ERP class systems are just one of the numerous options available to provide computerised support for logistics in crisis situations. Business Intelligence solutions and expert systems are other options. The Big Data technology which can support public administration with its mechanisms for analysing large amounts of various data is also more and more often discussed[3]. It is becoming increasingly popular and its development is gaining momentum.

Certainly, properly designed, dedicated systems (software tools) are not the only means of technological support for the areas in question. This also involves building a good quality, robust ICT infrastructure ensuring reliable and safe exchange of information. Further enhancements may include technologies serving to automatically transfer information from monitoring systems, measurement devices and sensors to databases[4] that, fed in this manner, will always provide updated information. *UAV* systems can also be used for this purpose, and this will, no doubt, be one of the challenges in the upcoming future.

In this article, we attempt to analyse the tools and technologies available in the market that can be used in the management of logistics processes, in particular with respect to the logistics in crisis situations. We selected them in a subjective manner, and are analysing them in order to find the grounds for, and define the key determining factors to formulate a concept and assumptions with a view to developing a comprehensive and coherent decision support system in the logistics of crisis situations. To the best of our knowledge, individuals in charge of decision making in the area under scrutiny do not have such a coherent tool at present, whereas they admit in interviews, this would be very useful in management, including in particular planning and organising actions.

1.Integrated Management Information Systems[5]

Most of the integrated systems that are currently in use are of a universal (general-purpose) nature. In other words, they are not meant for a specific institution (company, organisation) but have a certain number of standard functions and variable system parameters that can be tailored to the specific (current) needs of a user. This involves parameter setting (or customising), i.e. setting values for parameters that are variables defining the manner of operation of a system. Integrated management systems are classified among transactional systems designed to process/register on-going business events. In most cases, functions in integrated systems are divided by task areas, where the logistics area can encompass issues such as procurement planning, warehouse management (inventory accounting, space management), transport utilisation planning and optimisation issues. As mentioned above, thanks to parameter setting, IMIS are scalable to a certain extent. This does not mean that they are capable of meeting all the specialised requirements of specific companies or institutions that often have divergent needs. Where parameter setting is of no use, internal

[1] A. Szymonik, Zarządzanie Logistyką w Sytuacjach Kryzysowych. Logistyka 4/2011, Politechnika Łódzka, p. 960.
[2] S. Pociask, Systemy ERP – polskie przedsiębiorstwa nadal w ogonie Europy. Article available [online] at https://www.jcommerce.pl/jpro/article/systemy-erp-polskie-przedsiebiorstwa-w-ogonie-europy [accessed on: 14.04.2018].
[3] S. Drosio, S. Stanek, Big Data Jako Źródło Informacji Rozszerzające Funkcjonowanie Systemów Wspomagania Decyzji w Zarządzaniu Kryzysowym. Zeszyty Naukowe Politechniki Częstochowskiej - Zarządzanie No 26 (2017).
[4] A. Szymonik, Zarządzanie Logistyką ..., op. cit., p. 954.
[5] IMIS – Integrated Management Information Systems.

programming languages may help. This increases the possibilities of customising a system. Most integrated systems provide this opportunity, however, specialised knowledge is required to take advantage of it. Another way to increase the possibilities of customising a system is to build it according to the open-system concept that makes it possible to attach new software[6], exchange information with its environment and enabling co-operation among the various software components coming from various manufacturers[7].

Making available a system (understood as a sort of software) to a user as an open source code is still another opportunity. Unlimited access to the source code is, no doubt, the top advantage of Open Source solutions implementation, as they can be fully adapted to even most specific requirements. Moreover, they can ensure integration with practically any external systems[8]. The quality of work with the use of a perfectly customised platform having the proper modules, operating on the desired types of data and co-operating with other software is a huge asset in itself. However, in order to take full benefit of all these advantages, it is necessary to resort to specialists such as software programmers, testers or engineers, as the scope of activities necessary to reach this goal is far beyond the competencies of an ordinary system user.

2.ERP/ERP II[9] Systems

ERPs are IT systems that support enterprise resource management. Covering the main functional areas, they offer the opportunity to work with wide range of information, from quality management, manufacturing functions, service management, overhauls to many other issues. They can be applied both to internal logistics projects and to those carried out within the framework of a supply chain.

ERP systems use an OLTP (*On-line Transaction Processing*) database, where effective data writing and reading (measured by the number of transactions per specific time unit) is the overriding objective. One of the major requirements is also to preseve the integrity of data in a multi-access environment.

Thus, transactional (OLTP) systems are different from the analytical ones (OLAP – *On-line Analytical Processing*) whose main function is to support data analysis[10]. Business Intelligence systems, discussed below, are an example of the latter type of systems. At this point, it is worth to outline the difference between the integrated systems described above and the ERP solutions. These terms are often used as synonyms, however, in order for an integrated system to be classified as an ERP system, it must meet a number of additional criteria for consistency with ERP standards[11] [12]. A major asset of ERP systems is that they have a modular structure, meaning in practice that they can be implemented in several stages. ERP II is such a development of the ERP systems that enables them to be used in a web environment. By using web portals, direct communication is possible not only among users within a given organisation but also with external business partners. In this manner, the current stock of specific resources can be directly checked by their suppliers. Another advantage is that information is available from practically any place with access to the Internet (or another network enabling data transmission).

3.Decision Support Systems[13]

DSS are computer systems designed to support decision-makers in solving non-structural problems as well as making strategic and tactic decisions. Their main task is to provide processed and precise information ready to be used at any time and place. Since their inception, they continue to develop, especially in high-risk industries. They are of great importance for hazard management in situations where the risk of error is highly likely. IDSS are a next step in their development.

4.Intelligent Decision Support Systems[14]

IDSS use artificial intelligence technologies (enabling to retrieve knowledge also from sound, image and symbolic data), operations research models (e.g. for optimisation purposes), expert systems or fuzzy logic, among other things.

5.Expert Systems[15]

These solve problems by reasoning through knowledge bases, in contrast to traditional software that operate by running specific algorithms. Knowledge bases play a key role in the operation of ES, as they are basis for interpretation of the data introduced in order to be processed. Expert Systems are basically composed of at least the two following elements:

1. the inference engine that allows to ask questions and searches for replies,
2. knowledge base that, when analysed, can provide replies.

There are numerous types of expert systems among which planning, control, testing, diagnostic, repair, interpretation support and others. They are useful in practically all areas of knowledge. Their application in the logistics services market is also noticeable. As an example, there is an expert system supporting transportation troubleshooting and the organisation of a forwarding company's operations[16]. ES can successfully support the management of logistics in unusual circumstances such as crisis situations. One of the most popular logic programming languages for developing ES is *Prolog*. Currently, rather than being developed from scratch, often ready-made Expert System Shells are used. A shell is substantially a ready-made expert system without knowledge. There are free of charge versions such as *CLIPS* or *DROOLS*, and also payable ones such as *SPHINX*. Shell systems have the following characteristics[17]:

1. in contrast to dedicated solutions, they have an empty knowledge base and can be used in multiple areas,
2. they impose certain limitations as to the form of the knowledge base (as a result, shell systems of various manufacturers are unable to co-operate between themselves),
3. they usually offer many features facilitating the feeding of the knowledge base.

As a major asset, they reduce the time to develop area-specific expert systems.

[6] P. Lech, Zintegrowane systemy zarządzania ERP/ERP II charakterystyka, wykorzystanie w biznesie, wdrażanie. Article available [online] at http://przemyslawlech.info.pl/index_pliki/Lech_Zintegrowane_systemy_zarz%C4%85dzania_ERP_ERPII.pdf [accessed on: 14.04.2018], p. 8.
[7] System otwarty. Article available [online] at http://encyklopedia.interia.pl/informatyka/news-system-otwarty,nId,2090054 [accessed on 14.04.2018].
[8] Open Source. Article available [online] at https://evolpe.pl/open-source/ [accessed on 14.04.2018].
[9] ERP – Enterprise Resource Planning.
[10] OLTP vs. OLAP. Article available [online] at http://datawarehouse4u.info/OLTPvsOLAP.html [accessed on 20.04.2018].
[11] T. Małkus, M. Dziedzic, System ERP. Article available [online] at https://mfiles.pl/pl/index.php/System_ERP [accessed on 20.04.2018].
[12] P. Lech, Zintegrowane systemy zarządzania ERP/ERP II …, op. cit., p. 11.
[13] DSS – Decision Support Systems.
[14] IDSS – Intelligent Decision Support Systems.
[15] ES – Expert systems.
[16] Z. Buchalski, Wspomaganie Organizacji Pracy Firmy Spedycyjnej Przez Regułowy System Ekspertowy, Studia Informatica, Vol. 30, No 2B, 2009.
[17] E. Kołodziński, T. Lachowicz, P. Romaniec, P. Zapert, Wspomaganie Decyzji w Bezpieczeństwie, Wojskowa Akademia Techniczna, Warszawa 2014, p. 151.

5.1. Implementation in the Prolog Language – Example

The system presented below relates to commercial flights operated by *SOUTHERN AIRWAYS EXPRESS* from the airport at Morgantown (USA). The scheme of flights is presented on figure 1.

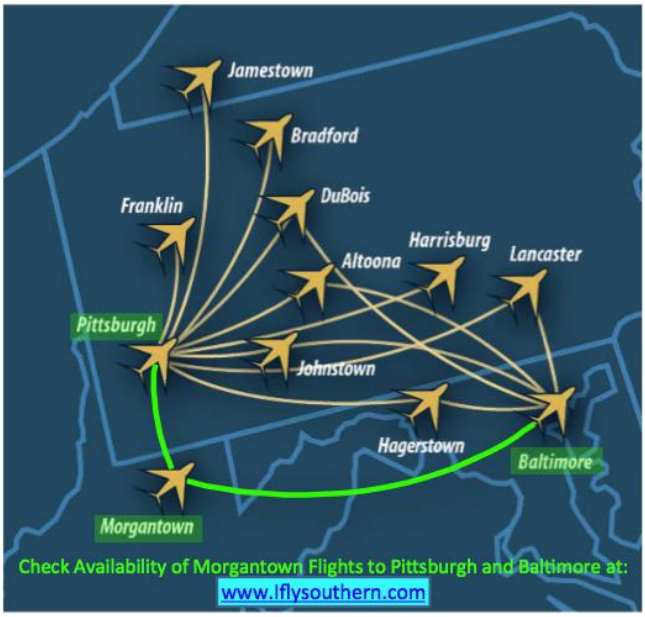

Fig. 1. Scheme of air flights. Source: http://www.morgantownairport.com/flight-information/ [Access on: 16.04.2018]

On this basis, a knowledge base was created describing the available air routes and statements (facts) that specific cities are located in proximity to each other:

Air-routes.pl[18]:

```
%sr1
short_route(morgantown, pittsburgh).
short_route(morgantown, baltimore).
%sr2
short_route(pittsburgh, franklin).
short_route(pittsburgh, jamestown).
short_route(pittsburgh, bradford).
short_route(pittsburgh, dubois).
short_route(pittsburgh, altoona).
short_route(pittsburgh, harrisburg).
short_route(pittsburgh, johnstown).
short_route(pittsburgh, lancaster).
short_route(pittsburgh, hagerstown).
%sr3
short_route(dubois, baltimore).
short_route(altoona, baltimore).
short_route(lancaster, baltimore).
short_route(johnstown, baltimore).
short_route(hagerstown, baltimore).
%sr4
near(morgantown, pittsbourgh).
near(franklin, jamestown).
near(bradford, dubois).
near(altoona, johnstown).
near(harrisburg, lancaster).
near(hagerstown, baltimore).
%symmetric relation
nearby(X,Y) :- near(X,Y).
nearby(X,Y) :- near(Y,X).
%transitive relation
route(X,Y) :- short_route(X,Y).
route(X,Z) :- short_route(X,Y), route(Y,Z).
```

Working with the software is like a conversation and is based on formulating queries to which replies are obtained based on the knowledge base. For example, if we ask: "Which place is located nearby Harrisburg?", i.e. we run the query: `nearby(U, harrisburg).`, we will obtain the response: `U = lancaster`. We can also ask about the availability of flights, e.g. for: `route(pittsburgh, baltimore).`, the value "true" will be produced, which means that this air service exists. In turn, `route(johanstown, altoona).` will provide a negative reply, as the route is not available.If we attempt to find out where we can travel from Pittsburgh, by running the query: `route(pittsburgh, W).`, the system will reply with the following set: `W = franklin ? ; W = jamestown ? ; W = bradford ? ; W = dubois ? ; W = altoona ? ; W = harrisburg ? ; W = johnstown ? ; W = lancaster ? ; W = hagerstown ? ; W = baltimore ?` ... All the replies are consistent with the graphic presentation on figure 1. The GNU Prolog (gprolog)[19] compiler was used in this example.

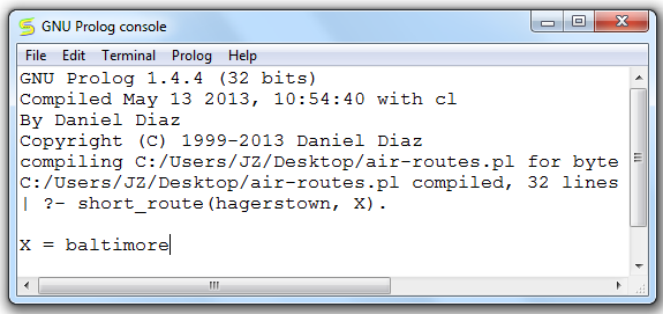

Fig. 2. Example of a query and reply obtained. Source: the authors' own study

6. Business Intelligence Systems[20]

In the current reality, in order for the right decisions to be taken, large amounts of data from various sources are necessary and must be properly interpreted. Thus, it is necessary to have reporting (analytical) tools that support such projects. This is possible thanks to BI (Business Intelligence) systems. An important asset of BI is that they can widely use the mechanisms of artificial intelligence, which considerably changes the techniques of data processing by increasing their efficiency and speed. In addition, BI solutions provide the possibility of integrating data from various sources (such as other IT systems, e.g. ERP, databases, CSV files, Excel, Internet, cloud). Of course, this opens up far greater possibilities than in the case of using several systems that do not communicate (exchange data) among themselves, even though, by definition, they support the same process[21]. A user is not required to know analytical techniques or a database query language in order to generate a report. Modern BI tools provide an opportunity to access the results of analyses of millions of pieces of information in terms of precisely defined needs, also from mobile devices[22]. With rapidly generated reports presented in a user-friendly interface (visualisations in the form of dashboards with interactive charts and diagrams), they

[18] Authors' own study.

[19] http://www.gprolog.org/

[20] BI – Business Intelligence.

[21] A. Jadwidzic, System Business Intelligence - narzędzie do precyzyjnego zarządzania. Article available [online] at https://www.jcommerce.pl/jpro/article/system-business-intelligence-narzedzie-do-efektywnego-zarzadzania [accessed on 17.04.2018].

[22] Business Intelligence, czyli jak wygląda zarządzanie w XXI wieku. Article available [online] at https://www.forbes.pl/technologie/business-intelligence-czyli-jak-wyglada-zarzadzanie-w-xxi-wieku/bz2sdxz [accessed on 17.04.2018].

enable users to make decisions in a fast and efficient manner. In turn, the OLAP (*On-line Analytical Processing*) techniques make real-time analysis possible, i.e. the analysis can be used to control a given process on an on-going basis[23]. The techniques used by BI include neural networks, regression analysis, correlation analysis, genetic algorithms, data/process mining, classifications, searching for rules. These tools are well appreciated in the business environment for their advantages. They offer an opportunity of viewing all the management aspects from a comprehensive perspective, and can support logistical planning (transport, storage, etc.).

7.Big Data Technology

The Big Data term is related to large[24], diversified and variable data sets. Their analysis is a hard task but extremely valuable as it can generate the necessary knowledge. Big Data makes it possible to support decision-making where new forms of information processes are required. This technology is often described according to the *5V model*:

1. *Volume* – amount of data generated by various types of sources /processes,
2. *Velocity* – speed of generating new information and its circulation,
3. *Variety* – variety of data structures/types to be processed,
4. *Veracity* – veracity and adjustment,
5. *Value* – data value[25].

In relation to BI, Big Data constitutes a next stage in the development of analytical processing techniques. As work can be done effectively on a larger amount of data, the prepared analyses can be viewed from a broader perspective. The transformation oriented toward Big Data results from:

1. the transition from a traditional to a logical data warehouse, which mitigates the risk involved in the implementation of the former and reduces the physical infrastructure,
2. the need to use parallel processing mechanisms,
3. the need to use solutions effectively working in a computing cloud,
4. the adaptation to the conditions of new reporting tools (creating visualisations)[26].

There is great potential as far as the use of Big Data in decision supporting in the area of crisis management is concerned. This is particularly noticeable if one takes into account the fact that crisis administration entities use heterogeneous (diversified) sources of data (the *Variety* element of the *5V model*), and, in the future, they will need to use the advantages of this technology more and more often in order to effectively counteract hazards and ensure uninterrupted functioning of the economy in a given area of responsibility[27].

8.Other Solutions

In addition, other solutions can be used in the area in question, including:

1. **MIS – Management Information Systems / EIS – Executive Information Systems / ESS – Executive Support Systems**, which were followed by Decision Support Systems.
2. **SCM – Supply Chain Management Systems** that are often part of, or a supplement to ERP systems.
3. **WMS – Warehouse Management Systems** – used in logistics and supporting all the processes taking place in warehouses. Just as in the case of SCM, certain suppliers of ERP solutions offer the WMS functionality as one of the integral modules of the package.
4. **EDI – Electronic Data Interchange** – a technique that makes it possible to exchange data electronically between co-operating entities. Transmission can take place in the form consistent with the UN/EDIFACT standard (*United Nations rules for EDI for Administration Commerce and Transport*), being an international standard developed at the UN[28]. This solution is widely applied in the logistics systems[29] as it enables to perform functions such as handling the procurement process. The main advantage of EDI is that it eliminates the need to introduce data repeatedly and streamlines the information flow. The UN/EDIFACT standard includes, among others:
   a) an interactive data exchange protocol (I-EDI),
   b) a set of syntax rules,
   c) a multi-level set of catalogues (the so-called standard EDIFACT base),
   d) stadard messages which allow multi-country and multi-industry data exchange.
5. **DMS – Document Management Systems / Systems Supporting Crisis Events Documentation** – e.g. *e-CZK* (Electronic Center For Crisis Management), *e-risk* / **OAS – Office Automation Systems** – used wherever it is necessary to prepare documentation in an electronic form.
6. **Geographical Information Systems / Mapping Systems / Dedicated Internet Systems Providing Geographical Data** e.g. *ArcGIS*, *PGO*, *Google Earth*, *Google Maps*.
7. **Simulation / Training Systems** e.g. *Joint Theatre Level Simulation (JTLS)*, *Joint Conflict and Tactical Simulation (JCATS)*, *Hazardous Prediction and Assessment Capability (HPAC)*[30], *ALOHA*, *Land Simulator*.
8. **Other** (*ARCUS 2005*, *ALASKA*).

Summary

In the current conditions, it is indispensable to appreciate the fact that in order to effectively carry out complex logistics tasks in crisis situations it will become increasingly necessary to rely on the effects of development of modern IT technologies. The human factor may and should be effectively supported in all the phases of the crisis management process requiring to process large amounts of information, including in particular in the context of increasing complexity of problems and pressure on the speed and quality of decision-making. Support can include collecting, transmitting, updating, archiving information as well as its proper analysis, which provides assistance for management bodies in undertaking action. IT systems can effectively support logistics in crisis situations (which is of great importance in this kind of situations), by making it possible to control even the most complex processes. They make it possible to use the capabilities and resources necessary to undertake a reaction in a proper/reasonable manner. They provide assistance in analysing hazards and their sources. They help to identify priority tasks. They ensure the possibility of exchanging information using

[23] Z. Głodek, Metody Rachunkowości w Systemie Informatycznym Zarządzania. Zeszyty Naukowe Uniwersytetu Szczecińskiego No 576, Studia Informatica No 24, 2009.
[24] Meaning amounts of data that are impossible to be processed with the use of standard available methods.
[25] B. Marr, Big Data: The 5 Vs Everyone Must Know. Article available [online] at https://www.linkedin.com/pulse/20140306073407-64875646-big-data-the-5-vs-everyone-must-know [accessed on 21.04.2018].
[26] S. Drosio, S. Stanek, Big Data Jako Źródło Informacji ..., op. cit.
[27] Ibidem.
[28] This is one of the numerous existing message standards of EDI.
[29] I. Nowotyńska, T. Trzepieciński, Wykorzystanie Systemów Informatycznych w Branży Logistycznej. Logistyka 12/2016.
[30] P. Kmiecik, Wykorzystanie teleinformatycznych systemów zarządzania informacją w zarządzaniu kryzysowym. Article available [online] at http://www.nowastrategia.org.pl/itwzk/ [accessed on 21.04.2018].

various communication tools and techniques, including chat, *P2P* technology, video conference, *MS SharePoint* and others.

If the systems described above are used, they will make it possible, through the synergy effect, to build up and effectively leverage the logistics potential. Moreover, dedicated information systems can prove useful in working out procedures for action in crisis situations and in training personnel by simulating events. Additional assistance is provided by simulation tools that make it possible to imitate crisis events by generating specific scenarios. They also offer the possibility of leveraging the information gained in the past and have huge training value. It is a good solution to transfer the technologies that are already used by commercial companies to the reality of logistics performing tasks in the context of crisis situations, as this will help to leverage the experience that proved efficient somewhere else. A concept of a dedicated system can be built based on this experience. This purpose can be equally well attained if certain functionalities of command support systems designed for use in the army, e.g. *SWD C3IS JAŚMIN*[31], are transferred to this area.

One should also bear in mind that, despite numerous advantages, the implementation of dedicated IT systems will always involve certain inconveniences. It is necessary to define and implement security mechanisms, taking into account that the processed information relates to the security status of the state along with its strengths and weaknesses. It may become necessary to adapt operator stations to work in the system. Various levels of access rights to information used by co-operating entities must be taken into consideration. The method for collecting information must be defined, specific standards relating to the IT systems and data transmission technologies must be met. One should also bear in mind that access to a good quality ICT infrastructure is necessary and users must be prepared to use such tools.

Based on the analysis carried out above, we can attempt to define the basic assumptions and expectations regarding a comprehensive decision support system in the logistics of crisis situations. Such a system should:

1. Be easy to use, have a legible and intuitive user interface (SIMPLE TO OPERATE);
2. Be highly reliable and fast (including to allow real-time data analysis) even if working with very large amounts of data (FAST, RELIABILE);
3. Allow for easy changes and expansion with new functionalities, if and when necessary (e.g. due to on-going development), so as to ensure seamless functioning (UNIVERSAL, SCALABLE);
4. Allow for co-operation with other systems by adjusting to applicable standards, handle data from various sources and allow for efficient exchange of information with its environment / co-operating entities (INTEROPERABLE);
5. Give the possibility of working on various hardware platforms (CROSS-PLATFORM) and from any place with access to a network ensuring data transmission (NET-CENTRIC);
6. Allow for simultaneous work of multiple users (MULTI-ACCESS);
7. Allow for a division to task areas, allow for a phased implementation (MODULAR);
8. Support a planning, analytical, monitoring roles, mapping function, present the effects of analyses in a graphic form (e.g. in the form of dashboards, on graphs), have search mechanisms, allow for a selective choice of, and for organising / sorting data according to specific criteria, make available various communication mechanisms to users (MULTIFUNCTIONAL);
9. Be coherent and foreseeable in operation, duly tested at all implementation levels, ensure the confidentiality, integrity and availability of data collected, processed, stored and sent, allow for the possibility of assigning roles and access rights to users in accordance with the principle of least privilege, register the activity of users in the system (SECURE);

[31] B. Biernacik, Możliwości wykorzystania HMS Web Portal na potrzeby zarządzania kryzysowego, in: Systemy Teleinformatyczne w Zarządzaniu Kryzysowym. AON, Warszawa 2012.

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IT in the logistics of crisis situations: a review of selected systems and technologies

Paper provides an analysis of available technologies and information systems that are (or can be) used in the area in question. It also contains the requirements that a dedicated support system for the logistics of crisis situations must meet.

Keywords: information systems, decision support, logistics of crisis situations.

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