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# Supporting Real Time Decision-Making

The Role of Context in Decision  
Support on the Move

 Springer

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# Foreword

Over the past 25 years, decision support systems (DSS) have become so widely deployed – from individual to organizational to interorganizational levels – that they are often taken for granted. Aside from common adherence to the generic architecture of DSS, they have become amazingly diverse in their implementations and applications. Across much of the world, they have come to a point of seamlessly blending into ordinary decisional activities of individuals and organizations. Now, with the relentless march of technology and the trend toward hyper-competition, we must look beyond ordinary decisional activities to those that are remarkable in the sense of demanding (or potentially benefiting from) real-time support. Growth, high performance, and even survival will increasingly depend on DSS that can provide needed knowledge to decision makers to fuel their efforts toward decisional processes and outcomes that are more productive, more agile, more innovative, and more reputable – all within the context of a modern world of high velocity punctuated with crises and underscored by incessant movement of ideas, people, and products.

This book is the first concentrated guide to understanding the emergence of real-time DSS as a phenomenon and as a generator of interesting issues for researchers, practitioners, vendors, and educators.

The international array of contributors to the book covers the nature of this phenomenon in ways that will provoke and stimulate the reader. They offer insightful explanations about the characteristics needed for DSS to be relevant and helpful for supporting decisions that must be made along the frontier of events as they unfold – some decisions sparking those events and others extracting value from them. The book discusses various technologies that can underlie the realization of systems that are essentially “aware” of the context within which they collaborate with users for real-time decision making along emergent frontiers. The wide applicability of such decision support is amply demonstrated through a diverse set of examples – emphasizing real-time decision making in the cases of emergencies, mobile situations, and medical events.

In general, DSS differ from other kinds of information systems (e.g., transaction systems, management information systems) in terms of both purpose and features. Their *purpose* is quite simply to support decisional episodes (rather than to handle transactions or keep records for management reporting). According to scholars

involved in the development of the DSS field, their distinguishing *features* include satisfying ad hoc knowledge needs (proactively and/or reactively), deriving knowledge, discovering knowledge, direct interaction with those who need knowledge (i.e., without the requirement of intermediaries), system customization for functionality and interfaces, fostering collaboration among multiple decision participants, and learning from prior decisional experiences. Now, we must realize that many such features were largely visionary at the time of their original introduction. Over time, progress has been made along each of these lines. It is very interesting that, in this book, we see the visions becoming real as the features coalescing into real-time DSS – a phenomenon driven by pressing needs in today's world.

The march toward support for real-time decision making is intertwined with other developments in the discipline of information systems: organizational computing, electronic business, and pervasive computing. Not only have these developments enriched transaction processing and management record keeping/reporting, they have added substantial wealth to progress in the DSS field. In this book, we can see many examples of the results and prospects for this value added for dealing with temporal, spatial, and environing facets of decisional contexts. Such contexts form turbulent frontiers in which a decision maker is buffeted by waves of rapid and unceasing change with respect to such considerations as global markets, interorganizational connections (e.g., supply chains), mass customization, continuous learning, sociopolitical diversity, culture shifts, and advances in distributed and intelligent systems. Competitiveness with respect to such contextual waves requires dynamic capabilities on the part of decision makers, and DSS are an integral component of such capabilities. According to the nascent *science of competitiveness*, the decision maker is confronted not only with contextual waves, but also with contextual storms and quakes – terrorist acts, natural disasters, financial calamities. Competitiveness with respect to such contextual waves requires improvisational capabilities on the part of decision makers, and here is where real-time decision support truly shines and holds great promise for further progress.

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# Preface

This special volume of *Annals of Information Systems* explores the issues associated with the design and use of real-time DSS in ubiquitous, mobile and distributed computing environments with the focus on the importance of context for successfully addressing dynamic decision-making processes.

The idea of the book on real-time decision support was born as a result of international collaboration on the topic of context-aware computing as part of the Task Force of the Australian Research Council initiative called Research Network in Enterprise Information Infrastructure [EII].<sup>1</sup> This unique initiative supported a series of events and activities, which brought together academics and practitioners keen on promoting an integration of ubiquity and mobility of devices, applications and users in order to significantly improve business processes and to reduce operational costs. This initiative is also aiming at establishing a focal point for bringing together researchers and practitioners working in the area of context-awareness in pervasive computing in Australia and worldwide. This collaboration gave us an opportunity to reflect and consolidate many years of research results in the use of intelligent technologies for decision support. We were able to establish the boundaries of current approaches to applying advanced technology for supporting context-specific and personalised information needs of field workers. One of such boundaries was established in the area of real-time decision support. The invitation from the *Annals of Information Systems* for the issue in the topical area of decision support provided us with a fortunate opportunity to put together this book with the aim of crossing this boundary and extending this exciting cross-disciplinary research area.

Sponsored by the Association for Information Systems, Special Interest Group on Decision Support, Knowledge and Data Management Systems (AIS SIG DSS), we organised a workshop “Supporting real-time decision-making: The role of context in decision support on the move” as a part of the International Conference in Information Systems ancillary events (pre-ICIS DSS workshop) in December 2008 in Paris. The call for papers for the event invited authors to contribute related theories, tools and techniques, as well as to share some case studies from their

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<sup>1</sup><http://www.eii.edu.au/>

experience. We were interested in collecting cases in which the real-time decision support was successfully provided based on context-aware information systems, as well as those where time-critical support failed due to the shortcomings of technology or social components of the information systems. Some of the chapters in this book are based on the presentations from that workshop. The authors came to present and discuss their research ideas on the role of context in real-time DSS. The presenters debated advantages of and obstacles to real-time DSS and the role of context in it. The workshop included a key note and a panel discussion on the future research required to successfully advance the DSS field, capitalising on the opportunities of the ubiquitous technologies and addressing the challenges of making better decisions ‘on the move’.

The review of the recent literature on decision support and submissions to the workshop reconfirmed to us that there was no other source, which would systematically cover theory, technologies and techniques applicable to capture dynamic context for the needs of real-time decision support. Hence, the need for this book has become even more evident.

Based on the identified themes, an open call for book chapters was issued, which resulted in multiple submissions not only from the participants of the workshop, but from other active researchers in the field. Each chapter of the book underwent at least three rounds of peer and editorial review. Although not all submissions found their way into this book, we do appreciate the effort of all the authors.

The overarching research question this book aims to address is: How discovering, extracting, interpreting, predicting and managing context can assist in real-time decision support? The volume’s focus is on the challenges of context modelling and management as a component of knowledge management for decision making and support. We collected a number of case studies and example projects where such technologies were successfully applied. A number of authors describe potential innovations which could support real-time decision making processes. In particular, the book contains a few examples of the use of innovative approaches for dealing with context in crisis and emergency management situations.

The volume focuses on the role of context for time-critical decision support. It includes chapters describing theory and practice of real-time decision support, and decision support ‘on the move’ in particular. The topics covered in the book include theoretical and technical aspects and application case studies of:

- Context-based decision-making methods and tools
- Contextualising information for time-critical decision making
- Processes and procedures of extracting contextual information for decision support
- Identifying context in decision making/support process
- Managing the contextualization process of decision making/support
- Dynamic filtering of information for real-time decision making and support.

The chapters describe concrete and constructive research results on the topics as well as more broad theoretical frameworks about the role of context in



decision-making and support, a comprehensive review of the available approaches to mobile real-time decision support.

The book is organised around three themes, which can be broadly labelled as theories in, technologies for and application cases of real-time context-aware DSS. The final theme covers a wide range of sample applications among the many that have been successfully implemented to deal with the contextual needs of decision-makers in various applications. It is represented by ten chapters. First three chapters of the final theme explore the real-time decision support for groups in emergency and crisis management. They are followed by four chapters looking at the real-time decision support in medical and business contexts. The remaining three chapters explore the issues related to mobile decision support.

The first theme provides a solid foundation by exploring paradigms and methods associated with real-time DSS, and how they fit with other studies and theories of computerised decision-making support. The theme is represented by an introductory note from the editors and two full chapters, which establish the ontology of the field of real-time decision support and establish foundations and new outlooks for enabling such systems and supporting organisations in realising the full potential of opportunities provided by the *anywhere, anytime computing* paradigm.

Chapter 1 by Dan Power looks at the problem of successful implementation of real-time decision support systems (DSS) emphasising on three major categories of challenges: technical, organisational and social/psychological. The author justifies why these are the challenges that the managers should be aware of in order to successfully implement real-time DSS and what benefits such awareness brings.

In Chapter 2, Eric Stein explores the concept of improvisation as a framework for understanding real-time dynamic decision making and systems support for it. He introduces a framework that classifies improvisational contexts according to problem structure and foreseen consequences, identifies the elements necessary for effective individual and team improvisation, and lists the design requirements necessary to support improvisational behaviours and conversations.

The second theme consists of five chapters that explore various innovative approaches trailed by the authors and offered as potentially beneficial technical solutions when making time-critical decisions.

Chapter 3 by Arkady Zaslavsky and Andrey Boytsov addresses the problem of context prediction and subsequent proactive adaptation. The authors start by developing and justifying the principles to analyse and compare various context prediction methods, followed by analysing the development in the area and comparing different context prediction techniques to identify their benefits and shortcomings. They conclude their empirical research by identifying current challenges in the area and proposing the potential solutions to address these.

In Chapter 4, Patrick Brézillon proposes modelling of real-time decision making in order to support the self-training of actors to modify weaknesses of their behaviour during task realisation. The author introduces a contextual methodology composed of a series of ten steps that cross the four levels of human behaviour known as policy, strategy, tactic and operation. Such contextual methodology proposes a unified framework that brings together aspects that are generally

contrasted – procedure versus practice, task versus activity, logic of functioning versus logic of use – and explains the two types of contextualisation in a context-oriented model with three layers. The contextual methodology and the framework are applied in the road safety domain.

In Chapter 5, Seng Loke uses a declarative programming approach to the situation programs that encapsulate and modularise the way context is aggregated to infer various situations. The author treats the situation programs as first-class entities, describes the initial prototype LogicCAP-S based on the language LogicCAP, and discusses how it could be further applied in the mobile environment.

In Chapter 6, Florence Aligne and Juliette Mattioli explore crisis management as a typical situation in need for real-time decision support. The authors outline the importance of the contextualisation of information in the situation understanding process. They propose a crisis management cycle structured along three crucial steps: information gathering, situation understanding and decision making. For each step, the authors describe the processes involved and propose some relevant techniques to implement them.

In Chapter 7, Norita Ahmad and Reza Barkhi attempt to establish how various contextual and collaborative approaches influence human decision makers through interface manipulations. Focusing on the Second Life (SL) technology that creates a virtual world, the authors design an experiment where they explore the SL context, user behaviour and perceptions about SL. Experiment results provide empirical evidence of the use of SL and the future of this technology for human interaction in the real-time decision-making context.

For the last theme, we have selected a range of case studies covering a range of opportunities and challenges associated with providing time-critical decision support on the move. Some of the case studies look specifically into the role of context in their cases and reflect on some lessons learnt in dealing with context in a particular way. We start this section of the book with three chapters addressing case studies in emergency, disaster and crisis management, which were identified in the previous section as one of the obvious areas in need of real-time decision support.

Chapter 8 by Tung Bui and Ina Sebastian explores the crisis scene and proposes that under extraordinary conditions that information provided to the decision makers should help them in dealing with emotions and stress, reinforce motivation to help and nurture a sense of altruism. In their research, the authors step outside of the rational decision-making paradigm and provide a new perspective on what constitutes effective decision support to the volunteer helpers.

Chapter 9 by Murray Turoff, Connie White and Linda Plotnick looks at the Threat Rigidity Syndrome and information overload as the genesis of various design problems of the emergency decision support systems. The authors investigate how these problems can be overcome using the example of High Reliability Organisations (HRO) that utilise a set of practices to manage low-probability/high-consequence events.

In Chapter 10, the authors Linda Plotnick, Murray Turoff and Connie White explore how the use of electronic communications allows Partially Distributed Emergency Teams (PDET) accomplish various tasks remotely instead of face to

face. The authors discuss how such teams, being empowered by the new technologies, form virtual communities of practice, and identify strategies that can help build and nurture these virtual communities by looking at the ways to further utilised new technologies.

Chapter 11 by Fergal Carton, Frederic Adam and Patrick Brézillon opens a subsection concerned with real-time decision support in business context. The authors look at the problems of providing real-time decision support to managers in the context of a case study of a multinational manufacturing firm that relies on an ERP (enterprise resource planning) package for transaction processing. Aligning the ERP system with the reality of doing business proves to be a real challenge and a subject to constraints arising from both the business and virtual context of the firm. By analysing the emerging gaps between the inflexible ERP system and the decision support needs of managers, the authors offer a theoretical framework for the relationship between real-time transaction processing and decision support.

Chapter 12 by Robert Baksa and Murray Turoff contrast continuous auditing systems with the emergency management and response systems that integrate continuous auditing's detection and alerting functions with the tracking of decisions and decision options for situations that could be more effectively handled by human judgement. The authors propose using emergency management and response systems as a prototype to help overcome some of the implementation obstacles of the auditing systems. The authors suggest possible architectures for the continuous auditing systems, list some common implementation challenges, and provide a case study to illustrate a few successful implementations.

Chapter 13 by a team of researchers and practitioners from Canada consisting from Ziad Kobti, Anne W. Snowden, Robert D. Kent, Gokul Bhandari, Shamual F. Rahaman, Paul D. Preney, Carol A. Kolga, Barbara Tiessen and Lichun Zhu is concerned with the real-time decision support in medical context. The authors discuss challenges faced by semiautomated decision support systems in health care, mainly in generating evidence-based recommendations in a short critical time-frame. They report on a multidisciplinary project between computer and health sciences resulted in a cumulative framework that encapsulates innovative distributed data collection methodology, coupled with an intelligent multi-agent, socially driven decision support system.

In Chapter 14, Shane Grigsby, Frada Burstein and Nyree Parker discuss the role of decision context within time-critical decision support in medical triage. The authors believe that establishing a decision context in time-critical decision support could assist in provisioning time-critical information to improve decision outcomes. They look at the safety measures and risk mitigation in the clinical health care setting, and how decision support systems can refine contextual guidelines on the task being undertaken in such settings. They identify contextual elements of a task being undertaken as a means to establish rules that can influence provided decision support in the given settings and subsequently improve decision-making outcomes.

Three final chapters of the book look at the approaches specific to mobile decision support. Chapter 15 by Yves Vanrompay and Yolande Berbers looks at how the current and future context of the system affects the quality of support provided

by that system. The authors propose to run a DSS on top of a middleware that helps the decision maker to contextualise information. They provide a set of requirements the middleware should fulfil to learn, detect and predict patterns in context to optimise the information flow to the decision maker, and validate their findings in the medical health care domain.

Chapter 16 written by Supavich Pengnate, Ramesh Sharda, David Biroš, Michael Hass and Upton Shimp looks at the military domain where availability of needed ammunition information is critical for decision making, especially in a war zone. The authors use a case study where the extension of a web-based ammunition multimedia encyclopaedia (AME), developed for the US Army Defence Ammunition Center (DAC), used mobile handheld technology to provide Quality Assurance Specialist Ammunition Surveillance (QASAS) personnel access to needed ammunition information via a personal digital assistant (PDA).

The final Chapter 17 of the book by Pedro Antunes, Claudio Sapateiro, Gustavo Zurita and Nelson Baloian describes the development of a model and tool supporting collaborative construction of situation awareness. The model organises awareness information elements according to situation dimensions, dimensional elements and correlations between dimensional elements, while the developed tool supports collaborative information management using mobile devices and pen-based interaction. The reported case study illustrates implementation of the developed model and tool in the support to disaster recovery of business operations.

From the above description, the reader can gain a fair idea of the breadth and the depth of the material covered in the book. We believe that this book will have a wide range of appeal to the readers who recognise the importance of providing relevant knowledge on the move in timely manner. It is written by academics and practitioners for academics and practitioners. It does not require the reader to have specific background in information systems in general and decision support in particular. It targets to reach four audiences:

- Practitioners involved with the design of real-time DSS
- Users of various levels concerned with effective use and management of these systems
- Technologists searching for empirical evidence and feedback on opportunities and drawback associated with the use of real-time DSS
- Researchers and students interested in study and further research in the area of context-aware DSS

The goal of this book is not to bring a final point to the current state on DSS on the move, but rather emphasise the importance of this new field for extensive research in the near future.

# Acknowledgements

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Finally we thank you, the research community, for your interest in this emerging field of real-time decision support and we hope that this book will be a worthwhile addition to the DSS body of knowledge.

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**Patrick Brézillon** defended his Thèse d'Etat (6-year duration) in 1983. He now belongs to the Laboratoire d'Informatique de Paris 6 for 20 years. His research focuses on context modelling and management applied to human reasoning (and especially decision making). He proposes now a coherent conceptual framework based on the concepts of generic frame and of situation dressing, framework implemented in a context-based formalism – called contextual graphs – for representing in a uniform way elements of reasoning, of knowledge and of contexts. This formalism is used in applications belonging to more than 20 different domains. This work will

conclude soon on a contextual methodology for modelling actors accomplishing a task in a given situation, in a given domain and a given context. The next step is a focus on context-based intelligent assistant systems in which context plays a role of same importance as the decision-making process itself.

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# Introducing Context into Decision Support on the Move

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**Abstract** This chapter offers a short entre to the book by reviewing the major concepts related to real-time decisions support. It aims to introduce to the reader three basic themes that are covered in this book. These themes are then expanded in the respective book sections. In a nutshell, this chapter helps to justify the need for any-time-any-space decision support, explain the semantics and definition of what constitutes “context” and clarify why it is essential to capture the context to address personalised needs of decision makers on the move. We supply some seminal definitions and references for studies in this area. In conclusion, some future research directions and challenges are also suggested.

**Keywords** Real-time • decision support • context modelling • ubiquitous computing • pervasive systems

## Introduction

Decision support systems (DSS) are computerised interactive systems that are widely used to support decision-making activities (Beynon et al. 2002). The main purpose of decision support--> systems is to deliver the data/information which is most relevant to the current decision-making context. In dynamic environments, only real-time data can provide decision makers with such relevant knowledge (Delic et al. 2001). The ability to access real-time knowledge opens an exciting new opportunity to enhance the quality and timeliness of decision support due to the widespread use of the Internet, the wider accessibility of wireless sensor technology and mobile communications (Burstein et al. 2008).

The phenomenal growth of mobile technologies over the last decade, along with the ‘anytime, anywhere’ connectivity in conjunction with the low cost of mobile devices, presents an unprecedented opportunity for mobile DSS. Such growth enables real-time decision making on the move when access to desktop computers is not available. In dynamic, high-risk and uncertain mobile environments, it is

equally important to study and propose approaches for making time-critical (namely in real time) operational decisions in the best possible way.

Recent development of information and communication infrastructures and sensor technologies has resulted in an opportunity to create a class of systems which are capable of recognising the environmental changes and of acting accordingly by adjusting their functionality to best suit the context of their operation. Such systems are often referred to as *context-aware pervasive systems*-->, or in short, context-aware systems (Padovitz et al. 2008). These systems are aware of not only the computational environment, but also, notably, of the physical environment, of human users, places, locations and other factors, which in combination represent the context of their operation. More importantly, they can respond intelligently to such context information when responding to the user's requirements. Quite often it is expected that such systems are pervasive and ubiquitous from the user and environmental perspectives, which should make interactions with them "transparent" and "unobtrusive".

## Decision Support in Real Time: Can It Be Achieved?

Decisions and actions are deeply intertwined. A decision usually leads to an action and an action modifies the environment. The environmental changes trigger the need for making some new decisions, which have to take into consideration and fit a new, revised decision context. Such a view on the decision-making process is much more dynamic and is no longer suitable to be modelled in a linear manner within a/the traditional decision analysis paradigm. In reality, there is little chance to plan all possible decision alternatives and to explicitly assess them in real time when the decision-making environment is constantly changing and decision outcomes are time critical. Hence, the emphasis for the real-time decision support is shifting from complex modelling of the alternative decisions, to representation of the context in which these decisions are situated. The complexity, multiple goals and various time-critical imperatives associated with such decision support, increases the importance of identifying, modelling, learning and managing the right context for making efficient decisions.

In dynamic and uncertain environments where instances of context elements constantly change, context-awareness is crucial for enabling applications, including decision support systems, to tailor their behaviours according to the contextual/situational changes and to better meet user and application needs (Salber et al. 1999).

The advantages of real-time, context-sensitive decision support have been investigated in several projects such as mobile business applications (Nelson and Wright 2004; Burstein et al. 2008), healthcare emergency decision-support (Burstein et al. 2005; Fitzgerald et al. 2008), and dynamic data driven application systems (DDDAS) (Darema 2004; Gaynor et al. 2006). Effective emergency and crisis management often depend on access to real-time information and decision support tools have been created for safe and successful rescue and recovery operations (Turoff et

al. 2004; Wallace and De Balogh 1985). Context-awareness enables decision support systems to assist the users in an efficient and intelligent manner and enhance their experience by increasing productivity and satisfaction with the process and outcomes of the decision-making process (Henricksen et al. 2002).

## **Why Context and Context Awareness Is Important for Timely Decision Support?**

In our view, making context explicit is a way to model the environment and create an interface between the decision maker and the tools needed to assist in real-time decision making. Context provides a representation of the environment as a set of contextual elements (CEs). This contextual information presents the decision makers with the necessary knowledge to react and respond as soon as they obtain the context instances. Some contextual elements will have a known instance, and thus can be taken into account in the decision-making process. Some other CEs will be known, but their instantiations may not be pre-defined. In the latter case, known as context-awareness, the instance of CE will change or will be known only in real time. Based on the new instance of CE obtained in real time, the decision maker will be able to react and make new decisions in an informed way. Aiming to support such real-time decisions requires continuous reflections on the environmental changes and explicit knowledge of the current context.

Context is a powerful and multifaceted concept. Context information can be sensed, derived, reasoned, computed, calculated or explicitly entered by users. There is a flurry of definitions of context in current literature. A general definition by Dey (2001); one adopted by most researchers, describes context as “any information that can be used to characterise the situation of an entity” (p. 5). Brézillon and Pomerol (1999) suggest that context consists of two types of knowledge, including external and contextual knowledge. External knowledge is the part of the context that is not relevant to the decision-making process on hand, and contextual knowledge is the other part of the context that is relevant to the decision. A subclass of contextual knowledge is called proceduralised context that is invoked and structured with respect to the task at hand and the decision-makers involved in the decision-making process (Brézillon and Brézillon 2008). It is essential for the decision support system to identify and obtain the contextual information as the decision-making situation changes, rather than focusing on the external knowledge.

Context can have different aspects and characteristics as follows (Delir Haghighi et al. 2008):

- Dynamic and static context – context can be dynamic, like heart rate; or static, like user-name or e-mail.
- Continuous data streams – context can be continuous like sensor data streams.
- Uncertain and imperfect context – context information is liable to imperfection and can be erroneous, ambiguous or incomplete.

- Temporal context – context can be associated with temporal data, which enables representation of histories of context.
- Situational context – contextual information can be used to represent a situation such as a user activity.

Quality of Context (QoC) – the same context information about an entity can be of different quality. To indicate this feature of the context a special measure of QoC marks such precision that, according to Buchholz et al. (2003), can be defined as “any information that describes the quality of information that is used as context information” (p. 5).

There is an abundance of approaches in the literature proposed for modelling of, and reasoning about, the context. These approaches apply well-known concepts and principles such as Bayesian reasoning methods (Fox et al. 2003), Dempster-Shafer theory (Wu et al. 2003), fuzzy logic (Delir Haghighi et al. 2008; Mäntyjärvi and Seppanen 2002), graphical modelling (Henricksen et al. 2002), and basic ontology-based modelling approaches (Chen et al. 2003; Ranganathan and Campbell 2003; Truong et al. 2005). Ontologies provide a formal representation of concepts and their relationships within a certain domain that can be used for knowledge sharing and reasoning about context. To improve context-management capabilities, different modelling approaches can also be used for predicting future context of mobile applications. A number of different techniques such as classification, neural networks, Bayesian networks and statistics-based techniques can be useful in predicting the future context.

One of the main application domains that can benefit from context-awareness is crisis and emergency management. The crisis and emergency management process heavily relies on the availability and quality of the crisis context, and requires in-time contextualisation to enhance the overall process of crisis management. The complex nature of emergency events, coupled with time-constraints, emphasises the importance of using real-time decision support systems. Due to the dynamic nature of disasters like fires or floods, ground commanders and central command officers need to gather and analyse data/information on a wide range of emergency management activities, and make instant and split-second judgments. The need for up-to-date information and data are critical in emergency management DSS, to determine the priorities for operation and resource allocation and management. Examples of such systems include the NSW Fire Brigades I-Zone planning system (Byrne 2009) and Gold Coast DSS for flood emergency management (Mirfenderesk 2009). Emergency responders depend on the availability of up-to-date information to guide them in making timely and effective decisions (Gaynor et al. 2006). In the emergency management environments, real-time decision support systems assist emergency managers in formulating, analysing and interpreting disaster-related issues. Management of safe and successful rescue and recovery operations requires access to real-time situational information and effective decision support tools (Kaloudis et al. 2005).

## Where to From Here?

It is known that the inclusion of real-time knowledge enables DSS to actively adapt themselves according to current available information and environmental conditions (Holsapple et al. 1993; Shim et al. 2002). There are a number of adaptive decision support systems introduced in the literature that aim to improve the decision quality and user experience. These include, for example, ADAPTOR (Paranagama et al. 1998), the adaptive DSS for real-time scheduling of a flexible manufacturing system (Piramuthu et al. 1993), the adaptive DSS for science and finance management (Fazlollahi et al. 1997), and the adaptive model based on multi-agent system for flood forecast (Georgé et al. 2009).

In dynamic and changing environments such as air traffic controlling, large amounts of information need to be processed in a very limited time, and consequently, decision makers need to solve new problems and adapt to new situations whilst preserving the evolving progress of decision-making tasks in their minds (Gonzalez 2004). Dynamic decision making (DDM) systems enable real-time, continuous and interrelated decisions in highly dynamic and complex environments (Edwards 1962; Gonzalez 2004, 2005).

In the context of business decision making, real-time decision support provides timely support to the decision makers. As an emerging trend, real-time data warehousing offers industry and IT managers the following values: (1) immediate information delivery by shortening the time-span between business events and information process and delivery; (2) data integration across the enterprise; (3) future vision from historical trends; (4) tools for looking at data in new ways to enable creative problem solving and posing new questions; (5) end-user empowerment with regards to writing queries and building reports; (6) consistency, timeliness and credibility of information delivered (Nelson and Wright 2004).

From the brief review provided in this chapter, it is clear that there are tremendous opportunities and challenges associated with the implementation of such context-aware systems. However, there are also clear benefits that can evolve from such implementation – ranging from, for example, context-aware mobile phones that know what to do with incoming calls; context-aware printing, which would be mindful of the resources constraints; context-aware enterprises that respond with agility to an understanding of physical circumstances; to context-aware toys that interact with children and have an understanding of their special needs and expectations; and context-aware bookshops that interact with personalised computer assistants to mine some profiles of users interests; from context-aware parking areas that tell drivers where to go, to context-aware road intersections that warn drivers of dangerous situations. We can envisage a proliferation of such systems in different walks of life once the theoretical and technical challenges are appropriately addressed.

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