The Intelligent City Operations Centre: An Integrated Platform for Crisis Management

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Abstract. Emergency and disaster management – collectively referred to here as crisis management – have traditionally been practised as distinct and separate disciplines. In recent years, however, it has been recognised that crisis management is a complex, multi-disciplinary problem that requires continuous collaboration among all stakeholders in order to be effective. At the same time, technologies have emerged that can support cross-disciplinary approaches to crisis management. This paper describes the essential components of the 'city crisis management problem', and then maps the people, process and technology requirements that emerge from this problem description. The intent is to identify the critical success factors by establishing clear linkages between the problem requirements, the solution space and crisis management best practices. The paper also describes an embodiment of the Intelligent City Operations Centre concept, an ICT platform that can be specifically configured to address these requirements in developing countries.

Keywords: crisis management, disaster management, emergency management, mobile applications, city management, collaboration.

1 Introduction

Instances abound of cities operating with relatively autonomous domains, where little or no collaboration exists in their day-to-day operational activities. Although the city is supposed to be a single entity, it generally delivers services through distributed means – for example, water, energy, public safety and housing services are typically delivered by different, and often independent, city agencies. The need exists for operational collaboration across these siloed domains, in order to facilitate more efficient service delivery. This is particularly true in the case of crisis management services, where it is recognised that collaborative, multi-disciplinary techniques often deliver the most effective interventions [1]. At the same time, technologies have emerged that enable Smarter Cities[1] to apply collaborative response approaches to

[1] Launched in 2005, Smarter Cities [2] is part of a multi-programme International Business Machines (IBM) corporate campaign known as Smarter Planet [3], whose goal is to develop and deploy technologies that promote more judicious use of our planet's scarce resources.

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crisis management. The focus is on cities because of their increasingly important role as the social, economic and political hubs of a globally integrated world [2].

In line with the AFRICOMM 2011 goal to share perspectives and opportunities on technologies relevant to developing countries, this paper motivates the notion of the "Intelligent City Operations Centre" (iCOC) as an ICT tool to aid crisis management in cities. The rationale is that cities need to become smarter in the way that they manage hazardous events, and the iCOC supports this goal by providing an integrated and consistent view of resources across city domains, that inform critical decisions during a crisis. In a crisis event, the iCOC effectively defines a shared problem space where various city agencies can decompose problems in an orderly fashion, so that they can be understood and acted upon in a coordinated manner. The use of an integrated, collaborative, cross-domain platform to manage both day-to-day and crisis operations is an essential pre-cursor for effective disaster and emergency management. The paper also outlines the anatomy of the crisis management problem, and presents an IBM embodiment of the iCOC, explaining how some of its features can aid crisis resolution in cities.

2 Smarter Cities

Operationally, cities may be viewed as comprising six fundamental domains composed of different networks, infrastructures and environments related to their key functions: people, business, transport, communication, water and energy [1]. Each of these domains delivers services that are essential to sustain modern metropolitan environments. As an example, the people system includes public safety, health and education and is central to citizens' quality of life; water and energy are also core city services.

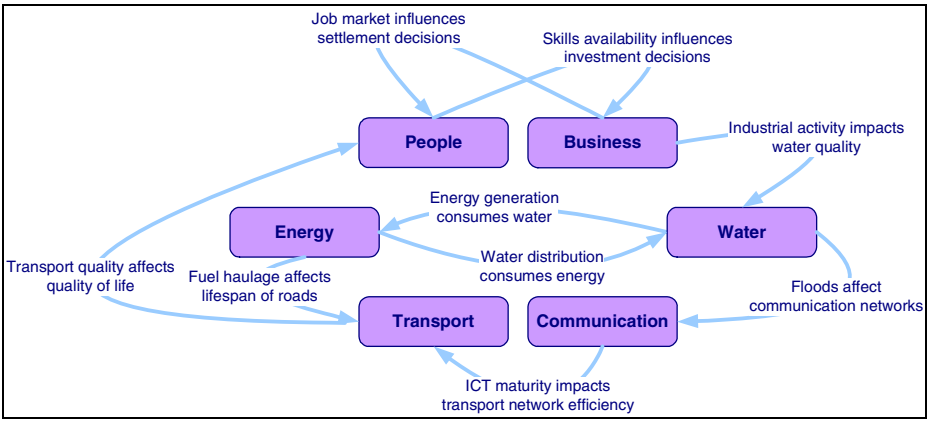

Fig. 1. Smarter City "system" showing some subsystem interrelationships

These domains effectively represent a "system of core subsystems" since they interconnect in a systemic fashion (Figure 1). These systems are characterised by

multiple inter-dependencies among them, and the challenges they face interact in complex ways, with consequences that are sometimes difficult to predict and assess.

A Smarter City acts as a single entity with interconnected subsystems where city domains share significant event information to aid smart decision-making which, ideally, optimises the overall performance and efficiency. These operations are supported by Smarter City technology, which provides an integrated view of city-wide issues and enables coordinated decision-making. The technology delivers key capabilities such as holistic monitoring of city services and operations, effective management of planned and unexpected events, and predictive analytics to resolve problems earlier with optimized service delivery. These capabilities enable city executives to understand the inter-dependencies between the city's subsystems, empowering them to make informed decisions in a collaborative fashion in real time.

3 The Crisis Management Problem

Crisis management refers both to managing (hopefully) occasional disasters and as well as day-to-day emergency operations. In order to understand the role of the iCOC within a crisis management context, it is necessary to explain the essential components of the problem.

3.1 Crisis Management Continuum

The crisis management continuum shown in Figure 2 (based on [6]) provides a useful discussion framework that views the problem as a repeating cycle that consists of three distinct but overlapping phases.

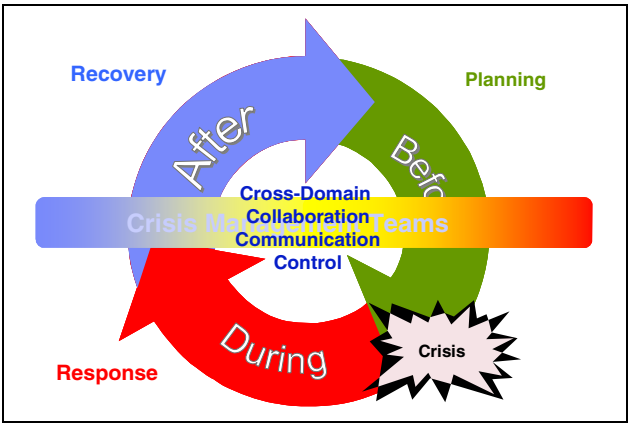

Fig. 2. The Crisis Management Continuum

- *Disaster Planning*: The collective term use to encompass all actions taken prior to the occurrence of a disaster in order to mitigate risk and impact. It includes preparedness, which consists of activities designed to minimize loss of life and

damage, organize the temporary removal of people and property from a threatened location, and facilitate timely and effective rescue, relief and rehabilitation. It also includes measures put in place to mitigate long-term risks, such as early warning processes that monitor situations in communities or areas known to be vulnerable to slow onset hazards (e.g. famine early warning).

- *Emergency Response*: The period during which extraordinary measures have to be taken. Special emergency procedures and authorities may be applied to support human needs, sustain livelihoods, and protect property to avoid the onset of disaster. This phase can encompass pre-disaster, disaster alert, disaster relief and recovery periods. An emergency phase may be quite extensive, as in a slow onset disaster such as a famine. It can also be relatively short-lived, as after an earthquake.
- *Disaster Recovery*: Describes the post-disaster phase of a disaster. It includes rehabilitation, which consists of the operations and decisions taken after a disaster with a view to restoring a stricken community to its former living conditions, while encouraging and facilitating the necessary adjustments to the changes caused by the disaster. Disaster recovery also includes reconstruction, which comprises the actions taken to re-establish a community after a period of rehabilitation subsequent to a disaster. Actions would include construction of permanent housing, full restoration of all services, and complete resumption of the pre-disaster state.

The phases in the crisis continuum are distinct in the sense that they deliver services specific to each phase, but overlap in practice because they tend to occur concurrently, and not sequentially, in time. Different activities become more or less prominent and frequent, depending on the lifecycle stage of a crisis and the relationship between the hazardous event and the vulnerability of the affected communities and resources.

3.2 Team Collaboration, Communication and Control

Experiences from previous hazardous events in South Africa [3] have highlighted shortcomings in crisis management practice that frequently manifest themselves in other countries and regions [4], [5]:

- The lack of proactive disaster policy and strategy usually leading to haphazard and reactive responses to disasters.
- Uncoordinated responses to disaster due to unfamiliar and inadequate mechanisms for team collaboration communication and control.
- Incomplete and inconsistent data and knowledge related to disaster management and the local environment, which makes it difficult to identify those who need relief, and to determine how to deliver that relief.

A seminal understanding that has been gleaned from these events is that crisis management operations can involve a large number and variety of agencies (see panel below, as an example), and that collaboration between them needs to be continuous,

although it typically peaks during the response phase. These participants need to be managed as one team during a crisis, using four main team management functions:

Johannesburg City Crisis Management Team

- Head: Emergency Services
- Head of the Disaster Management Centre
- Director of Metro Police
- Regional Directors: 11 Regions
- Regional Managers: Health and Social Services
- Regional Manager: Environmental Health
- Regional Managers: Housing and Urbanization
- Regional Managers: Sport & Recreation
- Managers: People Centres
- Director: City Power
- Director: Joburg Water
- Director: Pikitup (waste management)
- Director: Roads Agency
- Director: City Parks
- Ward councillors and/or committees
- Community leader(s)

Extract from the City of Johannesburg Disaster Management Plan [**Error! Reference source not found.**]: the city crisis management team will comprise any of the above agencies or entities, depending on the nature of the event. In practice the team will often include agencies external to the city, such as national and provincial units, and external Non-Governmental Organisations.

- *Locate***:** In preparation for, during, or in response to an event, rapidly identify and assemble a team across agency boundaries.
- *Invite***:** Using information provided during the location of those individuals or roles, invite them to collaborate.
- *Authenticate***:** Using authentication information previously available or now provided, authenticate those individuals or roles.
- *Collaborate***:** Work together, synchronously or asynchronously, to solve a problem or set of problems.

Collaborative, multi-disciplinary approaches are also useful in planning activities, such as hazard identification and mitigation, and recovery tasks that ensure continuity and restoration of service. Thus, best practice mandates mechanisms that support inter-agency collaboration, communication and control at all times, and not just during a response phase.

4 The Intelligent City Operations Centre

The Intelligent City Operations Centre (iCOC) is a concept that draws on the requirements of city day-to-day and crisis management operations, and melds them with commonly available ICTs and best practices to create an intelligent crisis management platform. The iCOC offers a relatively new perspective, even though emergency command or operations centres already exist in many cities to provide security (police), fire, rescue and medical emergency services. These centres generally focus on delivering time-sensitive emergency response services that are aimed at protecting lives and property. On the other hand, planning and recovery have traditionally been viewed as separate disaster management functions, and conducted by different teams with little or no collaboration with emergency response teams. The systems that support these

functions are typically implemented as islands, disconnected from any 'line-of-business' systems containing information that is vital for crisis management.

Furthermore, and critically so, experience informs that other city domains, such as water, energy and transportation, do not participate actively in crisis management planning efforts, even though they are obliged to respond during a crisis. Hence the view [3], that "disasters are often managed haphazardly" and therefore "the approach taken to disasters may thus be as costly (or even more costly) than the [hazardous] event itself". This outcome could be due, in part, to the fact that city domains typically implement focused centres to support domain-specific operations only.

The Intelligent City Operations Centre approach differs significantly in several areas:

- It provides greater width and depth of coverage because it is a cross-domain operations centre that encompasses many more domains. Furthermore, it provides capabilities that coordinate crisis management activities across them, by integrating with the 'line-of-business' systems that support these domains.
- It encourages a collaborative approach to all activities, especially decision-making and problem decomposition, by providing pervasive collaborative tools delivered through Web technologies.
- It is architected to address the full range of events from minor (e.g. day-to-day emergency response events) to major (e.g. large scale city disasters).
- It supports several deployment configurations, which make it fit for the operations in developing countries.

The next sections outline the key features of the iCOC from the perspectives of relevance to stakeholders, architecture and intelligent processing.

4.1 Relevance

The Intelligent City Operations Centre provides cross-domain awareness and important status information on city services. Realising this technique requires collaborative involvement from many stakeholders, throughout the lifecycle of the system, including city executives such as mayors or council representatives, citizens, business, and the city domains, amongst others. Each of these individuals or entities has a different role to play in crisis management and requires specific capabilities to collaborate via the iCOC. As examples:

- City executives need summary information that can hep them understand event dynamics and make informed decisions around their resolution;
- Citizens may be consulted when decisions are contemplated that affect their well being; they can also provide early warnings, and may need to be notified, about significant incidents or hazard events.
- City domains must collaborate continuously and provide information that supports executive decision-decision making; to do this they must understand the detailed event dynamics and the impact of certain courses of action both within and across their spheres of jurisdiction.

The implication is that an iCOC must provide capabilities that are relevant to each role – a blanket approach will not succeed here. The IBM iCOC provides its capabilities in personalised views that are structured in a hierarchy, from high-level summary views for city executives to detailed issue decomposition views for operational domain specialists.

4.2 Architecture

- The architecture overview (Figure 3) shows the high-level functional components that comprise the IBM Intelligent City Operations Centre. These include gateways for accessing domain-specific information, analytics to support advanced early problem resolution, and visualisation services that enable visualisation of events, alerts, KPIs, directives and impact assessments, with geospatial representation on maps.

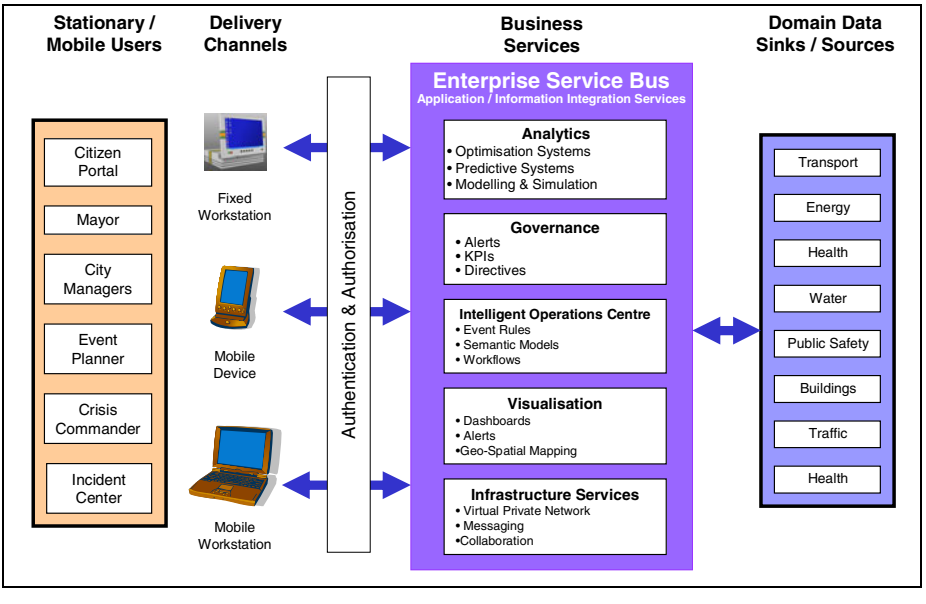

Fig. 3. Intelligent City Operations Centre Architecture Overview

The complementary software infrastructure provisions essential security (authentication and authorisation), collaboration, mobility, infrastructure management and messaging services, amongst others. In addition, the iCOC must also maintain and provide data for historical reporting as well as accounting and audit purposes. Please refer to [10] for a detailed description of the functions and architecture of the IBM Intelligent City Operations Centre.

4.3 Intelligence

So why is the iCOC said to be "intelligent"? With reference to Figure 1, let us suppose a flood event occurs in a part of a city with potentially undesirable consequences. In deciding a course of action, some of the key questions that city executives may need to answer include:

- What is the current extent of water coverage?
- How will the water coverage change in the next hour, day, month and/or year?
- What communities and assets (buildings, roads, communication/energy networks, etc) are affected and how?
- What are consequences of shutting down segments of affected energy and transport networks?

The different components of the iCOC would interact with each other and people to generate the required information. As examples in such a scenario:

- Modelling capabilities could be used estimate the extent of the affected area, and simulation could be used to project dynamic situational changes by hour or day.
- If combined with community and property vulnerability data in the city domain systems, as defined by the disaster management discipline, an impact assessment could begin to be built.
- Predictive systems could be used to evaluate the impact of shutting down portions of the energy network, and optimisation systems invoked to select the 'least cost' alternatives.
- Should decision-makers need unknown domain specifics, then they have the option to acquire such information by collaborating with city domain specialists.

The purpose of this rather simplistic scenario is to illustrate how the intelligence in different components of the iCOC can be brought to play in a crisis. We must note that the concept of the iCOC is wide ranging in scope and in the timescales involved; it is about managing predicted incidents that might or might not happen now or far into the future, as well as incidents happening now in real time. These intelligent capabilities can all make a vital contribution to managing such crisis scenarios in real time. By modelling patterns of subsystem behaviours and interactions, this intelligence allows iCOC users to explore, and thereby predict and assess, the implications of their decisions.

4.4 Fit for Purpose

A key characteristic of any viable solution is that it must meet the requirements of the operational environment in which it will be deployed. The iCOC incorporates features that are designed to leverage the exponential uptake of mobile technologies in developing countries, as well as to address some of their unique challenges, including:

- *Communications infrastructure*: Much of the data ingested by the iCOC will likely be captured on mobile devices in remote areas where communications are

patchy; an optional iCOC capability enables IP-based connectivity over multiple protocols including analogue an digital mobile, wireline, radio and satellite networks.

- *Disconnected operations*: For the same reason, the iCOC is designed to support disconnected operations, which allow mobile workers to continue working in areas which have no connectivity. It also supports traditional browser-based technologies, but it should be noted that they are useless in such situations, and that this may change with the emergence of the HTML5 standard which might support disconnected operations in the future [9].
- *Efficient power management*: Rural areas will typically not be connected to the national power grid and will rely, instead, on solar power, especially for mobile devices. Unlike traditional mobile applications, the iCOC mobile platform is based on technologies that only utilise resources on-demand (e.g. network, memory, etc), thereby keeping power consumption extremely low.
- *Skills availability and cost*: The iCOC can be delivered as a near black-box within a cloud infrastructure: the black-box approach reduces 'build-run-operate' expertise requirements, and there is increasing evidence that shared deployments on cloud architectures can reduce costs [11].

5 Conclusion

This paper has introduced the notion of the Intelligent City Operations Centre and showed how it can be deployed to enhance crisis management practice, by providing an integrated, collaborative, cross-domain platform to manage both day-to-day and crisis operations in Smarter Cities. Given that it takes time for teams to start using new collaboration platforms productively, especially in a crisis situation, an important feature of the iCOC concept is that it is designed to also support normal city operations. The paper has also illustrated the relevance, architecture and intelligence embedded within the IBM realisation of the Intelligent City Operations Centre, and highlighted how it addresses some of the key deployment considerations in developing countries.

The motivation for this paper was to stimulate discussion around the role of cross-domain approaches and ICT platforms in the practice of the disaster and emergency management disciplines in developing cities. Future work will focus on reporting the results of iCOC implementations around the world, including projects that are already underway in Gauteng Province, South Africa [12] and Rio de Janeiro, Brazil [13].

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