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Towards a spatial data infrastructure for technological disasters: an approach for the road transportation of hazardous materials

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Abstract Spatial data have been used for the environmental monitoring of the consequences of accidents that involve the transportation of hazardous chemical products. This spatial data infrastructure (SDI), which was created for the sharing and use of spatial data, is limited by the absence of policies to support its establishment. The main objective of this study was to explore the use of social network analysis (SNA) as a tool to identify spatial data sharing between organizations involved in the management of accidents related to road transport of hazardous materials (RTHM). In addition, to discuss the existing policies and institutional agreements, and to initiate a conceptual SDI framework for RTHM sector. In this context, the institutions that are involved with RTHM were identified and information concerning their interest in the use and sharing of spatial data via a SDI was collected through interviews and consolidated. The interviews were at 39 institutions with representative employees. The interview data were tabulated and entered into the UCINET software (2000 version) to calculate metrics of centrality. From the SNA, the flow of data among the participating institutions was identified through the visual representation of the spatial data sharing and use networks. Subsequently, the existing institutional agreements for spatial data sharing were analyzed and discussed. The compiled results enabled the proposal of a conceptual SDI framework to support the management of disasters involving RTHM, based on the application of SNA theory, and the development of a methodology that supports the analysis of interactions among the various actors of an SDI. The purpose is to facilitate the formulation of policies for the sharing of spatial data for decision-making and preventive disaster management. The results indicate that the 39 institutions share spatial data, but this sharing is not always predetermined by formal agreements. Furthermore, there is a strong demand, by the institutions involved in the management of RTHM accidents, regarding legal mechanisms governing the sharing of data for the purpose of producing maps that help to describe actions of preparedness, prevention, management and immediate relief involving RTHM incidents. Finally, it was possible to propose a conceptual framework with data that is considered essential for creating an SDI for RTHM.

Keywords SDI · SNA · GIS · RTHM · RTHM policy articulation · Technological disasters

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Introduction

The economic development of a society conducts to an increase in food consumption, which encompasses

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intensification of chemical products demand and, as a consequence, their transport to the destination (CETESB 2010).

According to UNISDR, 2007, technological disasters are due to technological and industrial conditions. It includes accidents at high risk, such as infrastructure or specific human actions that cause loss of life, injury, illness or other health impacts faults, and damage to public goods, social harm and impacts on the environment.

The type of technological disaster determines the nature of the emergency actions after an accident. The management of disasters concerning the road transport of hazardous materials (RTHM) is subdivided in three phases: prevention, preparedness, response and recovery the impacted area. The spatial data are extremely important to the disaster management, and it can be manipulated and analyzed in Geographic Information Systems (GIS) (Snoeren et al. 2007).

Milazzo et al. (2010) studied the land transport of dangerous substances in Eastern Sicily. Risk analysis, within a GIS environment, has been made on a regional scale, in order to identify some critical points (black spot points). It was also possible to evaluate the risk reduction after the planned application of the regional transportation plan for Sicily. Zhang et al. 2000 designed safer networks routings to reduce the potential negative impacts of road transportation of hazardous materials in Canada. They estimated the airbone contaminants (ammonia and Chloreine), modeling their dispersion by Guassian Plume model. Besides, they were able to estimate the population distribution to estimate risk, for a release at any point on a network, for all over the study area using Map algebra in a GIS environment. Tena-Chollet et al. (2013) developed a methodology implemented in GIS to analyze different possible hydrocarbon supply routes in order to determine whether modifying the flow of hydrocarbon transportation increases the risk for people, infrastructure and the environment. Bubbico et al. (2006, 2004) used GIS to perform risk analysis in the RTHM considering different information sources and layers, like population density and incidence of accidents, to perform the analysis.

From the above examples, it can be noted that spatial data have been used for the management of technological disasters regarding the RTHM. To natural disasters it also has been used in many applications (Snoeren et al. 2007; Ajmar et al. 2008; Groeve et al. 2010; Agosto et al. 2011; Molina et al. 2011). The spatial data and associate technologies have been important to the efficiency of decision making at disasters management (Mansourian et al. 2006).

A solution adopted by the scientific community to improve spatial data sharing is the spatial data infrastructures (SDI). However, despite the importance of spatial data in disaster management and technological consolidation in SDI field, policies and institutional agreements still limit spatial data massive use to road transport hazardous materials management.

This study explore a methodology to characterize how is the spatial data sharing between institutions that work with emergency of technological disasters, in particular, from RTHM, by applying "Social Network Analysis" (SNA) theory based in an applied survey at institutions engaged in this sector.

SNA was used to measure the ability of individuals within institutions to access and release spatial data in SDI (Omran and Van Etten 2007; Paudya et al. 2012). In such cases, SDIs have already been implemented.

For the present study, the SDI was not implemented at that time. The analysis was made to understand aspects from data sharing between stakeholders from RTHM sector. Measures of centrality were done, based on SNA application.

The SNA theory was used to characterize the relationships among 39 institutions from technological disaster involving RTHM management sector. Each of this institutions participated in an interview from which results were computed in order to calculate centrality metrics from the SNA methodology approach.

These measures would support a SDI development that could enable data sharing among organizations concerned with prevention and management of technological RTHM disasters.

The aim of this work was to investigate SNA theory application to characterize data sharing processes between RTHM disaster management sector, envisioning the possibility to map actual scenarium of institutional agreements and partnerships among different stakeholders that could participate in a possible SDI development.

Literature review

This section is organized into two parts. The first presents and discusses the theoretical framework for an SDI for disasters research. The second explores the use of SNA for developing an SDI.

In this section, studies concerning the use of SDI to support disasters management are presented, even though some are related to natural disasters, as they provided an important conceptual contribution used as basis for this study.

Mansourian et al. (2006) developed a research project that considered a disaster caused by an earthquake in Iran. An SDI conceptual model and a Web-based system were developed for the management of the disaster, with collaboration among the various organizations from the risk analysis community. The proposed model serves as a tool that defines a system of agreements among different organizations to produce and share spatial data.

Molina et al. (2011) described a pioneering system for the sharing of spatial information, which was developed for the Andean Community. This system, called SIAPAD (Andean Information System for Disaster Prevention and Relief, from the Spanish "Sistema de Información Andino para la Prevención y Atención de Desastres"), integrates spatial information from 37 technical organizations in the Andean countries (Bolivia, Colombia, Ecuador and Peru). The SIAPAD system was based on the concept of an SDI and includes a web application, called GEORiesgo.

Groeve et al. (2010) analyzed the use of an SDI and the application of mash-ups[1] for the crisis management of natural disasters. The authors concluded that the most complete solution must involve the use of mash-ups for simple visualization and analysis. However, the use of GIS for mapping and advanced analysis and the implementation of an SDI should serve as the basis for accessing the data from web services.

Within the scope of the UN, the Office for the Coordination of Humanitarian Affairs (OCHA) serves to ensure humanitarian actions within the UN system, including proposals for disaster management. In particular, the program UN-SPIDER (United Nations Platform for Space-based Information for Disaster Management and Emergency Response) aims to ensure that all countries and global organizations can access and develop the capacity to use satellite information to provide support during disaster management phases. Data from the Global Positioning System (GPS), remote sensing data (including that from the thermal and visible portions of the electromagnetic spectrum), and Radio Detection and Ranging (RADAR) and Light Detecting and Ranging (LIDAR) images have been considered essential for disaster management (Bruzewicz 2003).

In addition to traditional remote sensing, Global Navigation Satellite System (GNSS) data, and cartographic maps used in GIS environment, more recently, spatial data obtained from the Internet by non-technical users, called Volunteered Geographic Information (VGI) have also been widely used in disaster management. VGI was very important in the post-disaster recovery and relief efforts following Hurricane Katrina, which occurred in 2005 in the United States. User-generated information from mobile phones equipped with cameras and GPS technology contributed spatial data that was used for the management of the disaster (Goodchild 2007).

The program UN-SPIDER serves as a facilitator for the development of a vast array of spatial data applications for member states through agreements and institutional arrangements for the sharing of spatial data.

Social network analysis (SNA) for SDI

The purpose of using an SNA for this study is to measure the flow of information shared among 39 institutions involved with RTHM to support the creation of an SDI.

Analysis of Social Networks refers to a set of methods designed to detect, describe, and interpret patterns of social links among actors (NOOY et al. 2005). The patterns present in the networks constitute its structure and express the social environment within which an individual belongs (Wasserman and Faust 1994).

A social network is defined as a finite set of actors and their mutual relationships. The actors are social entities, which can be individuals, companies, cities, or countries, among others. Their relationships concern the collections of social links of a particular type, for example, friendships, collaborations, or other links (Wasserman and Faust 1994).

[1] Mash-ups: according to Butler (2006), the term mash-up originally referred to a mix of musical tracks and was then adopted to refer to websites that integrate data from different sources to provide a new service.

SNA incorporates measures of centrality of individuals and organizations to support the analyses of social networks. An example that considers centrality is the analysis of the star network. In this type of network, the most central person is the person who is the most 'popular' in the group or the center of attention (Scott 2013).

Centrality is one of the most studied concepts of social network theory. A considerable number of centrality measures have been developed, namely, degree, closeness and betweenness. Several authors have proposed various ways of calculating these measures, such as those proposed by Katz (1953), Hubbell (1965), Taylor et al. (2002), Freeman (1979) and Borgatti (2005) to characterize how fluxes occur within a network.

The sharing of spatial data is a key characteristic of an SDI (Omran and Van Etten 2007) and can be analyzed by the application of SNA. Omran and Van Etten (2007) applied SNA for an SDI in Egypt, Paudya et al. (2012) in Australia, Vandenbroucke et al. (2009) in Belgium, and Van Oort et al. (2010) in the Netherlands.

SNA has generally been applied for examining data sharing among institutions with an exclusive focus on individual behaviors (Paudya et al. 2012; Vandenbroucke et al. 2009; Van Oort et al. 2010). However, there have also been studies that seek to expand the focus and analyze the collective behavior for sharing spatial data, as in the case of Omran and Van Etten (2007).

The application of SNA to an SDI can also be used to analyze the flow of data, which often occurs anonymously, to identify how the users of data of a given SDI contribute to the enhancement of the SDI by providing "feedback" on aspects of data quality and metadata (Van Oort et al. 2010). To this end, Van Oort et al. (2010) published an online questionnaire sent to 339 e-mail addresses of users of two types of datasets of land use and cover that were being used by various organizations. Network classifications allowed users to be divided into intermediate users (manager/data vendor), direct users (working directly with spatial data), indirect users (indirect use of spatial data), or ex-users (temporary spatial data user).

Regarding the calculations used for the generation of networks, Omran and Van Etten (2007) used the following centrality analysis metrics: In Degree based, Out Degree based, In closeness, Out closeness and Betweenness to measure the flow of data among the different levels of the organization and to identify the central actors in the network. In turn, Paudya et al. (2012) used only the In Degree relationship metric, which was also able to measure the rate of information flow and the role of each organization in the data stream.

All of the abovementioned studies analyzed metrics, but the metrics were prioritized differently, as observed previously. Omran and Van Etten (2007) found that employees who occupy senior positions in an institution are central and have high decision-making power to share and access data. Employees who occupy intermediate and peripheral positions have less decision-making power for spatial data sharing. Thus, the sharing of spatial data follows a hierarchy that influences the exchange of data among the employees of this institution.

All the studies cited herein visualized the networks using graphs. Omran and Van Etten (2007) and Van Oort et al. (2010) enhanced their visualizations by using a sociogram, as shown in the example given in Figs. 2, 3.

In addition to the calculation of metrics and the visualizations of networks, the authors also used SNA as a basis to generate process flows that assessed how various types of data flow among various decision makers (Vandenbroucke et al. 2009) or to generate an actor usage diagram model using UML (Unified Modeling Language) (Paudya et al. 2012).

According to Vandenbroucke et al. (2009), business flows can be defined based on the process flows of data sharing in a network. The characteristics of each data flow were mapped as a representation of access. This allowed the technological barriers to the transmission and sharing of spatial data sets to be identified. Thus, the business flow for an application for a public project involving the drainage and runoff systems of areas susceptible to flooding, according to water management policies, was determined. This business process flow is based on various data sources, including: land use and cover, conservation units, river networks, land use maps and digital elevation models.

The usefulness of SNA as a tool for measuring the relationships among institutions, including communication relationships as well as power relationships among organizations participating in a project, has been well demonstrated (Paudya et al. 2012).

The methodology used in this study applied an SNA to evaluate the patterns in the flow of spatial data sharing in the RTHM sector.

Methodology

The methodology of the present study involved three main components. Firstly, a bibliography review was conducted about SNA and SDI related to technological disasters. Secondly it was related to the diagnosis of the coordination among institutions for spatial data sharing based on the SNA; the third step was the analysis of policies based on the interview responses.

Following the flowchart of the Fig. 1, above, illustrates the phases of the study. After the bibliography study about the social network analysis theory (SNA), SDI to disasters and application to SDI to SNA, it was necessary to identify the institutions that work with RTHM, for the interviews phase.

Interviews and data analysis

The interviews covered representative employees from 39 institutions involved in the RTHM-related technological disaster management sector. The answers included information regarding the links among the institutions, policies, and existing agreements, which are presented in the results and discussion sections. In addition, the interviews also helped to determine the classes represented in the proposed spatial data conceptual framework and served as the basis for the application of the SNA methodology.

The questionnaire that formed the basis for the structure of the interview was developed from the adaptation from the work presented by Omran and Van Etten (2007) and Paudya et al. (2012), presented at Table 1. The complete questionnaire is presented in Appendix A. The questionnaire addressed two aspects of network analysis. The first corresponds to the identification of the interactions among the institutions and the second identifies the frequency of availability and use of spatial data by institutions. The questionnaire also included two questions concerned with the basic data requirements for the production of an SDI for RTHM.

The primary reason for the use of SNA in the present study is to measure the variety of the relationships among the institutions that produce and access spatial data related to RTHM.

The questions were designed to elicit responses regarding the relationships among institutions for sharing spatial data. Two questions were designed to measure and quantify the degree of interaction among

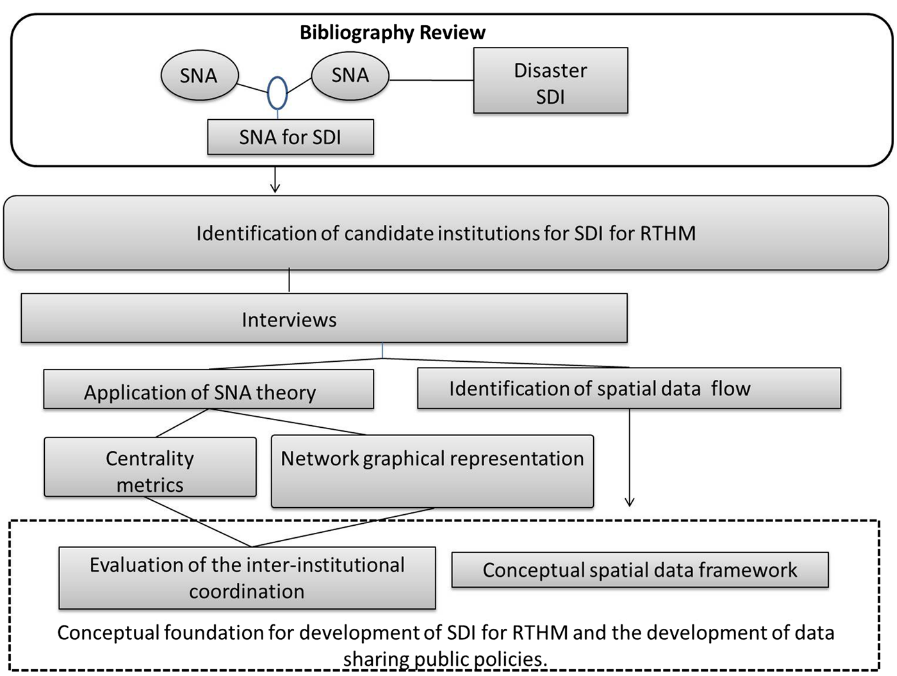

Fig. 1 Flowchart of the study steps

Table 1 Summary of network metrics and definitions (Borgatti et al. 2002)

Variable	Definition
In degree	Number of directional accesses oriented toward an individual originating from other individuals (INCOMING LINKS)
Out degree	Number of directional accesses originating from individual oriented toward other indivuduals (Outcoming LINKS)
In closeness	Extent to which an individual can be connected to all other indivuduals in the network. Measured as the sum of the reciprocal distances from all other members. A direct link is counted as 1
Out closeness	Extend to which an individual can reach all other individuals in the network. Measured as the sum of the reciprocal distances to all the other members. A link is counted as 1
Betweenness	Number of times an individual is found on the shortest route between two other individuals

the institutions and the frequency of spatial data exchange.

Data were processed using the UCINET 6 software and the design module of the software NetDraw 2:16 was used to visualize the network.

Results

The degree of interaction among organizations was used to evaluate the communication relationships among institutions that address the issue of RTHM. The centrality measure was used as a measure adopted in network generation. The results concerning the application of SNA are presented below and are organized into discussions of the visual representations of the network and the metric values, always considered in regards to the background information recorded during the interviews.

In the visual representations of the network, the node symbols represent the type of organization, as classified in Table 2. The thicknesses of the lines depict the frequency of communication. The positions of the nodes reflect the importance of each organization in the network.

Institutional agreements: degree of dependence among institutions

The centrality measure is used in the generation of the visual representations of the network.

The shapes of the network nodes indicate the type of organization. The thicknesses of the lines between nodes depict the frequency of communication. The location reflects the importance of each organization in the network.

Table 2 Network legend

Name	Acronym	Symbol
Associations	AA	○
Emergency response agencies	ERA	□
Licensing and legislating bodies	LLB	△
Service provider agencies	SPA	⊞
Providers of data for spatial planning	PDSP	▽

Spatial data availability

An SNA was performed to determine the flows of the interactions concerned with the sharing and access of spatial data among institutions that address RTHM.

Figure 2 displays the graphical results for the frequency of the availability of spatial data among the institutions that were interviewed. As mentioned previously, the shapes of the nodes represent the type of organization according to the classification presented in Table 2.

In Degree: the Emergency Response Agencies (ERA) and Service Provider Agencies (SPA) identified as ERA12, ERA16, AA4 and SPA31 are the most central nodes in the network and have high centrality values. These nodes can also be viewed as potential mediators of the spatial data sharing process because they possess many links with other organizations.

Out Degree: This metric shows the same pattern as that of In Degree. The ERAs and SPAs have the most frequent interactions. Additionally, groups with an affinity for the

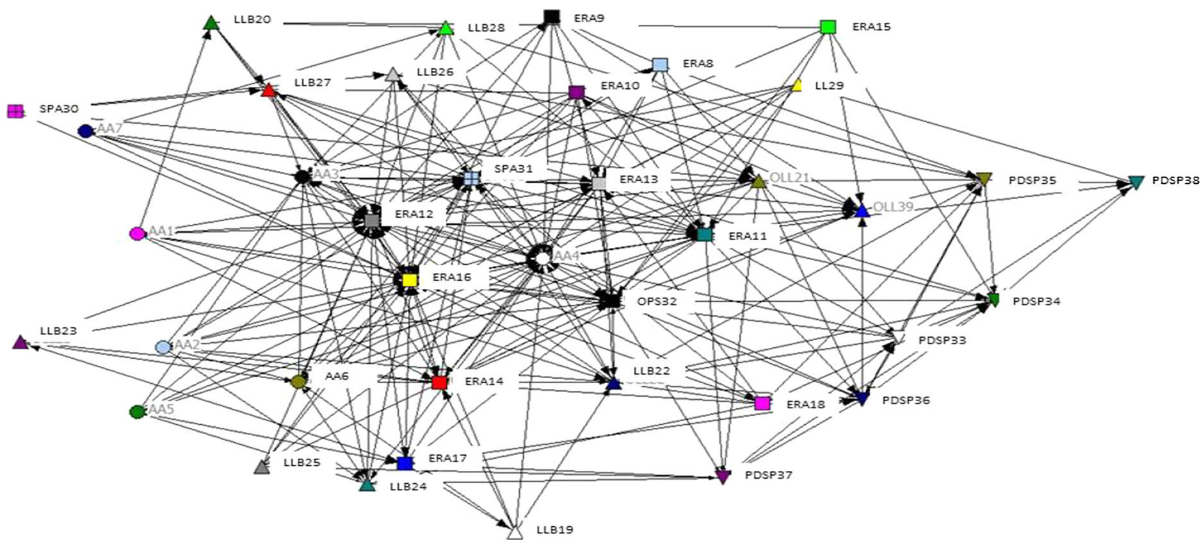

Fig. 2 Frequency of spatial data availability

performance of similar activities have stronger relationships. The ERAs that arrive first at the crash site for the immediate relief of victims and the containment of environmental damage are the institutions that have stronger inter-relationships, and for this reason, there is greater availability of spatial data among them.

In Closeness: this variable follows a similar pattern to In Degree, with the same core actors. Four institutions (ERA16, AA4, ERA12 and SPA31) receive information earlier and also promote the control of information.

Out Closeness: this variable follows the pattern of Out Degree, with the ERAs, Associations (AAs), and SPAs as the most central nodes in the network. The relative differences are less marked for this metric than for the Degree and Betweenness metrics. There is only a small difference between the highest and lowest values, in contrast to In Closeness.

Betweenness: central individuals who have high Degree values have high values of this metric. The ERAs identified as ERA16, ERA11, ERA12, and SPA 31 and the AA identified as AA4 behave as information controllers. This causes the network to be well centered and the flow of data is controlled by these "actor agencies", which are in fact the drivers of information. These agencies can behave as potential limiters of information sharing because they are the most powerful actors.

The Betweenness measure is used to measure the volume (frequency) of the movement of traffic from each node to all other nodes. It is a measure of the partitioning of network flow; that is, these nodes are powerful actors in the network because they have the power to stop information flow or pass information on to other network nodes. Figure 3 shows the frequency of interaction for spatial data sharing among the organizations surveyed.

In Degree: the AAs identified as AA6, AA4, AA7 and AA5 composed the most central group of data users, followed by ERA16, ERA13, SPA31, SPA32, PDSP13, PDSP3, LLB39 and LLB29. These nodes are characterized by a high number of directional accesses from other individuals in the network. These institutions can be viewed as potential mediators in the spatial data sharing process because they have numerous links with other organizations.

Out Degree: this metric shows the same pattern as In Degree, but with a smaller number of actors. Nodes ERA12 and LLB21 experience the most frequent interactions. Groups with an affinity for the performance of similar activities were found to have stronger relationships. The Out Degree metric is characterized by the number of directional accesses for the use of spatial data.

In Closeness: LLB39, AA6, SPA31 and AA4 are the most central institutions in the network and receive

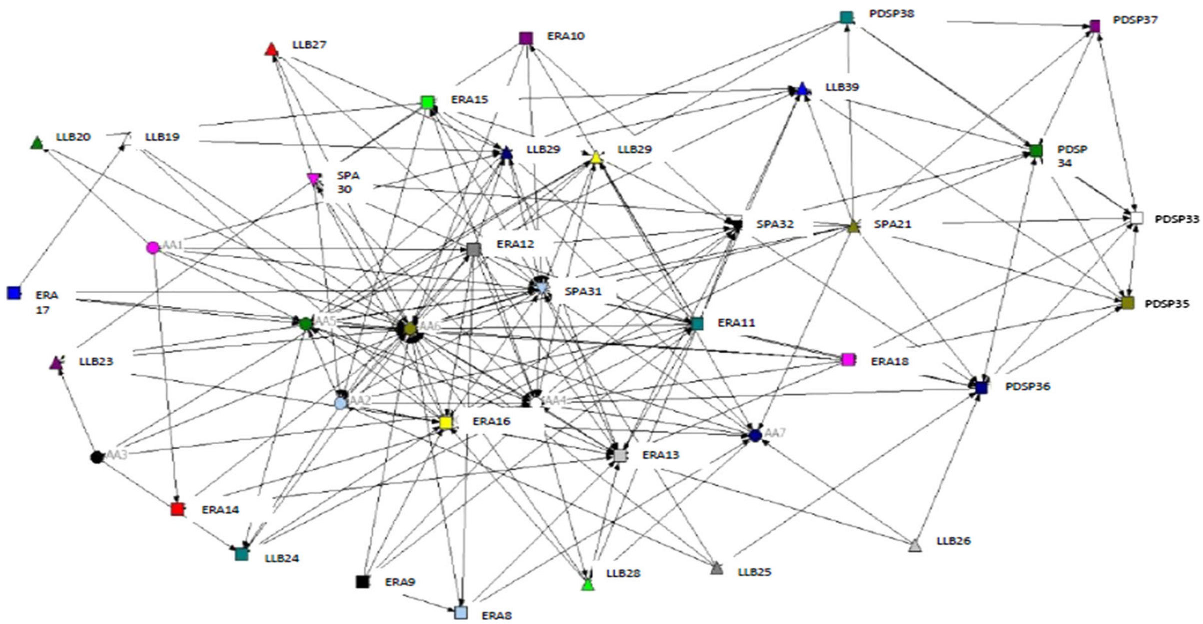

Fig. 3 Frequency of use of the spatial data accessed

information more rapidly because they are characterized by the shortest paths or accesses (geodesic paths) between their nodes and other nodes.

Out Closeness: follows the same pattern as Out Degree with respect to ERAs, licensing and legislating bodies (LLBs), AAs and SPAs, which are the most central in the network. There is not a large difference between the highest and the lowest values, in contrast to In Closeness.

Betweenness: this metric can reflect the potential for institutions to control information. According to this metric, the Associations AA4 and AA6 appear to have the greatest potential to act as controllers of information, as well as SPAs (SPA32) and a Provider of Data for Spatial Planning (PDSP36). The network configuration seems to be quite centralized. This configuration indicates that the flow of data depends on these "actor agencies" as the drivers of information. These institutions are powerful because they have the potential to impede the sharing of information.

The centrality measures considered in this study are presented in Tables 3 and 4, and a discussion of the results follows. And Table 5 presents a comparative summary of the metrics.

Proposal for a conceptual data framework for an SDI for RTHM

Based on two specific interview questions (questions 1 and 7), as well as an analysis of the meetings of the General Committee for Hazardous Material Transportation ("Comissão Geral de Transportes de Produtos Perigosos"), a conceptual spatial data framework was prepared that can serve as a reference for use in the process of establishing an SDI for RTHM.

This conceptual framework is based on a survey of the data that are fundamental to creating an SDI for RTHM. The maps, plans, and information desired by those working in the sector were surveyed from the responses to question 7 of the questionnaire. The data cited were locations of accidents, rivers, hospitals, slope, land use data, permanent conservation areas, areas with occurrence of fog (climate survey), areas susceptible to landslides (risk areas), and data from cameras.

Other data mentioned included the locations of chemical plants, carriers, environmental agencies, firefighters, and transportation routes (origin–destination), the density of roads with higher RTHM traffic, details concerning the regular rest and emergency

Table 3 Network measurements concerning the provision and sharing of spatial data by institution and the corresponding descriptive statistics

ID	Betweenness	Stat_bet	ID	Out degree	Stat_ outdeg	ID	In degree	Stat_ indeg	ID	In closeness	Stat_ inclo	ID	Out closeness	Stat_ outclo
ERA16	1,93,460	1	ERA11	1,01,000	1	ERA12	2,20,000	1	ERA16	84,444	1	ERA16	14,672	1
ERA11	1,84,931	1	ERA12	89,000	1	ERA16	2,17,000	1	AA4	77,551	1	AA4	14,504	1
ERA12	1,70,373	1	ERA13	79,000	1	AA4	1,92,000	1	ERA12	70,370	1	ERA12	14,449	1
SPA31	1,26,037	1	PDSP36	73,000	1	SPA31	1,16,000	1	SPA31	69,091	1	SPA31	14,340	1
AA4	92,029	1	ERA8	70,000	1	LLB39	88,000	0	SPA32	62,295	0	SPA32	14,232	1
LLB28	76,840	0	ERA9	68,000	1	AA3	83,000	0	AA3	60,317	0	AA3	13,818	1
AA3	71,600	0	SPA31	64,000	0	LLB22	81,000	0	LLB22	57,576	0	LLB22	13,380	0
SPA32	65,594	0	AA4	62,000	0	ERA11	81,000	0	ERA11	55,072	0	ERA11	13,103	0
ERA17	55,429	0	ERA17	62,000	0	ERA13	77,000	0	ERA13	55,072	0	ERA13	13,103	0
PDSP33	50,568	0	AA2	59,000	0	SPA32	76,000	0	ERA14	55,072	0	ERA14	12,969	0
OLL22	49,663	0	AA1	58,000	0	ERA14	70,000	0	PDSP37	52,055	0	PDSP37	12,925	0
ERA14	44,074	0	ERA10	56,000	0	PDSP34	61,000	0	LLB39	50,000	0	LLB39	12,881	0
PDSP38	38,088	0	ERA16	55,000	0	PDSP35	59,000	0	PDSP34	50,000	0	PDSP34	12,838	0
ERA18	29,423	0	LLB21	55,000	0	LLB21	50,000	0	PDSP36	49,351	0	PDSP36	12,795	0
ERA13	29,350	0	ERA18	54,000	0	PDSP33	44,000	0	LLB24	49,351	0	LLB24	12,752	0
LLB21	28,541	0	LLB26	53,000	0	PDSP36	42,000	0	AA6	49,351	0	AA6	12,752	0
PDSP35	26,828	0	LLB29	52,000	0	LLB24	39,000	0	ERA18	48,101	0	ERA18	12,667	0
AA6	20,894	0	LLB27	51,000	0	LLB27	39,000	0	ERA17	47,500	0	ERA17	12,667	0
LLB29	17,710	0	PDSP33	49,000	0	PDSP37	30,000	0	PDSP35	46,341	0	PDSP35	12,667	0
PDSP36	16,651	0	LLB28	49,000	0	ERA17	30,000	0	PDSP33	45,783	0	PDSP33	12,667	0

Table 4 Network measurements concerning the use of spatial data by institution and the corresponding descriptive statistics

ID	Betweenness	Stat_ bet	ID	Out degree	Stat_ outdeg	ID	In degree	Stat_ indeg	ID	In closeness	Stat_inclo	ID	Out closeness	Stat_ outclo
AA4	3,71,898	1	ERA12	1,08,000	1	AA6	1,45,000	1	LLB39	44,706	1	LLB21	14,844	1
AA6	2,09,472	1	LLB21	1,05,000	1	SPA31	1,13,000	1	AA6	44,186	1	ERA9	14,232	1
PDSP36	1,54,764	1	ERA11	91,000	1	AA2	90,000	1	SPA31	38,776	1	AA1	13,919	1
SPA32	1,54,202	1	AA4	80,000	1	AA4	90,000	1	AA4	38,000	1	LLB26	13,919	1
ERA12	1,16,397	0	ERA15	67,000	1	ERA16	80,000	1	ERA13	34,545	0	LLB25	13,718	0
SPA31	1,07,650	0	ERA16	65,000	1	LLB39	80,000	1	AA5	34,234	0	ERA12	13,014	0
ERA13	1,04,563	0	LLB22	59,000	0	ERA13	73,000	1	ERA16	33,929	0	ERA11	12,969	0
PDSP33	1,01,623	0	ERA13	55,000	0	PDSP36	60,000	1	AA2	33,333	0	ERA17	12,925	0
ERA16	1,00,679	0	LLB29	52,000	0	LLB22	56,000	1	SPA32	32,479	0	AA4	12,838	0
ERA11	91,132	0	SPA31	47,000	0	AA7	50,000	1	ERA12	31,405	0	ERA13	12,667	0
ERA18	65,163	0	PDSP36	44,000	0	PDSP33	50,000	1	LLB22	30,894	0	LLB29	12,500	0
ERA15	56,839	0	SPA30	42,000	0	LLB29	48,000	1	ERA15	30,645	0	PDSP36	12,459	0
PDSP34	51,721	0	PDSP33	42,000	0	AA5	45,000	1	LLB29	30,645	0	PDSP38	12,338	0
LLB22	42,866	0	PDSP38	42,000	0	SPA32	43,000	1	LLB24	30,159	0	SPA32	12,258	0
LLB29	38,563	0	ERA9	40,000	0	SPA30	40,000	0	LLB27	29,688	0	SPA31	12,219	0
AA7	25,188	0	AA1	39,000	0	PDSP35	33,000	0	LLB28	29,688	0	ERA18	12,179	0
AA2	18,613	0	LLB26	34,000	0	ERA15	30,000	0	LLB23	29,457	0	AA6	12,141	0
AA5	16,427	0	LLB25	33,000	0	LLB27	30,000	0	AA3	28,788	0	ERA16	12,141	0
PDSP38	16,083	0	PDSP34	33,000	0	PDSP37	30,000	0	ERA11	28,788	0	LLB22	12,141	0
SPA30	15,160	0	AA7	30,000	0	LLB24	28,000	0	SPA30	28,788	0	AA7	12,102	0

Table 5 Comparative summary of the metrics

Metrics	Provision	Use
Betweenness	ERA16/ERA11/ERA12 SPA31/AA4	AA4/AA6/PDSP36/SPA32
Out degree	ERA11/ERA12/ERA13/ PDSP36/ERA8/ERA9	ERA12/LLB21/ERA11/AA4/ERA15/ERA16
In degree	ERA12/ERA16/AA4/SPA31	AA6/SPA31/AA2/AA4/ERA16/LLB39/SPA13/ PDSP36/LLB22/AA7/PDSP33/LLB29/AA5/SPA32
In closeness	ERA16/AA4/ERA12/SPA31	LLB39/AA6/SPA31/AA4
Out closeness	ERA16/AA4/ERA12/SPA31/SPA32/AA3	LLB21/ERA9/AA1/LLB26

stops of vehicles and equipment used in RTHM, rest stop locations on the highway, locations of heavy equipment (winches), locations of operational bases, real-time traffic data, densely populated areas, and routes with higher frequencies of claims.

Using the information gathered, a conceptual spatial data framework for an SDI to aid in RTHM incident management was developed.

Thus, the conceptual data framework for an SDI for RTHM management will be a useful tool to group various data, with the purpose of facilitating actions and enabling rapid and effective decisions. The resulting actions are related to alerts for evacuations, means of transport to be used, access routes from which to choose, refuges for the protection of individuals, and measures to contain environmental damage to efficiently manage the disaster.

Discussion

Despite technological advances, SDIs are still under implementation in Brazil (Davis et al. 2011).

Efforts to organize an SDI on multiple levels, such as organizational, local, state or national, have become increasingly frequent. Therefore, given the benefits of the cooperative use of spatial information concerning hazardous materials transportation, the use of this data will become increasingly important for decision makers in the area of RTHM accident management.

To date, however, this level of integration is lacking because, while there is technology to integrate spatial data (for example, the National SDI (Infraestrutura Nacional de Dados Espaciais – INDE)), public policies to support the implementation of an SDI are lacking, though progress has been made via national and state decrees for the sharing of spatial data among various institutions.

Efforts are being made to enable the sharing of spatial data through institutional agreements between state public institutions, through the Use License Agreement (Contrato de Licença de uso - CLU No. 038/12) and the Unified Protocol for Relief of Chemical Emergencies in the State of São Paulo. This protocol includes several environmental agencies as signatories [Brazilian Institute of Environment and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e Recursos Naturais Renováveis – IBAMA) and Environmental Sanitation Technology Company (Companhia de Tecnologia de Saneamento Ambiental – CETESB)], State Traffic Police, Fire Department and Civil Defense agencies, and dedicated response groups [Preparation and Response to Environmental Emergencies with Dangerous Chemicals (Preparação e Resposta Rápida a Emergências Ambientais com Produtos Químicos Perigosos - P2R2)]. The purpose of the Use License Agreement is to grant licenses for the use of digital archives from orthophotos of the Project for Cartographic Update of the State of São Paulo. The Unified Protocol addresses the tasks of every emergency care agency and their responsibilities and functions at the time of an accident.

By establishing Terms of Cooperation, public digital spatial data can be distributed and reused by different departments. An example of data that are highly exchanged are satellite images and various spatial databases. Each department should have specific terms that cover their use of spatial data.

Most of the data flow among the Agencies Providing Data for Spatial Planning and ERA occurs according to informal institutional agreements. Due to the high usability of these data and because these institutions already have more cohesive institutional agreements, there is a pronounced exchange of data among these institutions.

SNA demonstrated to be a useful tool for identifying the transition, communication and power relationships among team Members. ERAs have the highest frequencies of interactions. Several ERAs (ERA8, ERA9, ERA11, ERA12, ERA13, ERA16) dominate both the delivery and use of spatial data that originates from other institutions. Two AAs (AA4, AA6) were identified as central and dominant institutions in terms of both the sharing and use of data in this category.

Service providers (SPA31, SPA32), which are characterized as carriers, dominate the flow of information in terms of both the sharing and use of spatial data. The LLBs (LLB21, LLB22, LLB29 and LLB39) were the most central institutions in this category.

All of the institutions interviewed confirmed the desire to share information via an SDI for RTHM. However, institutional arrangements that enable de facto data sharing are required.

Among the weaknesses of the present study, required for the possible replication of this methodology, is an understanding of the definition of spatial data. Each institution was presented with a definition of spatial data that stated these data can be inserted into a map before the administration of the questionnaire.

Concluding remarks

Spatial data are essential for the management of disasters involving RTHM. This article raised and presented several specifics that address the implementation of an SDI for RTHM.

A total of 39 institutions were identified and interviewed, all of which produce and maintain spatial datasets that can potentially contribute to an SDI for RTHM.

SNA was used to characterize the existing links among the 39 institutions involved with this sector. From the analysis, relationships concerning the use and sharing of relevant spatial data were identified and measured within the context of establishing an SDI for RTHM.

The power and usefulness of SNA, which is designed to not only identify but also map the flow of spatial data, was demonstrated. The qualitative analysis based on the interpretation of the visual representations of the network and the quantitative analysis related to the indices of centrality elucidated various aspects of the inter-institutional relationships within the network.

From the SNA analyses, the 39 institutions were found to share spatial data, though not always following pre-established formal agreements.

Notably, there is a great desire on the part of the institutions that manage technological disasters, in particular those related to RTHM, for the establishment of legal mechanisms for sharing data. Envisioning that the use of these data can support the timely mapping of actions to assist the preparedness, prevention, management, and immediate rescue efforts for RTHM incidents.

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Compliance with ethical standards

This article does not contain any studies with human or animal subjects.

Appendix

APPENDIX

Interview guided questionnaire for Road Transport of Hazardous Materials (RTHM) Institutions

Institution Acronym:

Name of the Interviewed:

Job of the Interviewed:

E mail of the Interviewed:

The present questionnaire belongs to a master survey, and aims to identify and measure the inter -relations between the institutions in comparison to the provision and sharing of spatial data with RTHM

Spatial data: data sets those are able to be in a map, or already exist on a map format. For instance: an accident report that should have the address of the accident report, a report fulfilled in some electronic devices (tablet, GPS, mobile) that brings the spatial localization data.

1. Could you please explain, in which the technological disaster phase your institution acts?

Prevention	**Disaster Risk Management**	**Response and Recovery**
Yes ( ) No ( )	Yes ( ) No ( )	Yes ( ) No ( )

2. Which are the institutions bellow your institution has a network interaction?

A) Associations

Institutions	No interaction	Interaction degree (0 a 10)
AA 1		
AA 2		
AA 3		
AA 4		
AA 5		
AA 6		
AA 7		

B) Emergency Response Agencies

Institutions	No interaction	Interaction degree (0 a 10)
ERA 8		
ERA 9		
ERA 10		
ERA 11		
ERA 12		
ERA 13		
ERA 14		
ERA 15		
ERA 16		
ERA 17		
ERA 18		

C) Licensing and Legislating Bodies

Institutions	No interaction	Interaction degree (0 a 10)
LLB 19		
LLB 20		
LLB 21		
LLB 22		
LLB 23		
LLB 24		
LLB 25		
LLB 26		
LLB 27		
LLB 28		
LLB 29		

d) Service Provider Angencies

Institutions	No interaction	Interaction degree (0 a 10)
SPA 30		
SPA 31		
SPA 32		

e) Providers of Data for Spatial Planning

Institutions	No interaction	Interaction degree (0 a 10)
PDSP 33		
PDSP 34		
PDSP 35		
PDSP 36		
PDSP 37		
PDSP 38		
PDSP 39		

3. This question aims to evaluate how your institution provides spatial data to some other institutions bellow.

(0) No Provision

(10) High Provision

A) Associations

Institutions	Evaluation degree (0 a 10)
AA1	
AA2	
AA3	
AA4	
AA5	
AA6	
AA7	

3.1 Which data sets your institution provides to the other companies? (Accident report, relevant digital reports)?

____

____

B) Emergency Response Agency

(0) No Provision

(10) High Provision

Institutions	Evaluation degree (0 a 10)
ERA 8	
ERA 9	
ERA 10	
ERA 11	
ERA 12	
ERA 13	
ERA 14	
ERA 15	
ERA 16	
ERA 17	
ERA 18	

3.1b) Which data sets your institution provide to the other companies? (Accident report, relevant digital reports)?

C) Licensing and Legislating Bodies

(0) No Provision

(10) High Provision

Institutions	Evaluation degree (0 a 10)
LLB 19	
LLB 20	
LLB 21	
LLB 22	
LLB 23	
LLB 24	
LLB 25	
LLB 26	
LLB 27	
LLB 28	
LLB 29	

3.1 C) Which data sets your institution provide to the other companies? (Accident report, relevant digital reports)?

____
____
____

D) Service Provider Agencies

(0) No Provision

(10) High Provision

Institutions	Evaluation degree (0 a 10)
SPA 30	
SPA 31	
SPA 32	

3.1 d) Which data sets your institution provide to the other companies? (Accident report, relevant digital reports)?

____
____
____

E) Providers of Data for Spatial Planning

Institutions	Evaluation degree (0 a 10)
PDSP 33	
PDSP 34	
PDSP 35	
PDSP 36	
PDSP 37	
PDSP 38	
PDSP 39	

4. This question aims to evaluate how does your institution use spatial data from some other institutions bellow.

(0) No Use
(10) High Use

A) Associations

Institutions	Evaluation degree (0 a 10)
AA1	
AA2	
AA3	
AA4	
AA5	
AA6	
AA7	

4.1 a) Which data sets your institution use from the other companies? (Accident report, relevant digital reports)?

____
____
____

B) Emergency Response Agencies

(0) No Use
(10) High Use

Institutions	Evaluation degree (0 a 10)
ERA 8	
ERA 9	
ERA 10	
ERA 11	
ERA 12	
ERA 13	
ERA 14	
ERA 15	
ERA 16	
ERA 17	
ERA 18	

4.1 b) Which data sets your institution use from the other companies??

____
____
____

C) Licensing and Legislating Bodies

(0) No Use
(10) High Use

Institutions	Evaluation degree (0 a 10)
LLB 19	
LLB 20	
LLB 21	
LLB 22	
LLB 23	
LLB 24	
LLB 25	
LLB 26	
LLB 27	
LLB 28	
LLB 29	

4.1c) Which data sets your institution use from the other companies?

____
____
____

D) Service Provider Agencies

(0) No Use
(10) High Use

Instituições	Escala de Avaliação (0 a 10)
OPS	
OPS	
OPS	

4.1d) Which data sets your institution use from the other companies?

___

___

___

E) Providers of Data for Spatial Planning

Instituições	Escala de Avaliação (0 a 10)
PDSP 33	
PDSP 34	
PDSP 35	
PDSP 36	
PDSP 37	
PDSP 38	
PDSP 39	

5. There is some institutional agreement to share spatial data among institutions? If yes, what kind of agreement (formal, legal, other)?

( ) Yes ( ) No

___

___

6. The institution uses social media (fabebook, twiitter, etc) to communicate amongst themselves when the accident occurs?

( ) Yes/ Facebook ( ) No/ facebook

( )Yes/ Twitter ( ) No/ Twitter

7. If you would be able to use a computer system based on maps (google maps), which data sets would you like to see in those maps?

( ) Hotspots representing the accident occurrence
( ) Rivers
( ) Hospitals
( ) Police stations
( ) Criteria of slope (topographic map)
( ) Land cover use (Residential area, vegetation areas)
( ) Native Vegetation zones
( ) Fog spot prone zones
( ) Landslides prone zones
( ) Camera data sets
( ) Photos of the accidents

Other:

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___

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