Advances in Civic Co-management within the Geospatial Ecosystem Applied to Disaster Risk Management

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ABSTRACT

The use of mobile devices for identifying risk and coordinating disaster response is well accepted and has been proven as a critical element in disaster risk management. As new tools, applications, and software are adopted by municipal governments and NGOs for the identification and management of urban risk, the need for greater integration of the various data they collect becomes acute. While the challenge of integrated data management is substantial, it is aided by the fact that many new tools have been developed to include an Application Programming Interface (API), which allows the machine-to-machine (i.e. automated) sharing of open data. While some proprietary platforms for the management of urban data are currently available, they are extremely costly and very limited in terms of data inputs; to date there are no open source geospatial software tools for the integrated management of various API sources to evaluate hazards for disaster response.

A key to improving disaster risk management as an element of risk identification is the development of an integrated open source Decision-Support Risk Evaluation Matrix that enables: 1) automated integration of multiple geospatial and non-geosapatial API sources into a low cost, user-oriented dashboard; 2) backend database and software design for the Risk Evaluation Matrix that enables data sources to be parameterized and interrogated; 3) the development of an output API stream that allows additional secondary applications to optimize their evaluations and analyses through open access to critical risk information. To address these challenges this paper presents an open source Risk Evaluation Matrix, currently in development, which aims to provide situational oversight of flood hazards from multiple data-sources, including social media, in the city of Jakarta, Indonesia.

1. INTRODUCTION

The use of mobile devices for identifying risk and coordinating disaster response is well accepted (Meier, 2015), and has been proven as a critical element in government disaster risk management. In environments where limited formal geographical data available, government agencies and organizations tasked with responding to natural disasters are increasingly relying on crowd-sourced data from mobile devices to inform decision makers in real-time (Holderness, 2014; Meier, 2015). However, as new tools, applications and software are adopted by municipal governments and non-governmental organizations for the identification and management of urban risk the need for greater integration of the various data they aid in collecting becomes acute. While the challenge of integrated data management is substantial, it is aided by the fact that many new tools have been developed to include an Application Programming Interface (API), which allows the machine-to-machine (i.e. automated) sharing of open data. Such architectures therefore afford the opportunity of creating an integrated information system, which automates requests for real-time information from multiple sources simultaneously, and integrates them to provide comprehensive decision support during disasters.

Jakarta and its surrounding conurbation (Jabodetabek) has the highest rate of urbanisation in the world and comprises the second-largest contiguous settlement on Earth. With a greater metropolitan area hosting 13 rivers, 1100 kilometres of canals, over 28 million residents, and 40% of the city below sea level, the annual monsoon season affects all residents (Jakarta city: 14 million, Jabodetabek: 28 million) and frequently necessitates evacuations of thousands of people (Peters, et al., 2015). For example, the 2007 monsoon season saw flooding cause the death of 80 residents, displace more than 340,000 people and resulted in economic loss in the capital of $453,000,000 (Ward et al., 2011). However, because flooding in Jakarta is mostly a function of infrastructure fragility at a given point in time, prediction and modelling of future flood situations is near-impossible (Turpin et al., 2013). The problem is further compounded by an extreme lack of information available on the hydrological infrastructure, the urban fabric, and population distribution required to undertake risk-based hazard exposure planning. The severity of the information shortage in Jakarta is so critical that the World Bank classifies Jakarta as “Data Starved” (Baker, 2012).

In contrast, Jakarta has one of the highest rates of mobile phone penetration worldwide, contributing to a significant social media footprint. The city alone accounts for 2% of the world's total Twitter activity (Semiocast, 2012). As such the potential for crowd-sourced situational information, from citizen reporters, is significant and proven in the context of improving flood response in Jakarta (Holderness & Turpin, 2015). The combination of unique geography and prevalence of formal and informal data-sources mean that Jakarta is a key case study for the development of improved risk management through new tools and open source software. Open source software software solutions are critical in Jakarta because cost-prohibitive private products are unrealistic under current budget constrains. Risk information and coordination through open data protocols is also critical to support decision-making about disaster response, emergency planning, and community resilience. Furthermore, rich suites of open and accessible geospatial risk data generate activity in NGOs and the private sector, empowering longer term planning tools such as InaSAFE and economic calculators such as JakSAFE. In contrast to systems using formal hazard data, the PetaJakarta.org project successfully demonstrated the utility of social media as a method for crowd-sourcing confirmed flood reports from the public, for rapid situation assessment by the Jakarta Emergency Management Agency (BPBD DKI) (Holderness & Turpin, 2015). Furthermore, PetaJakarta.org enabled two-way communication between Jakarta's citizens and the government, complimenting formal information dissemination process carried out by BPBD. In this context, improving the veracity and integration of informal data, such as those captured by PetaJakarta.org, is paramount to maximizing the potential of information from new media in an operational manner.

This paper presents a prototype open-source Risk Evaluation Matrix, currently in development, which aims to provide a real-time decision support system for flood hazard data in Jakarta. Given the prevalence and importance of geospatial data in disaster risk management, the system is structured using a geographical information systems paradigm where locational information is at the heart of the data structure, and the primary output of information is in the form of a real-time hazard map. This paper details how the proposed GIS is designed to integrate existing formal and informal data sources used for flood hazard management in Jakarta. Following this the paper sets out the technical architecture of the proposed system and a description of how it will be used by the emergency management agency for decision support in response to flooding in Jakarta.

2. JAKARTA'S DISASTER RISK MANAGEMENT ECOSYSTEM

Table 1 shows a summary of data sources available to BPBD DKI Jakarta used for decision support during flood events. Currently, all these information systems operate independently, with human operators corroborating data from the different systems manually. The two principle systems used by BPBD DKI are: (1) the Disaster Information Management System which provides a non-spatial record of reports of flooding, and (2) Flood Gauges which show the movement of water throughout the city's hydrological network. Data from these two systems is analyzed in the BPBD control room, and further verified against secondary sources of information such as CCTV imagery. Analysts at BPBD DKI use this information to manually assess the hazard across the city, which in turn is used to action response depending on the severity of the situation.

Despite significant recent advances in the use of GIS, and sharing of open data within the Jakarta government (Holderness & Turpin 2015), because there is no integrated approach to information systems within the control room, the process of compiling a spatial record of flood affected areas is carried out manually for each of Jakarta's 2,700 sub districts over a six hour period. The spatial records are created using the open source QGIS software to generate a series of static maps; whilst these are useful records of the flood situation at a given point in time, due to the time lag in information processing the outputs are often not used in decision making in the control room, which are frequently required to happen in near real-time. This solution is particularly unsustainable as the Jakarta government strives to improve the spatial resolution of hazard reporting down to the ward level – a ten-fold increase in data volume. The problem will be further compounded as a new generation of data sources such as social media crowd-sourcing come online and feed into the disaster risk management decision making process (Jain et al., 2015; Meier, 2015).

Table 1. Hazard Data Sources Available to BPBD DKI Jakarta.

Data Source	Description	Contents	API
DIMS	Disaster Information Management System	Confirmed reports of flooding (e.g. “911” calls).	Yes
Flood Gauges	Flood Gauge Alerts	Empirically derived risk metric based on upstream river heights	Yes
KoBo Toolbox	Reports from Emergency Service Personal	Ground-truthed hazards and needs assessments	Yes
PetaJakarta.org	Crowd-sourced reports of flooding	Citizen confirmed reports submitted by social media	Yes
OpenStreetMap	Crowd-sourced maps	Urban infrastructure (e.g. roads)	Yes
CCTV	Live imagery of major road infrastructure	Real-time video feeds	No

The PetaJakarta.org project was a proof-of-concept pilot study undertaken in collaboration with BPBD DKI Jakarta and Twitter Inc., to examine the potential and utility of crowd-sourcing flood reports from citizens via social media (Holderness & Turpin, 2015). In particular, the system demonstrated that using a GeoSocial Intelligence approach, that is, requesting confirmed reports directly from users via established communication networks, provided BPBD DKI with the most up to date information on locations of flooding within the city

(Holderness & Turpin, 2015). However, in the critical review of the system the validation and consolidation of the high number of reports from PetaJakarta.org (over 1,000 during five flood events), against existing formal sources of data such as DIMS, continued to be a labor intensive process (Holderness & Turpin, 2015). In short, while the PetaJakarta.org pilot study proved the utility and veracity of crowd-sourcing hazard information from social media, it essentially created a new stream of data, independent from other data streams (see Table 1) which had to be manually processed by BPBD.

In addition to PetaJakarta.org, the Kobo Toolbox is listed in Table 1 as it will be used by the Jakarta government for flood reporting during the 2015-2016 monsoon season for the first time. The Toolbox will be used by BPBD staff to collect pre-flood preparedness assessments, hazard and exposure surveys during flooding, and damage and loss assessments after flood waters have receded. The Kobo platform features an API for data access (Kobo Toolbox, 2015) making it interoperable with an integrated information system. In a related development a new API for the Disaster Information Management System (DIMS) has also been created, to help facilitate more integrated analysis of available data within BPBD. This initiative is also supported by the creation of a unique primary key index for each of Jakarta's 2,700 districts, meaning that non-spatial sources of information (e.g. from the DIMS API) can be joined to spatial records for cartographic visualization and analysis.

Therefore, to build on the success of new data inputs and technologies such as crowd-sourced reports from social media via PetaJakarta.org, and the Kobo Toolbox data, the process of integrating and producing hazard record information presents a significant opportunity for improvement. In this context, leveraging the established use of free and open source geospatial software and open data at BPBD will help maximize transparency and utility of the system for decision support during flooding. Furthermore, as an integrated information management system the Risk Evaluation Matrix will have its own API to facilitate improved sharing of hazard information in real-time, both to the public (e.g. via the BPBD website) and to other partners within the DRM ecosystem in Jakarta (Holderness & Turpin, 2015).

3. GEOSPATIAL ARCHITECTIRES FOR INTEGRATED RISK EVALUATION

3.1 Proposed System

To reap the benefits of accessible, low cost mobile devices and their various applications, emergency management agencies like BPBD DKI Jakarta require an open source Risk Evaluation Matrix for the management of their API-derived data. *CogniCity* is a GeoSocial Intelligence Framework currently used to deliver PetaJakarta.org – a decision support system developed by the SMART Infrastructure Facility with BPBD DKI Jakarta based on citizen reporting of flood events via social media. This project will extend CogniCity to gather data from additional APIs so as to deliver field reports from other sources in a real-time manner to aid BPBD's decision making during flood events. The system will leverage CogniCity's geospatial capabilities to present reports via the existing map interface used by BPBD DKI Jakarta. In this way, CogniCity would enable critical data integration, by extending the information ecosystem to fuse data gathered from citizens via social media and formal reporting via API-derived sources into a single Risk Evaluation Matrix. The resulting decisions will then be recorded by the system for dissemination to secondary users via a robust API, further helping to foster the disaster risk management ecosystem in the region.

The aim of the system is to improve BPBD DKI's ability to identify and confirm the need of government response of flooding across the city of Jakarta. The system will support the human-based decision making process by effectively parallelizing the analysis of multiple data streams amongst BPBD DKI staff; instead of six staff working to corroborate the flood situation from the six data feeds listing in Table 1, one district at a time, six staff could use the Risk Evaluation Matrix to evaluate all the available information for six districts concurrently. This process will be supported by a cartographic data interface, which will enable BPBD DKI verification of reports, to qualify areas of the city flooded and requiring assistance. The resulting verified flood hazard geospatial layer will be shared for communication with the public and other government agencies via a real-time map on the BPBD DKI website.

Figure 1 is a schematic representation of the CogniCity Risk Evaluation Matrix, showing input from the four API-enabled data sources listed in Table 1. Once these data are received by the system they are displayed on an interactive map, which plots hazards from each of the four data sources against their location within the city. Hazard reports are organized by city district, and presented in an accompanying matrix table which lists the details of hazard reports from each data source for each district. The matrix view and map are linked interactively, such that interrogation of hazard reports in the matrix will be reflected in the map, for example through a drill-down operation, commonly used in decision support (Wickramasuriya et al., 2013). The matrix facilitates decision support by allowing a BPBD DKI analyst to use the existing data sources available to gain an on-the-ground situational insight, based on the combination of hazard reports displayed on the map. The analyst is then able to evaluate all data sources, except for CCTV imagery, for each area, in an integrated manner. BPBD DKI can then toggle whether an area under examination is currently exposed to the hazard (i.e. flooding), generating a corresponding record in the system. Records for all areas are then automatically combined into a single spatial dataset at regular, frequent intervals, representing the current flood extents in the city. New, incoming reports from any of the four streams which have not been checked are subsequently highlighted, alerting analysts to the presence of new data within the matrix. Thus, the system helps support the identification of hazards in the city by complimenting the existing socio-technological structure of information management system at BPBD DKI, where critical decision making on hazard exposure is a human-led activity (Holderness & Turpin, 2015). The resulting data are subsequently shared through the open data API in real-time, and are consumable by other information systems such as the InAWARE and InaSAFE situational overview and real-time risk response and planning systems, used within the Indonesian government.

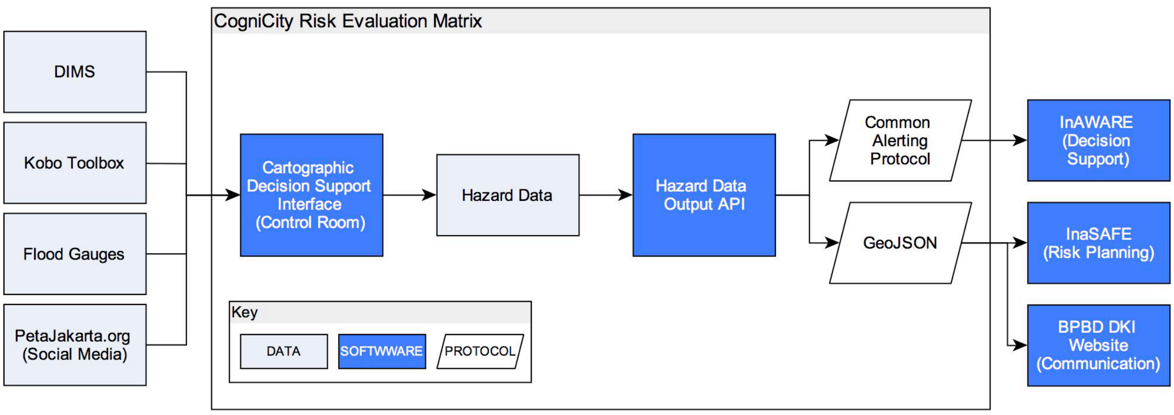

Figure 1. Schematic Showing Open Source CogniCity Risk Evaluation Matrix

3.2 System Architecture

The system is modeled on a web-based geographical information system architecture, comprised of four components. (1) A reports module to gather data from the input API streams. (2) A spatial database to cache incoming hazard reports, and store incidents of flooding as verified by the user interface. (3) A web-server to serve both the data for the risk matrix, and the API of resulting hazard layer. (4) A web-based user interface consisting of the Risk Evaluation Matrix for use by BPBD DKI. The system will be based on the aforementioned CogniCity framework, which provides a scaleable client-server architecture for handling real-time geospatial reports of flooding, powering the crowd-sourced flood map at PetaJakarta.org. For the Risk Evaluation Matrix, CogniCity will be extended to support the additional three API data sources. The reports module, created using the NodeJS platform will periodically poll each of the APIs for data updates, and send this data to the PostgreSQL/PostGIS spatial database for caching. Once data is received by the database, the server module, also written in NodeJS, pushes this data to the client interface within the BPBD DKI control room (Figure 1). The use of NodeJS and the open source PostgreSQL/PostGIS is a proven technology stack in this context, effective at handling high-throughput of information and capable of scaling to meet demand of concurrent users. For example the PetaJakarta.org CogniCity instance deployed during the 2014-2015 was shown to be capable of handling 250 tweets per second, and more than 10,000 concurrent website users (Holderness & Turpin, 2015).

The client interface will also extend the technology developed for PetaJakarta.org, using the LeafetJS library and HTML5 technology to provide a scaleable “slippy” map of the city of Jakarta, as well as embedded data table forming the Risk Evaluation Matrix. Once an area is marked as flooded in the interface, this information is pushed back to the database, whereupon it is available via the system API in the Common Alerting Protocol or GeoJSON formats for consumption, primarily by the InAWARE and InaSAFE software and BPBD website. The Risk Evaluation Matrix is open source software, and while the output hazard data will be freely accessible under an open license, due to sensitivity of incoming reports and potential malicious use, access to the operational system itself will be restricted to the BPBD control room. It is envisaged, however that by making the software open source and available online other organizations, such as other regional governments in Indonesia, could implement the system as part of their own disaster risk management systems.

4. CONCLUSIONS

This paper presents an open source system, currently in development, which has the potential to significantly improve information management and resulting response to flooding in the city of Jakarta, Indonesia. This is an important evolution of the disaster risk management ecosystem in the region as the number of new and innovative hazard data, such as crowd-sourced information, comes online. This approach is applicable across a number of Southeast Asian coastal megacities, many of which will bear the brunt of future climate change and resulting extreme weather events. Further, it is important to recognize that the system has been designed in conjunction with, and based on the requirements of, the Jakarta Emergency Management Agency, using a detailed understanding of the organization's information flows and institutional ethnography carried out as part of the preceding PetaJakarta.org project. However, through the use of open source software and standards-compliant data APIs it is envisaged that the system will be readably transferable to other cities, hazards, and languages in the region.

8. REFERENCES

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