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Research Article

Development of Interoperability Principles for Disaster and Emergency Management System of Türkiye

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Abstract

Due to their complex nature, disasters and emergencies require a data-intensive management system in which many actors from different sectors participate and simultaneous processes are managed. Due to this complexity, there are problems in managing and sharing process services and geographic data effectively. The key to solving these problems is the introduction of a complete interoperability model. In this context, interoperability models based on existing international standards are analyzed in this study. FEI and EIF models are taken as basis in terms of disaster and emergency management interoperability requirements. Accordingly, the interoperability reference model was created in legal, organizational, semantic and technical frameworks to meet the interoperability levels. This general framework model has been evaluated in the service and data layers that need to be fully defined in disaster and emergency management phases, and a basic model including interoperability solutions for the service and data model has been created. In this study, an approach for data sharing and presentation has been developed to ensure the interoperability of stakeholders who are responsible for managing the processes at every phase of disaster and emergency management in Turkey. With well-established policy at the legal level, process management information for organizational interoperability will also be available. Data model components at the semantic level and service model components, which also define the sharing rules of data and processes at the technical level, form the basis of the disaster management geographic data infrastructure.

Keywords: Disaster and Emergency Management, Interoperability Model, Semantic Interoperability, Geo-Data Model, Service Model

Introduction

Disaster and Emergency Management (DEM) is the management of all institutions and organisations of the society and their resources in line with these common objectives in order to manage the processes within the scope of mitigation, preparedness, response and recovery phases of disasters (Bullock et al., 2012). Stakeholders involved in the processes of DEM also need the coordination of complete and up-to-date data enabling reliable decision-making. Thus, the DEM needs an iterative system or a model covering official policies and strategies covering all activities within the scope of the processes including structural and non-structural measures (Trogrlic et al., 2022). In this context, in order to minimise the loss of life and economic losses at every phase of disaster events, Disaster and Emergency Management System (DEMS), which is an integrated and technological system where relevant data and information are provided in a timely manner in coordination and can be easily exchanged in a virtual network environment, is being established (AFAD, 2012).

The integrated DEMS, which will ensure coordinated and effective management of disasters and emergencies, should be capable of covering all phases of management, all regional disaster risks, all actors who have direct or indirect responsibility in management and the activities for which they are responsible, all data to be defined in detail in the processes and their needs (International Atomic Energy Agency, 1998). Although Turkey does not have an integrated and unified DEMS, GIS-based Disaster Management and Decision Support System (AYDES) within the scope of Turkey Disaster Response Plan (TAMP) for the management and coordination of operation teams has started to be used in AFAD since 2015. Risk Management System Creation Project, Disaster Risk Reduction System (ARAS) and Turkey Disaster Risk Reduction Plan (TARAP) projects are ongoing (AFAD, 2023).

The concept that existed as GIS in the 1990s has been developed with many flexible approaches such as Geographic Data Infrastructure (GDI), geographic web services, Service Oriented Architecture (SOA) and today, together with Cyber Infrastructure (CI), the concept of Geospatial Cyber Infrastructure (GCI) has emerged (Zongyao and Yichun, 2010; Gotlib et al., 2022). CI is based on the concept of "data-intensive" which is accepted as the 4th paradigm in science (Hey et al., 2009). Due to the dynamic structure of the world, the complexity of the geographical area and the dense data requirement in multidisciplinary research areas that require the interoperability of many disciplines in process management such as DEM, state-supported GDI and semantic web services are not sufficient for distributed geographic data access, sharing and analysis. In order to carry out joint scientific studies more efficiently, the need for a flexible and dynamic environment that enables distributed data sharing and effective use of computing capabilities and meets the needs of the change in the direction of the user to access increasingly distributed geographic data services has arisen (Yang et al., 2010). In this context, GCI integrates CI, GDI and Geographic Information Technologies (GIT) capabilities to support end-user processing capabilities such as geospatial analysis, environmental modelling and decision-making, and brings new perspectives to make existing web GIS an important component of the GIS environment (Sun et al., 2019). The architecture and integration of GCI consists of many technologies and sciences with the aim of bringing together human, information and computational tools to realise scientific or other data-intensive applications. Some of them are: GIT, GDI, CI, earth observation and sensor networks, web technologies, interoperable open access technologies, computer platforms, web computing platforms, high-performance computing computing platforms, distributed geographic information processing resources, multiple data input channels (including citizens), open source software, network protocols, SOA, system integration architectures, workflow chains, etc (Gong et al., 2015).

Minimisation of the consequences that cause the occurrence of a disaster and the losses and damages that occur at the time of a disaster is only possible with an effective CI-supported DEMS that provides inter-institutional interoperability and accurate information sharing. Interoperability at various levels between different institutions and organisations at local, regional, national and international levels, between service providers, between data providers and service providers, between end-users and service providers is needed in the DEM (Migliorini, 2018). According to Open Geospatial Consortium (OGC), interoperability is "the ability to communicate, execute, or transfer data between various functional units in such a way that users require little or no knowledge of the different characteristics of the units" (Giannecchini et al., 2006). Interoperability enables data integration across organisations, applications and industries, resulting in the generation and sharing of more useful data (Esri, 2003). Interoperability is also defined as the ability of different systems or entities to communicate in a common environment in accordance with a set of standards and the ability to understand and use the data shared between themc (Diallo et al., 2011).

There are many different models in the literature to classify interoperability levels. Enterprise Interoperability Framework (EIF), Levels of Information System Interoperability (LISI), Organisational Interoperability Maturity Model (OIM), North Atlantic Treaty Organization C3 Technical Architecture (NC3TA), Levels of Conceptual Interoperability Model (LCIM), Layers of Coalition Interoperability and The System of Systems Interoperability Model (SOSI) also provide comprehensive information on the need for interoperability within the scope of the DEM (Lu, 2012). Although these models address interoperability at different levels, they are all based on the principles of unified interoperability.

Level 1 refers more to software hardware independence and is classified as integrability rather than interoperability in advanced models (Salvadori, 2018). Parallel to the use of GIS in different application areas and the development of technology, most applications now provide 1st level interoperability (Hare et al., 2018). In terms of the needs of other application areas that use geographic data, 2nd, 3rd, and 4th level interoperability has been emphasized frequently and in detail in most studies and GDI initiatives. Levels 5 and 6 are concerned with the organisability principle of interoperability (the principle that deals with the ability of software components or modules to be combined and assembled in various combinations to meet user requirements). These levels are usually addressed in GCI studies. Due to the need for virtual reality, its dynamic nature and the uncertainties based on the chaos theorem, these levels are of critical importance in determining the interoperability principles of the DEM.

The European Union ATHENA Interoperability Framework (AIF) Project, which establishes an interoperable system design framework for applications and software, has presented a modelling concept for application areas such as the DEMS. Within the scope of AIF, modelling is presented at 5 levels: task, process, service, data types, and data (AIF, 2006). In this context, in order to ensure interoperability in the design of the DEMS, the need to create a "method and task model", "data model" and "service model" is generally emphasised.

In this context, the objective of the second part of the study is to examine and compare the existing interoperability models and frameworks in terms of their use in the DEM Reference Model (DEM-RM) in order to define and shape the field of the DEM-RM and to determine the models and frameworks that will form a reference to the DEM-RM and their characteristics to be taken as reference. In addition, international standards were not added to the analysis made in this section, but the implementation methods of the standards were analysed. The frameworks and models analysed here are the studies that use, implement and output international standards. In section 3 of the study, according to the selected methodology, a model proposal is presented that shows the general structure and relational status of the legal, organisational, semantic, and technical layers of the AADYS-BC-RM. Section 4 summarises the study and shows the planned future work.

Determining the Methodology of Interoperability Model

Within the scope of the study, the interoperability frameworks and models given in Table 1 are analysed. Some of the frameworks and models categorise interoperability levels based only on their approach, while others also categorise interoperability evaluation levels. Table 1 shows how many levels of interoperability are expressed by frameworks and models and what these levels are.

Table 1: Levels of interoperability frameworks and models.

Approaches	No. of Levels	Interoperability Levels
AIF	4	data-service-process-institutional
EIF	4	technical-semantic-legal-organisation
EIMM	6	legal-technology-service-service-organisation-process-institutional
FEI	4	data-service-process-institutional
IAM	8	requirement-standard-data-data-link-protocol-information-flow-transition-interpretation-information-use
ICM	8	data-network-service-application-infrastructure-security-platform-system
i-Score	4	technological-biological-organisation-environmental
LCI	9	physical-protocol-data/object-information-understanding-procedure -harmonised transactions-strategy-policy
LCIM	7	none-technical-syntactical-semantic-pragmatic-dynamic-conceptual
LISI	5	isolated-connected functional-impact area-conceptual
NMI	5	none - unstructured data exchange -structured data exchange - seamless data sharing - seamless information sharing
NTI	4	social-personal-process-organisational
OIAM	5	static-preparation-possession-clarity-dynamic
OIM	5	independent-purpose specific-collaborative-combined-unified
QoIM	6	tool-language-standard requirement-environment-procedure-human

The prominent features of these interoperability frameworks and models are analysed and which framework or model meets which interoperability level is shown in Table 2. Accordingly, LCIM and FEI are the approaches that fulfil the highest level (Wang et al., 2009; Yang et al., 2013; Song et al, 2012). Considering the multi-actor, multi-risk and complex interrelationship structure of the DEMS, the need for interoperability also increases. In this respect, NTI non-technical interoperability levels are of great importance for the DEMS considering the human and sociological dimension of the DEM (Billaud et al., 2017). For the conceptual level, different and detailed definitions and approaches of EIF, ICM, LISI and NMI contain features that can serve as a reference for DEMS-RM (Maxim et al, 2021; Tolk and Muguira, 2003; Morris et al., 2004). Pragmatic and dynamic interoperability is important in DEM due to the dynamic determination and execution of operations and the unpredictability of the risks that will occur. For these levels, OIAM, EIMM and LCIM are important in terms of providing detailed information and approach (Jabin et al, 2019; Maremi et al., 2020; EIMM, 2006). It is of vital importance to ensure full operational interoperability, especially in the response phase, for the AADY. IAM provides a detailed model for operational interoperability (Cretan et al., 2012). For semantic and organisational interoperability, many models and frameworks provide detailed approaches, but the most detailed approaches are defined in EIMM and I-Score for organisational interoperability and AIF for semantic interoperability (Ford et al., 2007). Technical interoperability is described in detail in many frameworks and models.

Interoperability frameworks and models and literature studies have been analysed to determine the interoperability level needs of DEMS, the current status of these levels and which model meets these needs. Below is a summary of the analysis according to interoperability levels.

The EIF architecture is based on a task, process, service and data approach, and this approach underlies the determination of interoperability levels (Wimmer et al., 2018). In some models, it is argued that ensuring interoperability is related to the removal of interoperability barriers and these barriers have been modelled (Cestari et al., 2014). According to the results, interoperability barrier levels were created. EIMM barrier levels were determined as isolated, initial, executable, connectable and interoperability barriers (Chen et al., 2008). FEI determined interoperability levels by including conceptual, organisational and technological barriers in the model (Leal et al., 2019). In addition, ICM, which covers the non-technical level, identified the levels as culture, programme, structural, operational, political, semantic, collaboration, organisational.

Semantic interoperability is related to data and service meanings and the relationship between them (PAHO, 2021). In this context, the level of semantic interoperability is vital in complex management systems such as DEMS, where decision-making time is limited and many different organisations and data are involved in management. In order to achieve semantic integrity, it is recommended to use common languages, common concepts and conceptual models (Linden and Zee, 2014). Nowadays, studies on semantic interoperability by solving fuzzy cross-relationships are emphasised. In current data exchange models, the use of XML, XML schema and UML languages together with ontologies has contributed greatly to semantic interoperability (Memduhoglu and Basaraner, 2018). The most basic study is carried out on the Internet of Things (IoT). The aim is to provide dynamic environmental management by creating artificial intelligence through smart objects. This can only be achieved by ensuring full semantic interoperability (Kumar et al., 2019). These studies are of vital importance for the DEM. The LISI model is the most suitable model for semantic interoperability needs and forms the basis of the studies carried out in this context in the USA.

Syntactic interoperability refers to the implementation of databases of different paradigms (relational, objective) or the geometric representation of objects (raster, vector) (Bizid et al., 2016). In a web-based system, syntactic interoperability standardises the communication between a software client and a server (Sydmanns et al., 2018). Since the DEMS includes a large number of public institutions, private institutions, NGOs and all citizens in its organisational structure, and since it needs to integrate, analyse and disseminate information from many different sources, including citizens, especially during a disaster, it needs syntactic interoperability at a very high level sectorally. Today, some of the barriers to syntactic interoperability have been overcome through the use of SOA technologies and information encoding in XML format (Niedermayr et al., 2013). In addition, much current research is focused on achieving syntactic interoperability by standardising the data exchanged between heterogeneous devices. This represents a current challenge and research topic, especially in the IoT context (Ullah et al., 2017). In LCIM, a syntactic level has been created using standardised formats, which enables data exchange to a large extent. FEI has provided existing syntactic interoperability issues and modelled the barriers to full interoperability. Syntactic interoperability within the scope of the DEMS will be handled within the semantic interoperability model in accordance with the EIF.

Table 2: Levels fulfilled by interoperability frameworks and models.

Interoperability Type	AIF	EIF	EIMM	FEI	IAM	ICM	i-Score	LCI	LCIM	LISI	NMI	NTI	OIAM	OIM	QoIM
Nontechnical						X						X			
Operational	X	X	X	X				X	X				X		X
Technical	X	X	X	X	X	X		X	X	X	X				X
Semantic	X	X	X	X		X		X	X	X	X				X
Conceptual	X	X		X				X	X						
Pragramatic				X					X						
Dynamic				X					X						
Organizational	X	X	X	X	X		X	X	X				X	X	X

Technical interoperability covers the technical issues that link computer systems and services (Hellberg and Grönlund, 2013). In other words, it is generally related to information technology, data transformation and service management. The technical level has evolved over time towards the development of interoperable portals and web services equipped with interfaces as well as standards for data communication, data exchange, data modelling and storage (NIFO, 2023). The most current topic of technical interoperability is the service and communication model. In this context, studies are carried out on service levels such as public interfaces, interconnection services, data and service integration, and the accessibility, security, sharing and presentation of services (EIF, 2023). In order to be able to manage the complex and multi-actor workflow processes of the DEMS, a fully defined service and data model and therefore technical interoperability is needed. In some models, technical interoperability is considered together with syntactic interoperability. However, the technical model and hence the service management content at this level will not be adequate for DEMS. Technical interoperability in DEMS is a user of syntactic interoperability standards. The syntactic level and the technical level cannot be modelled together as they are completely different topics.

Organisational interoperability relates to how different organisations cooperate through mutual agreements and standards to achieve their goals (EIF, 2017). In practice, this level requires the identification of workflow, related data exchange and integration, and the relationship between workflow and process modelling (Sadiq et al., 2003). Organisational interoperability also aims to meet user requirements by making services easy to define, accessible and user-oriented (EIF, 2022; Kouroubali and Katehakis, 2019). In order to ensure organisational interoperability within the scope of the DEMS, unlike other areas, it is necessary to determine in detail when, why and how the data will be changed. For this purpose, the DEMS organisational interoperability model should include a reference framework for data exchange. Another distinctive feature of the DEMS organisational model is that it includes a large number of stakeholders from different sectors, in fact almost all institutions can be considered as stakeholders directly or indirectly. Within the scope of the study, organisational modelling will be performed using the FEI task-process-service-data approach.

Pragmatic interoperability refers to the purposes, responsibilities and implicit or explicit consequences of data, information or messages (Asuncion and Sinderen, 2010). This level encompasses distributed computational models that make it possible to share and analyse geographical processes between different institutions (Chen et al., 2020). In this context, pragmatic interoperability relates to the fact that the roles of all parties involved are defined. This level is achieved when, in addition to system interoperability, process requirements and organisational coherence are established between stakeholders (EU4Digital, 2020). Within the scope of the study, the error detection, correction and retransmission components of pragmatic interoperability in data sharing will not be addressed. Since stakeholders need to understand, share and execute mutual tasks in order for a process to be conducted for the DEMS, issues in this scope will be addressed in the DEMS interoperability model. These aspects will be organised according to the LCI data context approach and, as in the EIF model, this interoperability issue will be included in the organisational interoperability model covering workflows.

Conceptual interoperability can be explained as creating a common framework of the thematic area or system under consideration based on epistemology (Danielsson, 2022). In this framework not only knowledge and models but also multiple temporal relationships between them are represented. A conceptual model is an abstract and simplified representation of the system by language, figure, diagram, table or format for specific purposes. In the literature, it has been emphasised that the design and components of conceptual models should be standardised as a first condition for achieving holistic interoperability (Tolk and Muguira, 2003). The EIF conceptual interoperability model, which provides a detailed standards-based definition in addition to LCIM, will be used as a reference for DEMS. In addition, the conceptual model will be modelled according to layered design principles within the scope of GCI requirements. In this respect, FEI, which is the most appropriate framework for the DEMS organisational model, will be taken as reference. In this context, in addition to the general conceptual modelling, data, service, process and sectoral conceptual modelling will be performed.

Legal interoperability is considered in two aspects. The first refers to the definition of interoperability aspects with political issues, and the second refers to the creation of legal regulations within the scope of establishing common use, methodology and terminology according to interoperability needs (Reichstadter, 2018). Determining policies, establishing principles, producing standards, regulations and directives on issues such as data sharing, updating and maintenance are considered within this scope (SLDS, 2019). In addition, instructions, rules and parameters for workflow and communication management, which are part of legal interoperability, are made under sectoral GDI in most countries within the scope of DEM. In Turkey, studies on this subject have been started within AFAD, but there is no information on the connection of these studies with Turkey's National Spatial Data Infrastructure (TUCBS). The requirements given here under legal interoperability are divided into two as political and legal interoperability in some models. In frameworks such as EIF, all interoperability levels are considered within the political scope. Within the scope of this study, interoperability models with reference to EIF will be discussed within the framework of Turkey's political and legal situation, and the political interoperability level will not be defined in the model. In addition, legal interoperability in the model will be limited to the standards and their contents that need to be developed within the scope of other interoperability levels.

Physical interoperability covers aspects related to the physical appearance, the environment and the contact or interaction between systems (Zdravkovic, 2012). Physical interoperability is usually considered within technical interoperability within the scope of interoperability between systems (National Research Council, 1999). However, it is among the current research topics, especially within the scope of IoT studies, since systems, environment and physical earth should be evaluated together (Clapp, 2020). Apart from these, a physical interoperability model was presented within the scope of the European Union 5GChampion Project (Destino et al., 2017). Almost all of the existing physical interoperability studies are carried out within the scope of CI and GCI and are generally referred to as cyber physical systems (Ying et al., 2013). It is argued that the main factor for ensuring physical interoperability is fast connections, and in this context, the focus is on the creation and standardisation of new connection types (Noura et al., 2018).

Social interoperability is one of the levels that should be included in the DEMS design to ensure effective results for all citizens. Social interoperability addresses factors such as sociological structure, cultural structure, education level as well as policy and training (Tedla, 2016). Although only the social dimension of interoperability is addressed in some models, this is not sufficient for DEM. In the developed conceptual model, social interoperability will be included in the general design, but it will not be elaborated since it is a subject of a different field of science (Lukyanenko et al., 2022).

In the literature, it has been observed that dynamic and schematic interoperability are added to the interoperability levels in some approaches. By its very nature, the DEM requires complex relationships, computations and dense data. Today, advanced systems are designed in accordance with the principle of creating simple models for integrated interoperability models, and as we go down to the sub-headings, the models begin to show complex relationships (Zacharevicz et al., 2020; Petrasch and Petrasch, 2022). In this context, schematic interoperability will be modelled within technical interoperability within the DEMS-RM model. Dynamic modelling is a level added to ensure that interoperability for the community is not impaired if a particular system or systems change over time. The need for the DEMS model is to provide a high level of semantic and technical interoperability, in which case dynamic interoperability will already be provided.

As explained above, DEMS-RM will be modelled at five levels with respect to existing models and frameworks and future projections: conceptual, legal, organisational, semantic and technical interoperability levels. In this phase, the conceptual, legal and organisational levels will be built based on the EIF. The semantic and technical levels will be based on the AIF. Due to the complex interrelated data intensive content of the EIF, the interoperability levels will be applied by modelling it in four interrelated layers: sectoral, process, service and data, with reference to the FEI model. Table 3 shows which model or framework is chosen as reference for each layer for all interoperability levels in detail.

Table 3: Mapping reference models to DEMS interoperability requirements

			EIF			AIF
	Layer/Level	**Conceptual**	**Legal**	**Organizational**	**Semantic**	**Technical**
FEI	**Sector**	ICM	i-Score	OIM		LCIM
	Process	EIMM				
	Service		LCI	OIAM		LSI
	Data	LCIM				

The Interoperability Reference Model of Disaster and Emergency Management System

To support the interoperability of the DEMS, the DEMS Reference Model (DEMS-RM) has been developed. The DEMS-RM is a content metamodel that defines the architectural structure components needed to support interoperability between DEM stakeholders across administrative levels and sectors. Developed in accordance with the principles of the Service Oriented Architecture (SOA) and the EIF, the DEMS-RM uses the ArchiMate language as the modeling notation. DEMS-RM framework describes four levels of interoperability: legal, organizational, semantic and technical. Each of them is an element that needs to be considered when setting up a new DEMS process or data service.

The principles underlying the DEMS interoperability framework set out the characteristics to be considered in terms of the objectives and principles to be followed in order for the DEMS to achieve interoperability between stakeholders in different sectors. The interoperability principles are the basic behavioral aspects for developing interoperable DEMS data and process services. In addition to these general interoperability principles, the principles that need to be addressed for the implementation of the DEM are described in Figure 1.

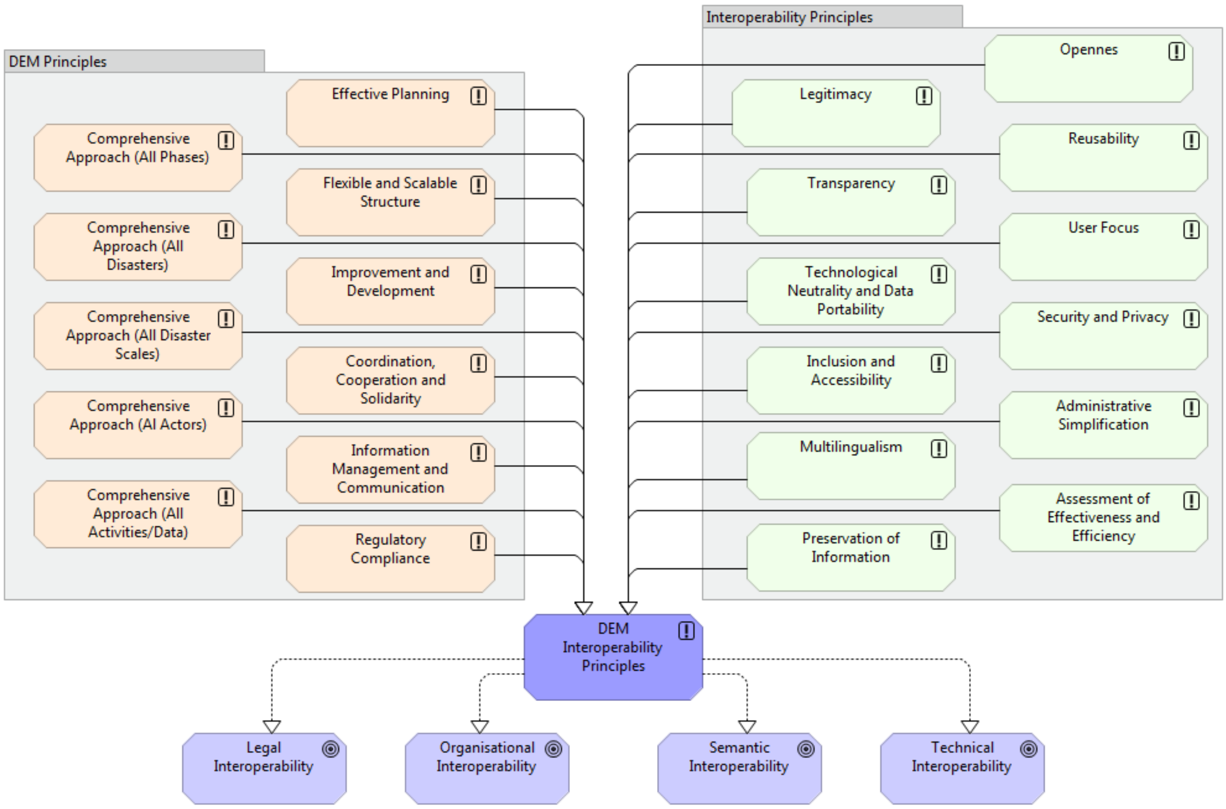

Fig. 1: DEMS interoperability framework principles view

The basic framework of the DEMS-RM, shown in Figure 2, defines the overall architectural structure of each view. The basic framework of DEMS-RM is based on the service delivery model described in the IMM and the EIRA based on the EIF conceptual model. The architectural structures covered by the basic framework represent the relationships that connect the different views of the DEMS-RM. The views presented in the model provide solutions for each interoperability level. In this example, the architectural structures connecting the views are shown at the generic level.
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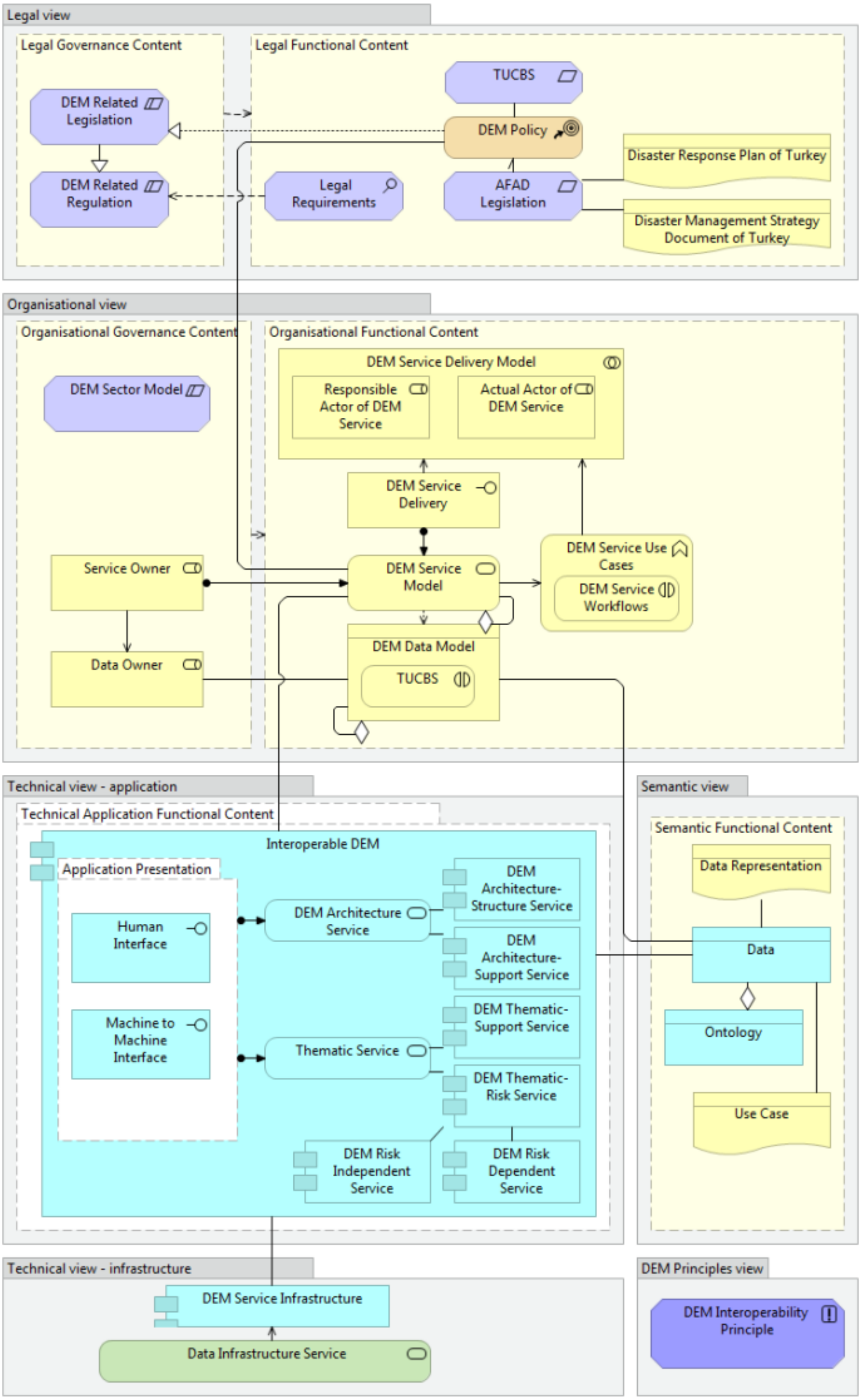

Fig. 2: Basic framework of DEMS-RM interoperability

This framework shows the architectural structures from five different levels of interoperability that encompasses DEMS-RM views:

- The legal view shows the policy relationships within the scope of DEMS.
- The organizational view shows the implementation of the services provided by the actors responsible for the DEMS activities and the services performed by the actual actors of the DEMS activities. The DEMS service is realized by the workflow, which is a combination of other services or worksteps. The workflow describes the basic functions that create the services of the DEMS. Data exchange accesses process data.

- The semantic view shows the scope of data exchange that enables the interaction of DEMS stakeholders, relevant sectors, responsible and actual actors in process management.
- The technical application view defines the service structure of the DEMS offering interoperability and user access to the services through machine and human interfaces.

The technical infrastructure view uses service infrastructure that uses network infrastructure

The Interoperability Reference Model of Disaster and Emergency Management System Service Layer

In order to ensure interoperability, a service model should be created to deliver the process model and data model determined using human interface to DEMS stakeholders over the network and to create the system technical infrastructure using machine interface. By using SOA, access to business processes, geographic data and analytical functions can be provided over the web. The processes in DEM phases are complex due to the involvement of many responsible and actual actors and the use of intensive geographic data and functions. The service integration required to manage these complex processes involving geographic data often uses services published by different stakeholders. This requires the use of semantic description in service integration. According to DEMS-RM principles, DEMS services and interfaces include software/hardware independent standards-based service specifications. According to architectural principles, DEMS services and interfaces include platform independent service specifications.

Figure 3 shows the basic DEM service model. Each DEMS service depends on one or more interface types. An interface type can be defined as a set of operations that contain the visible behavior of the process containing the service network. For reusability and interoperability, the operations that make up the processes should be aggregated into an interface type and the interface definitions with these processes should be complete. The interface type definition should statically include the definition of the process operations. The requirements and constraints related to the initialization of the processes are included in the dynamic part of the interface type definition. DEMS-RM specifies DEMS services and interfaces in two different ways. It uses a standard service description framework for each service, providing a summary service description for human perception. An abstract description of the interfaces to be realized by the services is given using the language of conceptual schema.

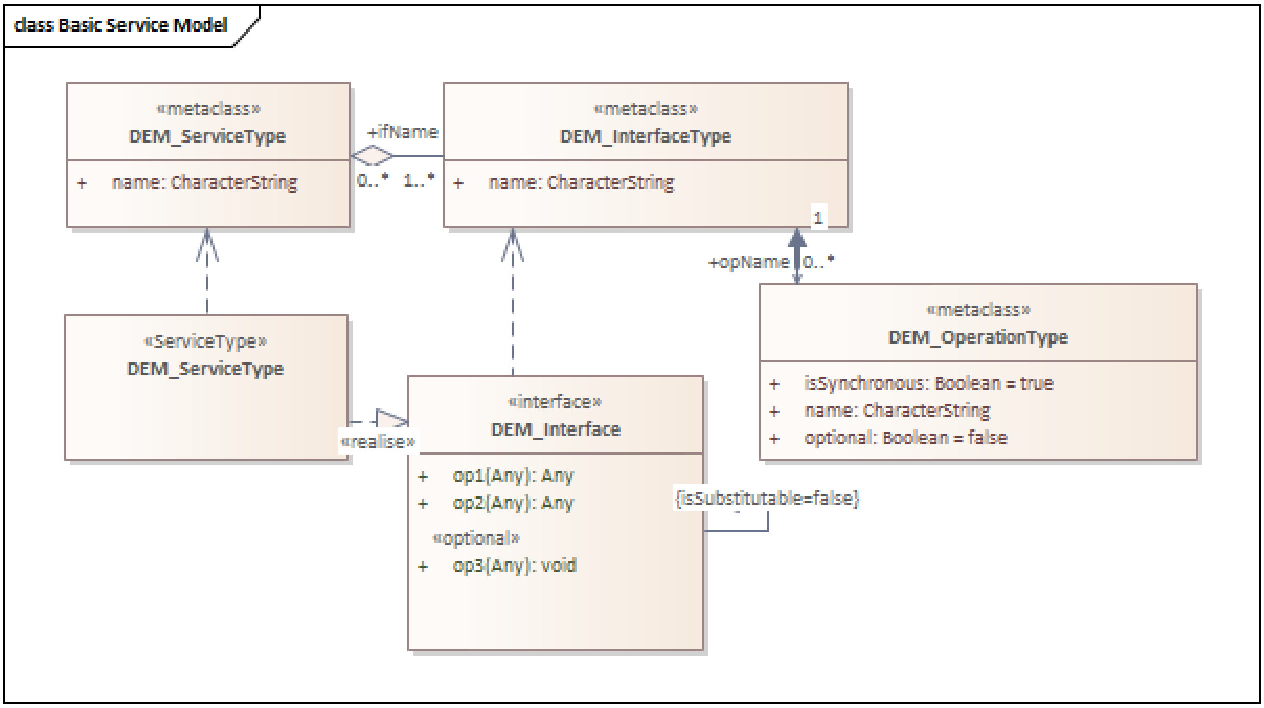

Fig. 3: Basic service model

Services are the core component of interoperability in practice. Interoperable services both distribute tasks to stakeholders based on common concepts in line with their responsibilities and authorities, and support the management process by determining the infrastructure, conditions, constraints and rules of these authorizations.

DEM-RM service layer specifies the properties for the DEMS services that support interoperability between DEMS resource systems and between services. Figure 4 shows the service layer of the DEMS-RM. The service layer is considered in the context of legal, organizational, semantic and technical views.

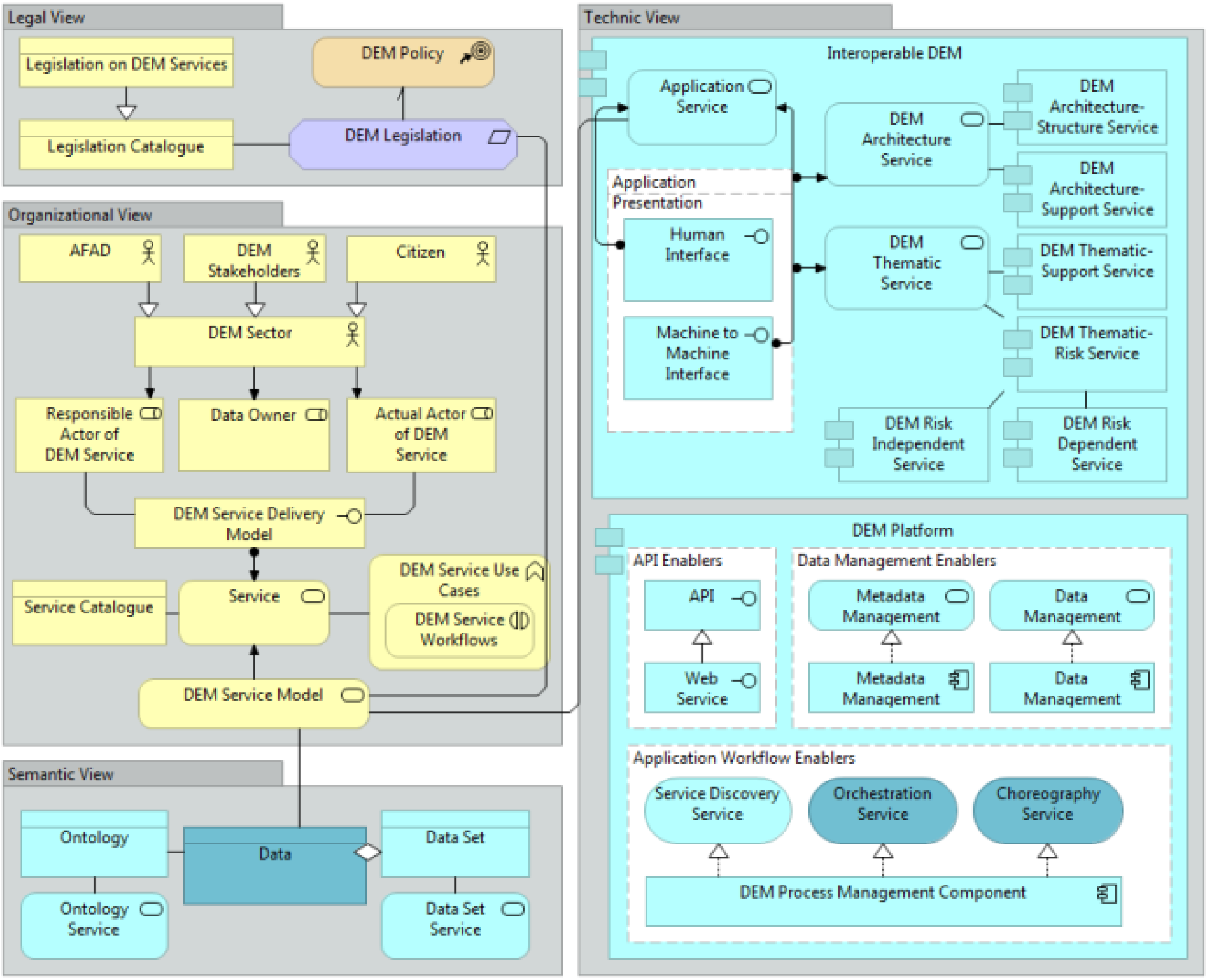

Fig. 4: DEMS-RM service layer

Within the scope of the legal view service layer, the legislation related to DEM is analyzed to establish the basis of the service model by analyzing the requirements of interoperability and to determine its comprehensive scope for the DEM sector. In the organizational view, an analysis of the scopes defined based on legal legislation is carried out. The DEMS services are provided by the stakeholders whose work steps are determined as the activities of DEM. It is aimed to ensure interoperability effectively by breaking down the work steps that constitute the activities of the DEM into the smallest parts and offering them as a service. Workflow is the work steps that a stakeholder has or can be developed to achieve a specific purpose or result. Accordingly, the process-based services are divided into small process steps, and the requirements, responsible and actual actors for the realization of the services are determined. Since DEM contains complex relationships and processes, especially at the phase of response, the service delivery model and service catalog are of great importance in order to avoid repetition and to ensure collaborative management of processes. The semantic view shows the presentation of data services and metadata.

The technical view shows an overview of the platform enabling service interoperability and the technical structure of the application services. The human interface is the means for exchanging data between the person and the service, while the machine interface is the means for exchanging data between the service and other services. As a component of the DEMS architecture, DEMS service types are defined by the combination of the types of interfaces that support them. DEMS-RM categorizes service types according to their functionality. The classification used here is based on the ORCHESTRA Project (ORCHESTRA, 2007). The main service categories are DEMS architectural services and DEMS thematic services. DEMS architecture services provide application independent functionality and are mainly divided into two as DEMS architectural structure services and DEMS architectural support services. Architectural structure services are required as mandatory for the operation of the DEMS service network. At least one instance of these services must be available in the service network. DEMS architectural structure services can be listed as general service, detail access service (for maps and ontologies), map and schema service, document access service, sensor access service, catalog service, name service, user management service, authorization service, authentication service and service monitoring service. DEMS architectural support services, together with the structure services, enable the realization of DEM service network operations. They are architectural services that support the provision of DEMS information structure service functionality or facilitate the operation of a service network. The architectural structure and support services constitute the information infrastructure of DEMS-RM. Architectural services therefore provide a functional foundation specific to the application domain. It does not address any specific thematic application area and does not provide any structure to the thematic services. In addition, thematic services can use both architectural structure services and architectural support services to fulfill a specific function.

DEMS thematic services provide application specific functionality. However, high-level functions with a generic structure can be defined both within and across different application domains. Thematic service is divided into two as thematic support services and thematic risk services. DEMS thematic support services are generic services that facilitate the development or interactive composition of thematic functionality. These services enable the development of thematic functionality such as statistical data processing, workflow and process management. DEMS thematic support services include processing service, simulation management service, sensor planning service, project management support service, communication service, calendar service and reporting service. DEMS risk services define the domains that provide DEMS functionality. These services are based on the results of the organizational view analysis. Risk services are divided into risk independent and risk specific services within the scope of DEM. Thematic risk independent services are services specific to the scope of the DEMS, such as data services that facilitate the development or interactive composition of risk-neutral DEMS functionality. Thematic risk specific services are services specific to a particular DEM domain (for disasters such as earthquakes, floods, landslides, avalanches, epidemics, transportation accidents, urban and forest fires) that facilitate the development or interactive composition of risk-specific DEMS functionality.

The Interoperability Reference Model of Disaster and Emergency Management System Data Layer

DEM event types are directly related to geographic data. Planning a response or responding to a disaster requires access to data that is directly geo-referenced and the management of the regions involved. Actors in the processes of DEM use geographic data to perform tasks in their areas of responsibility, and as a result, they can generate new data or update existing data. Thus, it is expected that the data needed for the completion of a management process should be available in the geographical data model of the DEMS and open for sharing to the responsible institutions. In this respect, it is the most important part of an effective DEMS that the data to be used and produced throughout the processes are defined completely and accurately and that they are up-to-date and accessible. Some of these datasets should be collected and kept up to date before the disaster occurs (such as topographic maps, city maps and infrastructure maps) and some of these datasets should be collected and kept up to date after the disaster (such as damaged areas, closed roads and burned areas). Interoperability between the many sectors and actors within DEMS will only be possible by ensuring the interoperability of these data.

The DEM-RM data layer defines the features that support the interoperability of geodata used at each phase of management. Figure 5 shows the data layer of DEMS-RM. The data layer is considered from a legal, organizational, semantic and technical perspective. Within DEMS, actors at different administrative levels need geographic data to perform tasks within their area of responsibility. A well-defined data model is needed to ensure reusability and interoperability between these actors without duplication of data.

The legal view includes the national GDI policy scope and associated sectoral models. DEMS of Turkey is based on TUCBS and the related sectoral model TRKBIS. In addition, the legal view determines the data needs for implementation within the scope of DEM legislation. The organizational view is about how stakeholders within the DEM collaborate to achieve their common goals. In practice, processes and related data exchange need to be integrated. he representation and data are influenced by data policies with organizational context, which are determined by the policies of the DEM. Data exchange is the communication of data in the workflow. In the organizational view, actors responsible for services use data from TUCBS or DEMS data model and produce data for DEMS data model while performing work steps in their areas of responsibility. In the technical view, service data represents workflows and data in any form. In thematic risk services, data such as topographic maps etc. are presented as risk dependent or undependent.

The semantic view data layer defines the architectural structure that needs to be considered to support semantic interoperability of data exchange between stakeholders. Data can be grouped into data sets that are recorded in catalogs. The data plan defines a guiding framework for data use. The data plan is divided into a core data plan, an open data plan and a descriptive metadata plan. The basic data model defined in the data models is elaborated as character encoding schema, syntactic encoding schema, data level mapping, schema level mapping or descriptive schema. The content of the semantic view consists of representation, data plan and data. A representation is the data format carried by the service data. A representation can be classified in several ways, such as environment and format. Semantic interoperability rules allow stakeholders to process data from external sources in a meaningful way. It ensures that the meaning of the data is understood between the parties throughout the data exchange.

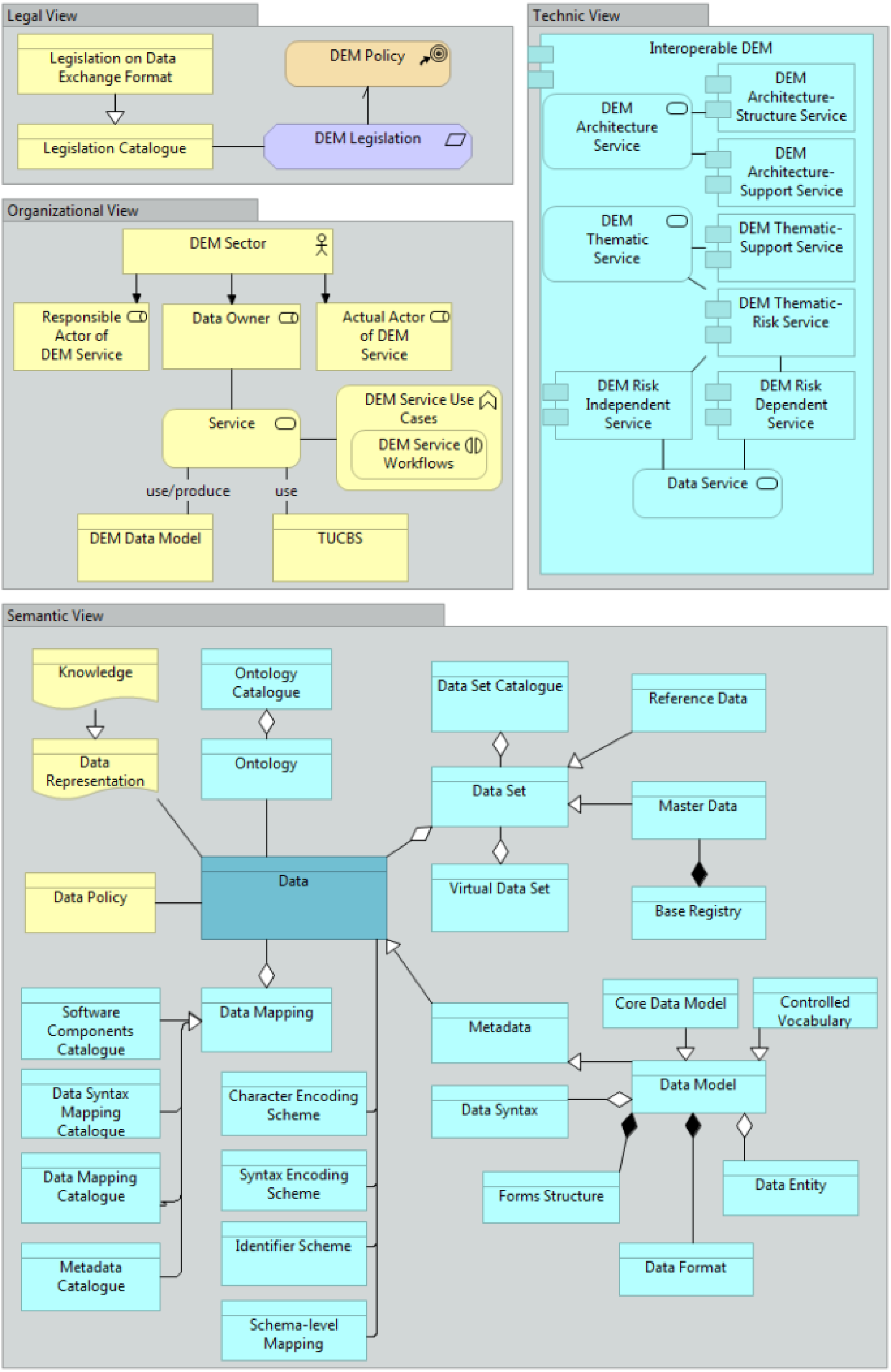

Fig. 5: DEMS-RM data layer

Semantic interoperability encompasses semantic and syntactic elements. Semantic interoperability is concerned with the meaning of data objects and the relationship between them. It involves developing vocabularies to describe data exchanges and provides a common definition of data for stakeholders. The class diagram in Figure 6 is a summary representation of the data model based on the relationship between DEM_FeatureTypes, DEM_PropertyTypes and DEM_AssociationTypes. This relationship is based on the definitions in the 1SO 19109 GFM document and the GF_FeatureType properties.

Figure 7 shows the data model attribute type. The DEM attribute type is defined by the UML class diagram in the architecture service scope as an instance of the metamodel attribute type. The attribute type is defined by the data model or by the service software component of the DEM application. The metamodel can extend the attribute type definition depending on the requirements of the thematic areas.

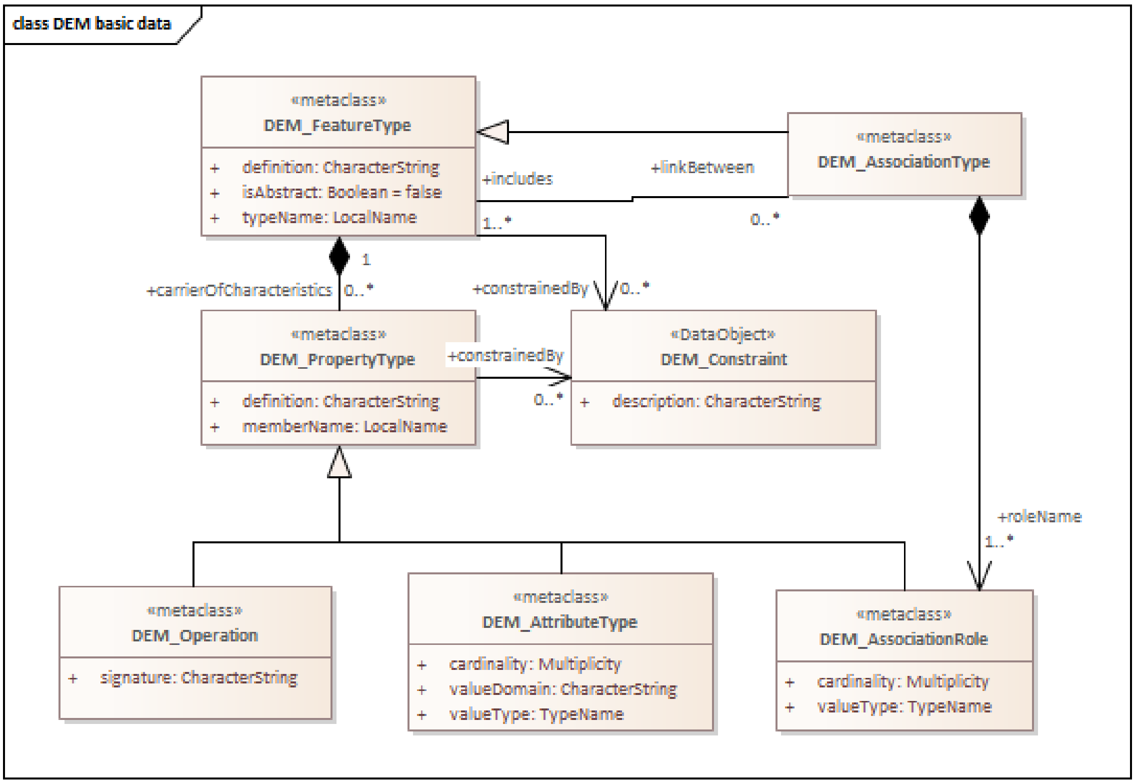

Fig. 6: Basic data model

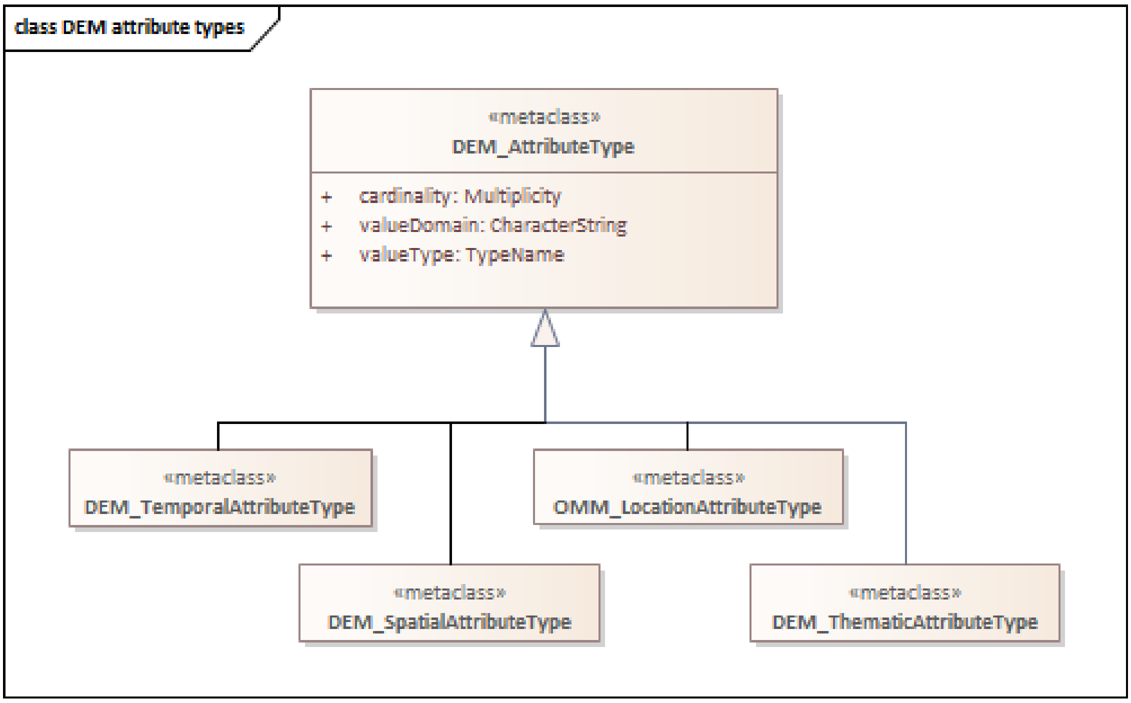

Fig. 7: Attribiute types

Discussion and Conclusion

In this paper, a general framework is presented by defining the interoperability principles for DEMS of Turkey. For this purpose, existing interoperability models have been analyzed and as a result, EIF interoperability levels and FEI interoperability layers have been taken as a basis for DEM Turkey. In this context, the general framework model created to ensure interoperability consists of legal, organizational, semantic and technical views. The technical framework is divided into two as application and infrastructure. Thus, within the scope of the study, service and data layer general specifications for interoperable DEMS were determined.

The outline of the DEMS service model is shown to ensure interoperability between the actors responsible for the activities according to the interoperability framework defined. DEMS service architecture development studies based on actual and legal standards continue at a detailed level. Following this, the necessary services and data will be produced with applications prepared with disaster scenarios showing the needs of stakeholders and users within the scope of DEM activities.

Although a national interoperability framework has been initiated with the TUCBS Strategy and Action Plan, a comprehensive legislative structure from national to local level is needed to ensure legal interoperability. Organizational interoperability for DEMS stakeholders of Turkey will only be possible through well-defined process management to be established through regulations. With a well-established legislative structure, not only the duties, authorities and restrictions of the institutions should be determined in order to ensure process management, but also the data and service structure that will ensure interoperability between DEM stakeholders should be defined. In order to ensure data management and thus semantic interoperability, it is necessary to first establish the DEMS data model as TUCBS sector model. In the current national model, the dynamic and 3D data structure, which is important for DEMS, is not defined. This is a major obstacle for semantic interoperability in the management of DEMS processes. In order to ensure semantic interoperability, data themes should be identified and a model should be created by determining the data needed by the processes required to manage the types of incidents defined in the regulation. While creating this model, TUCBS requirements, constraints and relationships need to be re-evaluated in line with current technological developments. Since DEM needs data from multiple sources, including citizens, especially in times of intervention, standards should be set for the secure sharing and access of data with the principle of open data. There is a need to improve the service capabilities of DEMS for sharing data from different sources, especially during the response phase. In this context, projects should be initiated to identify and test innovative information sources and technologies, including real-time data from mobile sensors, social media and IoT. Establishing a service model and developing service capabilities will contribute greatly to technical interoperability.

Many research topics were also identified during the process of determining the DEMS interoperability infrastructure. First, we need to do more research to determine how the model works with real data. For this purpose, well-defined process models and temporal data are needed for different types of disasters.

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