Ad-Hoc Architecture of Systems for Disaster Risk Management

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Abstract. The essence of functioning of present-day systems of disasters risk management is information processing for decision making in target domain of risk management. Risk management is the specific field of situational management. Disasters is a result of evolution of situations concerned with different environment natural, technogenic, and human activity processes. The main purpose of disasters risks management (DRM) systems is to provide organizational and technological services to participants in risk management processes to perform the functions assigned to them. DRM system is a complex organizational and technical system. The result of its configuration should be accorded with the architectural model of the organization and cover all levels of organizational and technical means that ensure its operation. Ad-hoc architectural views should reflect point of views concerted with situation context (semantics), stakeholders' positions and available required management means. Organization of DRM system based on ad-hoc architecture approach is proposed in the paper.

Keywords: Disasters Risk Management, Information Technologies, Ad-Hoc Architecture.

1 Introduction

By United Nations Office for Disaster Risk Reduction (UNISDR) definition disaster is '*a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.*' [1]. Disaster risk management according to the terminology of UNISDR [2] '*is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses. < > Disaster risk management actions can be distinguished between prospective disaster risk management, corrective disaster risk management and compensatory disaster risk management, also called residual risk management.*' The first phase of disaster risk management is disasters awareness.

Disasters is a result of evolution of situations concerned with different environment natural, technogenic, and human activity processes. We can say that disaster is some catastrophic situation caused by different factors. Situation, in general sense, defined as all of the facts, conditions, and events that affect someone or something at a particular time and in a particular place [3]. The situation notion could be defined as a conscious knowledge of the individual (-s) about the dynamics of the environment, represented by certain types of information messages that is the basis for constructing a substantiated interpretation of the sequence of changes in states (dynamics) of the world (subject area) from a certain point of view [4]. In situational management information presents as assessment on a state of a target domain through the formal logical treatment of knowledge and beliefs in the context of information theory, results of questionnaires, or propagation of general messaging. Semantic information theory [5] defines semantic information as well formed, meaningful, useful and (it is desirably) truthful information.

Situation awareness is one of important elements in the complex problem of situation management [6], [7]. Situation management is considered "as a framework of concepts, models and enabling technologies for recognizing, reasoning about, affecting on, and predicting situations that are happening or might happen in dynamic systems during pre-defined operational time" [6]. One of important kind of situation awareness is disasters awareness in disasters risk management [8], [9]. Correct disasters awareness is a first step to prevention and elimination of their consequences in context of expression "forewarned is forearmed". In its turn, disasters awareness is a phase of situational, or emergency, or crisis management in the case of disasters risk management.

2 System Architecture and Disaster Risk Management

Various systems, including organizational, describes their architecture. There are various definitions of system's architecture [10-12] and one of generalized definitions presented in the standard ISO/IEC/IEEE 42010:2011 "Systems and software engineering - Architecture description" [13]: architecture – fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution. Systems and enterprise architecture assembles different components for providing system aimful activity. Enterprise reference models includes components for providing:

- Staffing (who?);
- Motivation (why?);
- Localization (where?);
- Resource (what?);
- Timing (when?);
- Functioning (how?).

These components might be grouped as active and passive entities. Active entities perform processing and add value to passive entities. Because the essence of risk management is decision making for controlled domain then active entities are stakeholders of risk management and passive entities are information objects concerned with risk management area. In enterprise architecture of risk management, system staff (personnel) represents active entities and different resources are passive entities. According to reference architecture model, a staff is characterized by motivation, localization, timing and controlling of functioning (information processing). Resources are characterized by localization, timing, and involving to functioning (information processing) from another side. Thus, formal model of risk management process may be wrote as:

$$Y(t) = P\ (C(F(R(t)),\ t),\ F(R(t),\ t)) \qquad (1)$$

where Y – result of system's functioning, P – function of processes management in system, C – function of information processing control in system, F – function of information processing, R – function of resource variation, t – time variable within domain of definition of function P (process lifetime period).

Risk management is the specific field of situational management. Risk management is a process based on the set of principles, realized by the appropriate framework. Relationships between the risk management principles, framework and processes are depicted in fig.1 [14].

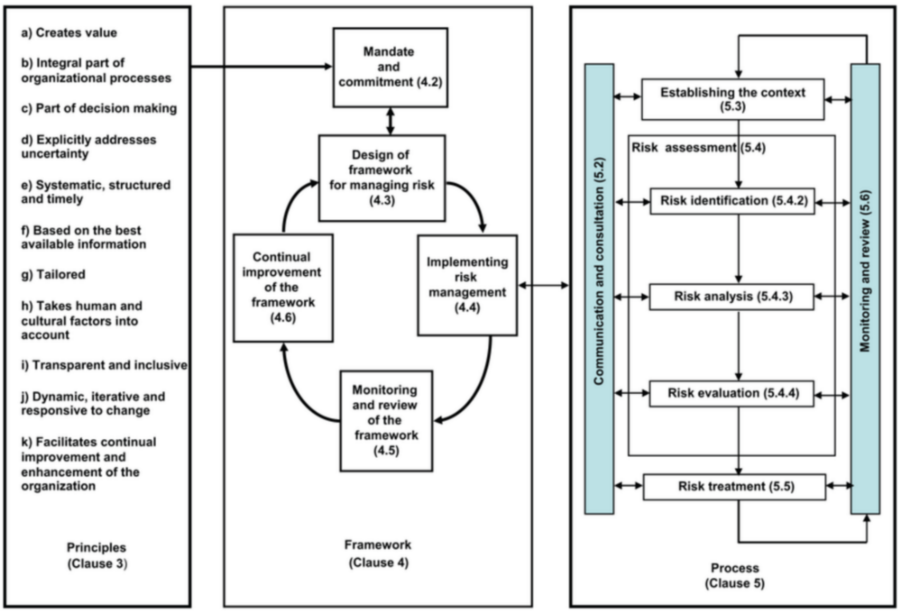

Fig. 1. Relationships between the risk management principles, framework and process [14].

Because situation management in general and disaster risk management (DRM) in particular concerned with unpredictable occasional events then appropriate regulatory system (DRM system) should be adapted to specifics of concrete disaster situation. Such adaptation might be realized based on ad-hoc system architecture. General model of DRM as situation management is depicted in fig 2.

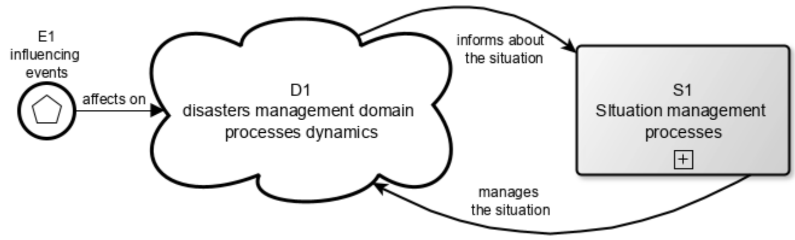

Fig. 2. General model of disaster management as situation management process.

Ad hoc architecture solutions might be designed for a specific problem or task, not generalizing solutions (only having stored for case based choice), without intending to be adapt them to other purposes. Thus, architectural views must reflect views concerted with situation context (semantics), stakeholders' positions and available required management means. Situation management process S1 (see fig.2) is a kind of project activity [4] that include subprocesses depicted in fig.3.

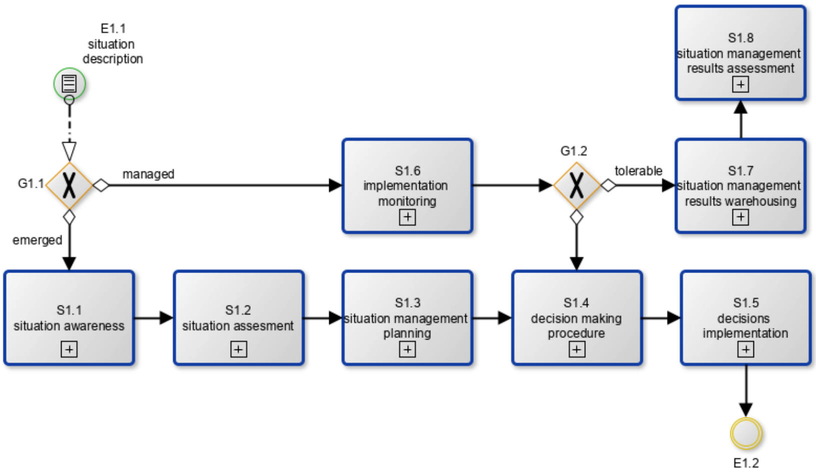

Fig. 3. Subprocesses of situation management process S1.

Pointed in fig.3 processes should be supported by system of situation management (DRM system) with appropriate type of ad-hoc architectural model. Because the main mission of DRM system is decision-making and their implementing then the main stakeholder is decision-approving person (DAP). DAP may be individual or collective. Other stakeholders are involved in process of risk management (see eq. (1)) with appropriate roles to support subprocesses and use processing results as defined according to specifics of DRM domain. All stakeholders divided on two groups: personnel and experts. Personnel perform a supporting role and experts are participants of decision-making process.

3 Convergence in Ad-Hoc System Architecture

3.1 Model of Ad-Hoc System Architecture

Formal model of DRM system [15] is based on system's aspects presented by category model M_K, organizational model parameters M_O, architectural model M_A, process (functional) model M_F, logical model (including model of modalities) M_L:

$$W=\langle M_K; M_O; M_A; M_F; M_L\rangle. \quad (2)$$

Category model M_K is defined on the base of mission, objectives and tasks of DRM system functioning using composition of classification parameters groups. The first (general) group contains parameters of aim mission, subject domain, scale and tasks determinacy. Parameters of second group determine control aspects of DRM system functioning, in particular, subordination, staff, and methods of situational information processing, and time restrictions for decision-making. Third group parameters define constructive specifics of DRM system and contain deployment technique, universality, number and type of physical locations etc. Fourth group parameters define engineering and technological aspects of DRM system functioning with technical equipment list, situation modeling tools nomenclature, using technologies, security level, grade of automation of situational assessment etc. Parameters of DRM system organizational model M_O are defined by main coordination mechanism, organization core type (main part), general design parameters, situational factors (motivations). The architectural model M_A is defined by chosen architectural pattern (framework) for modeling of architecture for software intensive systems. Logical model M_L of DRM system based on modalities models that take into account the relevant modalities [16]. Modal logic and their extensions are used to formalize statements of weakly formalized systems, including natural languages. The logical model of modalities formed on the Kripke scale with the corresponding Kripke semantics [17].

Collaborative activities of staff can be viewed from the point of view agents-based approach and use the behavioral model of agents for this [18]. The behavior of staff agents is based on its knowledge and have some sense (situation semantics). Hence, the formalization of organizational support for staff agents' activity in situational semantics aspect is actual problem.

Resulting integrated behavioral model of service agent is presented as tuple:

$$A_b = \langle T, P, C, M, D, W \rangle \quad (3),$$

where T is a set of means of situation description; P is a set of means of communicative control in changeable communication environments; C is a set of means of coordination mechanism; M is a set of means of messaging between agents; D is a set of means of action description, W is a formal model of DRM system (see eq.(2)) and defines the context of components T, P, C, M, D.

Typical workflow patterns (scheduled procedures) are supported by DRM system services [19]. Information processes in DRM system implemented based on the hierarchy of procedures of technological (routine), organizational (administrative) and subject area (profound, special) levels.

The meaning of the management processes in the DRM system is determined by the specific problems and tasks of risk management that need to be resolved. To ensure the effective operation of the DRM system, it is necessary to organize the appropriate environment of functioning. The main purpose of the DRM system is to provide organizational and technological services to participants in risk management processes to perform the functions assigned to them. Therefore, DRM systems can be considered as service management systems and must comply with the requirements of the relevant standards, in particular ISO/IEC 20000, ISO/IEC 17788, and ISO/IEC 17789. In particular, the ISO/IEC 17788 standard defines the lists of cloud services capabilities types and cloud services categories corresponding to these types of capabilities (see Table 1).

Table 1. Cloud service categories and cloud capabilities types.

Cloud service categories	**Cloud capabilities types**		
	Infrastructure	Platform	Application
Compute as a Service (CompaaS)	X		
Communications as a Service (CaaS)		X	X
Data Storage as a Service (DSaaS)	X	X	X
Infrastructure as a Service (IaaS)	X		
Network as a Service (NaaS)	X	X	X
Platform as a Service (PaaS)		X	
Software as a Service (SaaS)			X
Database as a Service (DBaaS)	X	X	X
Desktop as a Service (DTaaS)	X	X	X
Email as a Service (EMaaS)	X	X	X
Identity as a Service (IdaaS)	X		X
Management as a Service (MaaS)			X
Security as a Service (SecaaS)		X	X
Other Emerging Services	?	?	?

Implementation of the DRM system on the basis of the concept of service-oriented architecture (SOA) and cloud computing requires the creation of tools for configurations of DRM system in accordance with the conditions and requirements for their use. Since the DRM system is an organizational and technical complex, the result of the configuration of this one should be accorded with the architectural model of the organization and cover all levels of organizational and technical means that ensure its operation. Unlike the usual service management systems, DRM system should provide not separate information processing services, but technological services packages that are oriented to support the technological stages of risk management processes for a particular problem. Therefore, the tools for configuring the DRM system should support the creation of such technological packages.

The functioning of the DRM system takes place in the mode of multilateral cooperative activities of interested stakeholders and involves the convergence of scientific methods and technological means of various subject areas of activity related to the specific problems of risk management. Consequently, the configuration of service packages for DRM system should provide the possibility of convergence of the necessary scientific methods and technologies. Creation of technological packages can be based on knowledge of subject areas of risk management using the multi-agent approach. Convergence of methods and technologies within the technological package is carried out based on a formal description of the risk management problem, which includes the following elements of risk management:

- Characteristic of the problem;
- List of objectives criteria;
- Design model for solving the problem;
- Resources requirements;
- Resources constraints.

The description of the problem of risk management should be presented as a formal model of business processes of risk management taking into account certain resource requirements and constraints. Information about the requirements and constraints of the risk management environment is stored in the catalogues and reference books that characterize the relevant categories of services. Configuring the risk management environment for a particular problem is done using the system configuration tools based on the "Infrastructure as Code" (IaC) approach, in particular such as, Ansible, Puppet, CFEngine, and others.

3.2 Building of an Ad-hoc Architecture

Ad-hoc architecture for realizing of formal processing model (see eq. (1)) based on formal model of DRM system (see eq. (2)) and formal behavioral model of DRM service agent (see eq.(3)) might be presented using model based system engineering (MBSE) languages and tools, such as UML, SysML, Archimate, BPMN etc. Main aim of system architecture modelling and simulation is presenting relations and interactions between active entities called actors, and passive entities called architectural artifacts. Architecture models should include structural and dynamic aspects of the system.

Two types of project activities are coupled in ad-hoc DRM systems. The first one is project for building of DRM system to support the set of projects of second type for providing of situation risk management processes like depicted in fig. 3. In essence, project activity for building of DRM system concerned with creating of technological platform for maintaining of situational risks management processes for specific groups of actor roles. Actors as intelligent agents are characterized by their capabilities based on beliefs, desires, intentions, obligations and restrictions as knowledge elements. Technologies of risk management platform should met with requirements of each stage of processing according to assignment of separated processes of risk management taking into account actors' capabilities.

Convergence of intelligent agents' and technological platform capabilities provides functionality of DRM system in a whole.

3.3 Transformation of Information in DRM Systems

Situational management activity concerned with consolidation and processing of information of heterogeneous origin to receive semantic information. Hence, it is important to develop adequate means (principles, methods and tools) for information consolidation. Most common approach to information consolidation is based on information fusion methods.

According to Data Fusion Information Group (DFIG) Model [20] there are defined six levels of information fusion:

- Level 0 – Data Assessment;
- Level 1 – Object Assessment;
- Level 3 – Impact Assessment;
- Level 4 – Process Refinement;
- Level 5 – User Refinement;
- Level 6 – Mission Management.

To refinement of different levels, it is necessary to build sound hierarchy of notions concerned with basic notion of "information". This hierarchy called I-SDKW model [21] covers different cycles of thinking such as learning, intelligence, and decision cycles. Information is transformed through receiving, collecting, aggregating, filtering, representing, awaring, interpreting, estimating, using, enrichment, composing, and growing to higher-level stages. I-SDKW model is based on taxonomy of information that differs four categories of information: signal, data, knowledge and wisdom. Facilities of these categories by attributes, using and focus of processing are presented in Table 2.

Information transformation concerned with bidirectional transforming of different kinds of information in process of its use. Information perception begins from receiving a signal from environmental source, because the absence of signal means the absence of information ('it is impossible in a dark room to find a black cat that is not there'). Therefore, signal about some phenomena carries primary information about this phenomenon as symbol, or sign, or image, or dynamic process represented appropriate data structures. These data structures may be composed by meanings (context) in facts of TBox (terminological part of knowledge base) and ABox (assertions' part of knowledge base) [22] of some knowledge domain and the linked set of such facts are framed the knowledge base.

The problem is what and how observer(s) can know something about knowledge domain. The top-level fragment of I-SDKW ontology in OntoGraf view is depicted in fig. 4. In this model, information appears and transforms in different manifestation. So information is manifested either signal, or structure, or theory (system), or recommendations, or best practices etc. However, knowledge is not enough for wise decision. Wisdom is that the decision should be conformed to context of situation.

Table 2. Facilities of Information Categories [21].

Information categories	Category facility (feature)		
	Attributes	**Usage**	**Focus**
Signal	Source, medium, strength, time	Transmitting, receiving, communicating	Attributes
Data	Volume, type (structure)	Storing, warehousing	Structure
Knowledge	Semantic fullness	Understanding, interpreting, motivating	Logic model and expressiveness
Wisdom	Efficiency, effectiveness, usefulness, purposefulness	Decision making, reasonable behavior	Practical results, objectives achievement

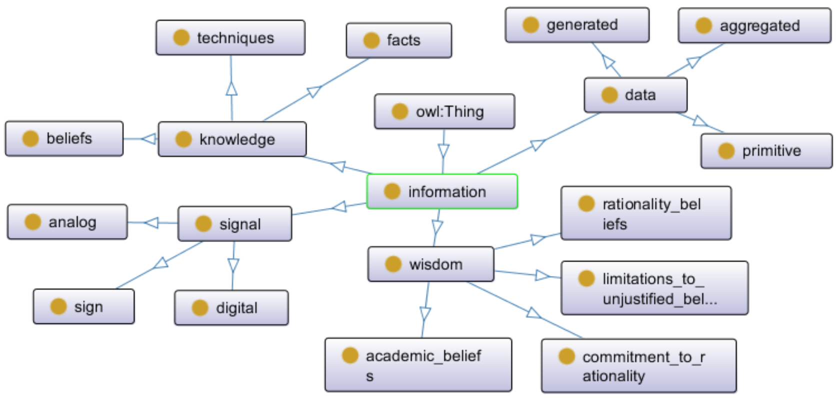

Fig. 4. Fragment of I-SDKW ontology in OntoGraf view [21].

I-SDKW ontology is the result of systematization of knowledge domain thesaurus. The information about problem domain is structured from signals (sequences, symbols, signs, and icons) to data structures, further to controlled vocabularies, further to taxonomies, further to thesaurus, further to ontologies. Therefore, we can to build perceptual hierarchy from signal to wisdom and effector hierarchy from wisdom to signal.

I-SDKW information transformation paradigm takes into account attributive properties of information and manner both of its representation and the use. It is especially actually for information processing during situational risk management when environmental situational information have different forms and assignments.

4 Conclusion and Further Research

Convergence and configuration of information technology in the DRM system based on formal models of business processes of risk management and artifacts catalogs of systems, allows adapting the DRM systems to solve various problems of risk management and provides sets of technological services depending on the context of the risk management.

Variety of DRM problems cause needs to adapt architecture of DRM system for specifics of problem domain. Such adaptation may be provided in the bounds of project activities of the building of ad-hoc architecture for DRM platform and its using to supporting of DRM processes in problem domain. Building of ad-hoc architecture is provided through coupling of active entities (actors) with passive entities (architecture artifacts) in accordance to formal model, described in architecture description language. Architectural model of DRM platform describes artifacts sets convergent composition. DRM processes on specific DRM platform are described by composition of dynamic artifacts of DRM processes fragments.

Practical use of proposed approach is concerned to adequate building of ad-hoc architectural models for DRM systems and theirs proper utilization according to problem domain specifics. Further research will be concerned with case study for creating patterns for variety of practical tasks of DRM and other situation management using ad-hoc approach.

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