CO-254

TOWARDS CONTEXT-AWARENESS MOBILE GEOSPATIAL BI (GEOBI) APPLICATIONS

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1.INTRODUCTION

Since the 1990's, Business Intelligence (BI) which is the activity of intelligently gathering, integrating, storing, processing and analyzing business data in order to find out pertinent and meaningful information to improve business decision making, has been massively adopted by decision makers. Meanwhile, Geo-spatial BI (GeoBI) systems, by providing spatio-temporal data support, cartographic visualization and spatial analysis capabilities, has specifically improved the capacity to analyze the state of business on the field and make well informed decisions ([1]). However, as BI and GeoBI systems rely on fix, cumbersome and client/server technologies, they are not suitable for mobile workers whose number is increasingly growing.

To give an improved support to these mobile workers, it is necessary to go further than just allowing a simple remote access to a business intelligence platform (as do most of the present commercial solutions). An actual context-aware and location based mobile GeoBI system that fully takes into account the specificities of mobility (opened and dynamic workspace, working while moving, mobile technologies are specific, etc.) is required. In this prospect, understanding and handling the contextual information in the scope of mobile business intelligence is important given that context-awareness relies on it.

The proposed paper deals with mobility and mobile context in the scope of decision making. First, mobility is scrutinized through two points of view which pertain to the decision making domain, namely: the information technology side (mobility as remoteness) and the user experience side (mobility as dynamic change of context). Then, key elements that could structure a mobile business context (such as personal context, social, spatial, temporal, business and technological contexts) will be explored and several models will be proposed in order to improve context and situation awareness in decision making.

2.UNDERSTANDING MOBILITY

Depending on the thematic, the concept of mobility has been described or understood differently by various authors. Among the various acceptations of this concept, the following have been proposed:

>> Mobility according to the activity

Authors distinguished professional mobility ([2,3]) – mobility of workers –, from social mobility – daily mobility of people – ([4,5]). According to [6a], professional mobility can be partly explained (i) by the emergence of service-based jobs in a post-industrial society, (ii) by the strengthening of intra and inter-organizational cooperation, and (iii) by the popularization of mobile devices.

>> Mobility according to the distance

Depending on the perimeter, [3] distinguished micro, local and remote mobility. Relying on this work, [6] proposed a classification of mobility into three instances: (i) traveling, i.e. moving from one place (e.g. a city) to another one using transportation (car, train, plane, etc..); (ii) visiting, i.e. spending some time in a place before moving to another one, such as a mobile worker who spends a week working in a city, and (iii) wandering, a local mobility which consists of patrolling, touring or walking within a building or a small space.

Considering the mobility as a travel, [5] has identified 4 classes of mobility: physical mobility of inanimate objects, imaginative mobility, virtual mobility in a digital world, and physical mobility of humans.

>> Mobility as interactions

Given that social relations and the need to physically interact with other persons are involved in the justification of mobility, mobility is not then only a geographical and temporal displacement, but also concerns how the person who moves interacts with his environment and other persons ([7]). In this context, [8] provided a classification of mobility into three dimensions: spatial mobility ("where?"), temporal mobility ("when?") and circumstantial mobility ("in which way?", "under what circumstances?", "in interaction with which actors?").

Alongside these various taxonomies, mobility has to be also scrutinized under two additional viewpoints which pertain in decision making domain, namely: the information technology (IT) side (mobility as remoteness) and the user experience side (mobility as dynamic change of context). These two perceptions of mobility are presented in the following sections.

2.1 Mobility as remoteness and remote access to a resource (IT side)

Mobile phone can be seen as a solution to landline phone that does not allow access to a person when this one leaves the fixed location where the landline phone is installed. From this point of view, mobile phones allow a remote access to mobile persons.

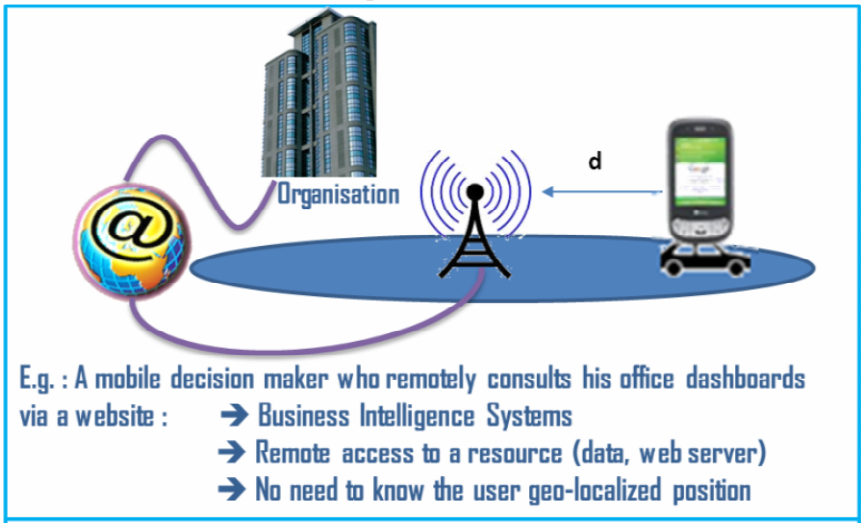

Figure 1 : Mobility as distancing, remoteness vis-a-vis a fixed point

As such, and legitimately, mobile devices have long been used to remotely access to persons or data. Even today, they continue to be used for such a purpose.

In the mobile decision support field, early solutions ([9, 10]) as well as recent solutions ([11, 12, 13, 14]) were primarily designed in this perspective: enabling decision makers to access their data remotely as if they were in their office.

As figure1 shows, distance is put forward in this perception of mobility, and what matters is to stay connected to the business data of the organization (such as dashboards) , no matters where the user is or his surrounding environment.

This vision probably palliates to the information access need once on the field ([14]), but ignores the fact that the mobile worker evolves in a dynamic environment which is often very different from the closed environment of an office. Therefore, mobility should also be considered as a dynamic change of environment.

2.2 Mobility as movement and dynamic change of environment (user side)

Instead of hiding mobility so that mobile workers feel they are still in their office, [15] stated that «we should explore and provide infrastructure to support new mobile-aware applications».

Figure 2: Mobility as change of contexts, dynamic change of position and environment

To achieve this goal, mobility should be considered in its primary nature, namely: a physical movement in space and time, a change of locations and surrounding.

And when on the move, not only the worker position changes. His workspace changes too, so that mobility can also be perceived as a dynamic change of environment (Figure 2). In this perception of mobility, the mobile worker is primarily an active entity that moves, changes his position, his work environment, before being an entity that works remotely.

Taking into consideration the position and the working environment can give to the mobile user a better perception of his work context ([16,3]) and could subsequently contribute to improve decision making in mobility. For example, a manager who is analyzing road incidents data and is performing an analysis on the field may be interested in having an answer to a query like: "What is the status of road accidents over the past two months, within 5 km of my current surrounding? The answer to such question involves not only the use of multidimensional geo-spatial business data, but also (at least) the exploitation of the decision maker geo-located position by a decision support application which access to sensors and services.

3.UNDERSTANDING MOBILE CONTEXT

Many definitions of context have been proposed. For instance, [17] recalled that the term “context” can be etymologically broken down into “con” which means “with”, and “text” that refers to the text, the speech or more globally the task that is performed. The notion of context then, goes beyond the task carried out and involves everything which accompanies it and which may easily help understand it (e.g.: non-verbal actions, environment, etc.).

In the same way, but being more technology-oriented, [18 and 15] defined context as any information that can characterize the state of an entity (person, object, event, etc.) located in the operating environment of an application and that can interact with it or change its behavior. This technology-oriented definition implicitly refers to the context awareness of applications.

Context awareness generally refers to the ability of an application or a device to adapt itself to its environment, automatically - active awareness -, or at the user request - passive awareness - ([19]) or based on the user’s preferences ([20]): personalization and adaptability, i.e. the possibility for users to configure how the application should behave according to the context. Simply put, the purpose of context awareness is to make applications more intuitive and intelligent in order to improve their usability in different contexts. Thereby, context awareness can help the decision maker via intelligent applications, to be well informed of his environment, to be aware of his contextual situation and then take more informed decisions.

3.1 Context awareness versus situation awareness

While context awareness is the ability of applications to sense some contextual information (e.g. the user position, the surrounding temperature, etc.), situation awareness is the cognitive process by which the

decision maker learns, understands and builds a representation of his current decision situation (context + problem to solve).

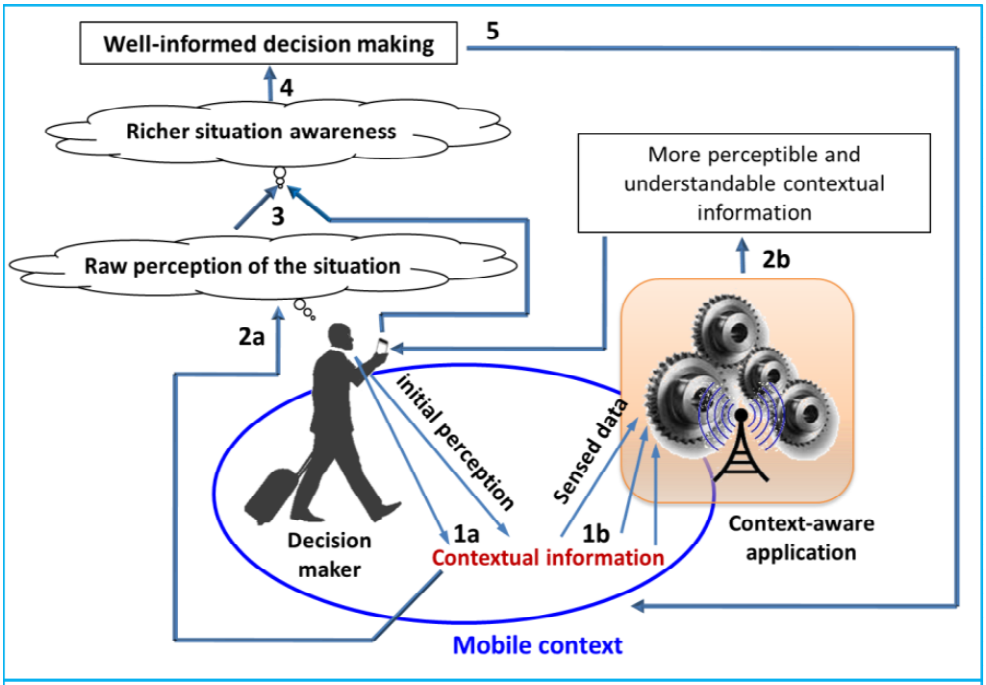

Figure 3 : Simplified model of relationships between the applications' Context Awareness and the decision makers' Situation Awareness

Indeed, several authors ([21, 22, 23, and 24]) recalled that the concept of situation awareness comes from the military aviation where it means the pilot's knowledge about the aircraft and his flying environment. Situation awareness can evolve through three levels ([22]): (i) The perception of the status of relevant information in the environment; (ii) the comprehension of perceived information and (iii) the capacity of the decision maker to anticipate or predict the future of his environment based on his comprehension of the current one. In short, "situation awareness is about knowing what is going on around the decision maker" and "richer Situation Awareness is more likely to lead to good decisions and then to good performance." ([25]. See also [26]).

Accordingly, context-aware applications could lead to better decisions and better performance if they are able to improve the raw situation awareness of the decision maker through contextual information which are easily perceptible and understandable, especially in a mobile context where the workspace changes more often. To illustrate this relationship between applications' context awareness and the decision maker's situation awareness and the improvement that can stems from it, we propose a simplified model illustrated by figure 3.

This model shows that when data sensed from the contextual information are intelligibly processed and presented on a mobile device, they can help the decision maker to be more aware of his contextual situation and bring him to well-informed decisions.

However, an important question remains: "Which data should be sensed in a mobile business context to assist decision makers?" The following sections explore the main features which could compose a mobile context dedicated to mobile GeoBI applications.

3.2 Exploring a mobile business context's key elements

When designing context-aware applications for mobile business intelligence support, IT engineers would certainly like to be helped in determining the main axes they should consider to handle mobile context elements.

As already explained, mobility involves not only a change in the decision maker position but also a change in his environment. Therefore, when on the go, the decision maker can see, hear, smell or feel different things that could affect his state of mind, his situation awareness. Thus, the following stakeholders and components can be distinguished in the mobility context: the decision maker, his surrounding environment and some natural or artificial (e.g. via the mobile device) communications between the decision maker and his environment.

Based on this empirical observation and analysis, at least three key elements should be considered as being part of a mobile context:

- (i) The user's personal bubble or personal context, in which the decision maker acts, thinks, and tries to decode the information he perceives.
- (ii) The surrounding environment or environmental context in which external things change while the decision maker is in motion.
- (iii) A set of natural (eyes, ears, nose, gestures, touch, etc.) or artificial (GUI, mouse, keyboard, sensors, etc.) interfaces which allow an exchange of information between the decision maker and his surrounding.

Personal and environmental contexts have been already addressed by authors (see [27, 28, 29]) but not in details. Figure 4 provides a more comprehensive and detailed description of these concepts, organized as a large inventory of contextual information derived from several researchers' works (see [12,11,29,30,19,4, 31,17,9,32,28, 33,34,35,36, 37,38,39,54]).

Figure4 shows that taking mobile decisions may involve some key elements which describe in one hand, the user situation (goal, actions, cognition, identity); and in the other hand, several contextual information categories which describe the environmental context (temporal context, spatial context, social context, technological context, business context). The arrows, in the personal and environmental contexts respectively, indicate the main direction to consider (respectively the user needs and the business reality). The double lined arrows **(1)** and **(2)** illustrate the communications flow between the personal context (the user) and the environmental context through natural or artificial interfaces which can be multimodal or not.

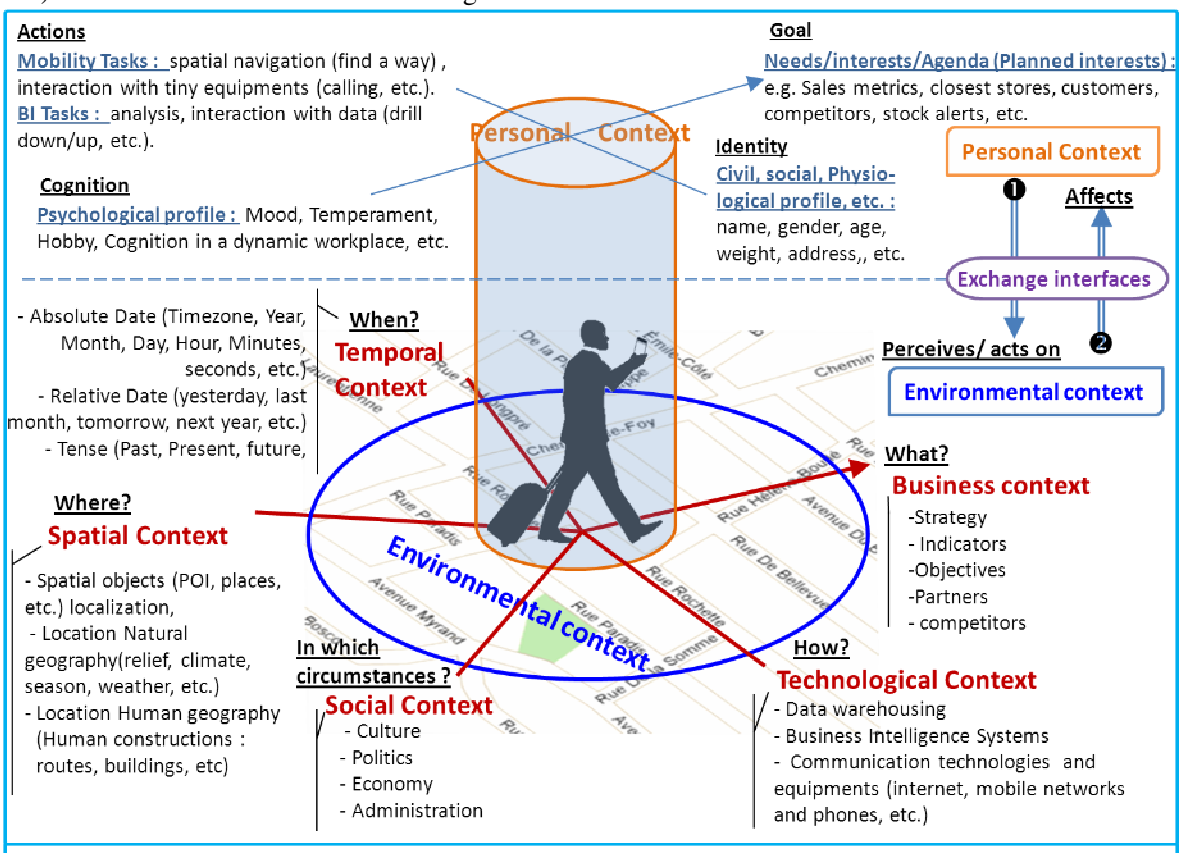

Figure 4 : Large exploration of contextual information for mobile GeoBI support

For reasons of limited number of characters allowed for this paper, only the personal and environmental contexts will be described in the sections below. A graphical and axes-based description has been chosen as a way to provide a quick overview and a dimensional representation of these contexts. Each axis in the horizontal plan represents a dimension that could be considered (if pertinent) in the application domain when designing contextual information for context-aware applications. The most important dimension is the arrowed axis. The vertical arrow which originates in the middle of the context (represented by the ellipse) is there to highlight the main information resulting from the horizontal dimensions if put together. This arrow can be seen as the outcome of the contextual dimensions.

3.2.1 The user's personal context

The user's personal context may include (i) the user's goal (needs, interests, etc.); (ii) the

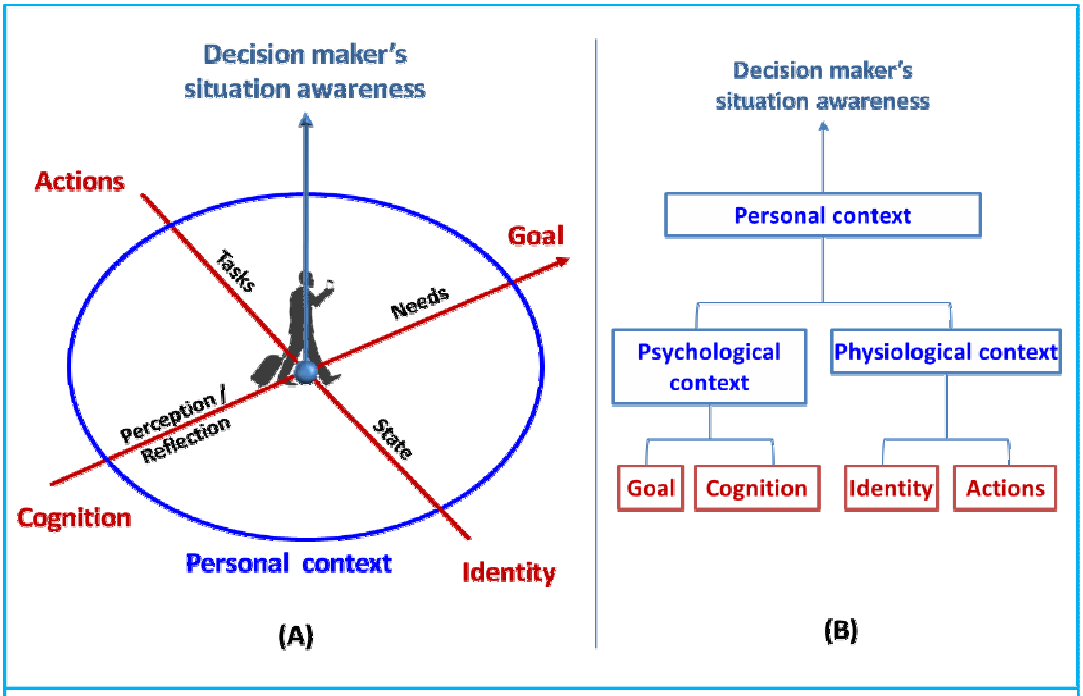

Figure 5 : Characterization of a user personal context's key elements : A typical model

user's cognition (his psychological profile, attention, feelings, preferences, etc.); (iii) his identity (civil, physiological, social, professional profile, etc.) and (iv) the user's actions which can be divided into two groups: (1) mobility tasks such as spatial navigation tasks or interactions tasks with mobile devices (e.g. calling, messaging, etc.) and (2) the business intelligence tasks the user performs to take a good decision. These four main elements that structure the user personal context are intended to bring answers to questions related to the mobile worker, namely: (i) "who are you?"; (ii) "what do you want/need?"; (iii) "what are you doing/what do you have to do?"; and (iv) "how do you proceed to think of, solve a problem/How are you sensible to things?". Figure 5-A provides a simplified model which illustrates the answers to these questions as dimensions tied to the user's situation awareness (vertical axis).

Figure 5-B shows a hierarchical model which underlines the key concepts of this context. It is partly based on the work of [29] in which the user personal context was limited to mental and physiological contexts.

3.2.2 The environmental context

Similarly to the personal context, the environmental context has been designed based on the answers to the main questions related to contextual issues which usually are: when? Where? And in which circumstances are things? The primary mobile contexts have then been retained i.e. the temporal context (when?), the spatial context (where?) and the social

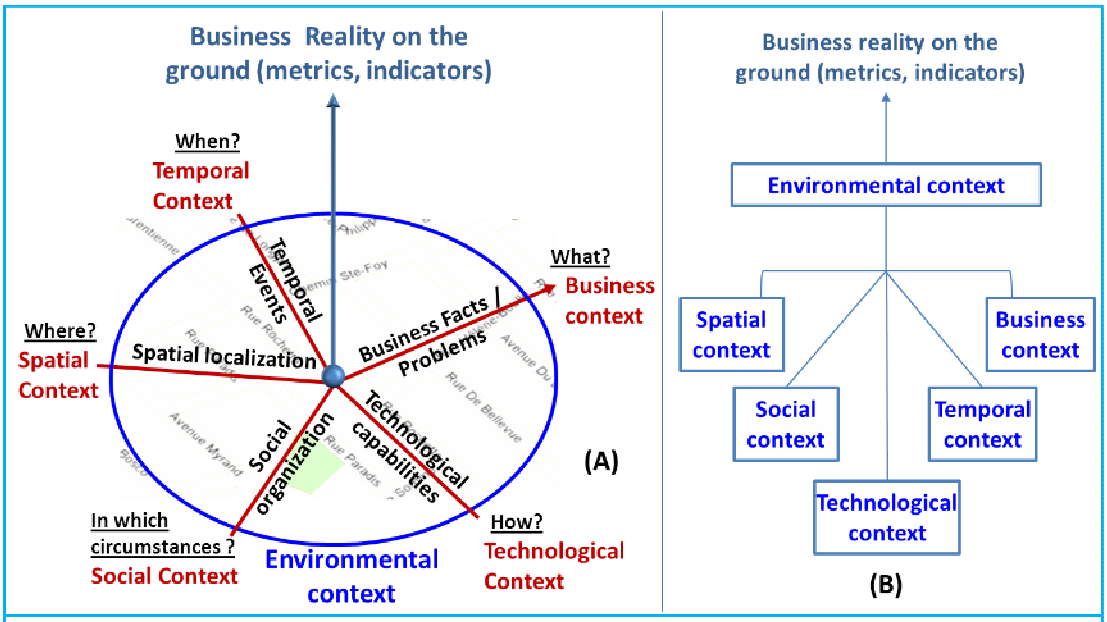

Figure 6 : Characterization of environmental context's key elements : A typical model

context has been extended to include political, economic and financial issues in order to provide a comprehensive response to the last question "in which circumstances?"

As far as business intelligence is concerned, new contexts need to be introduced to take into account business and technological aspects providing answers to the following questions: "what is concerned?" (business, of course); and "how to achieve that?" (by exploiting technological capabilities). When reviewing the literature on mobile context, it can be noticed that there is a kind of agreement among authors that a mobile context should include at least: (i) a spatial dimension (spatial context), (ii) a time dimension (temporal context), and (iii) a social dimension (social context). But rarely technology and business have been considered as parts of mobile context.

Figure6-A draws the general contour of environmental context while Figure6-B shows the hierarchical structuration of the top level concepts.

3.3 A mobile business context model for decision making

Both Figure5-B and Figure6-B showed partly a hierarchical structuration of contextual information and their ties to decision making aspects (decision maker's situation awareness and business indicators on the field). The model presented by Figure7 provides an overall and comprehensive view of this hierarchical composition/decomposition of contextual information and their ability to support decision making. It is intended to give a quick and helpful focus to designers on the following aspects:

(i) Like mobility (see section 2), mobile contexts as well as contextual sensitivity and decision making have to be handled considering two sides: the user side (personal context) and the user's surrounding side (environmental context) when modeling and structuring contexts; the user side and the application side when designing and dealing with context-aware applications.

(ii) Structuring contextual information into personal and environmental contexts helps distinguishing and designing separately what is common to users (the environment) from what is specific to each user. This way, various personal contexts or different occurrences of a personal context can be aggregated to the same environmental context, ensuring then reusability of contexts.

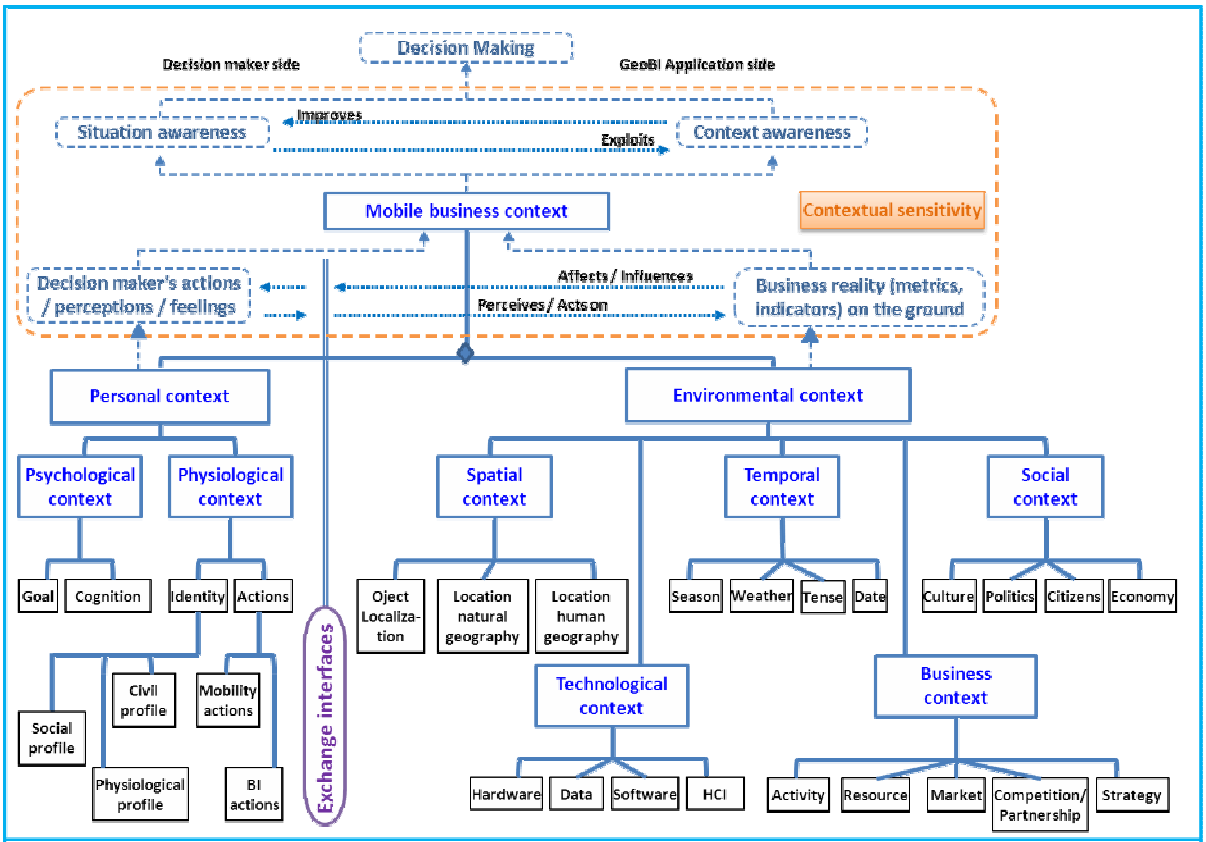

Figure 7 : Mobile Business context model for decision making

(iii) Contextual sensitivity is not only one-sided (context-awareness for applications) but two-sided because the mobile user is also aware (situation awareness) of contextual information. Figure7 points out that from a mobile business context, two kind of awareness are involved: the user awareness and the application awareness. Thus, context-awareness has a real purpose namely it is intended to be exploited to improve the mobile user's situation awareness.

To retrieve only useful and helpful contextual information from the mobile business context, it has to be mapped to the context in which business is ruled.

3.4 Mapping mobile context to business context

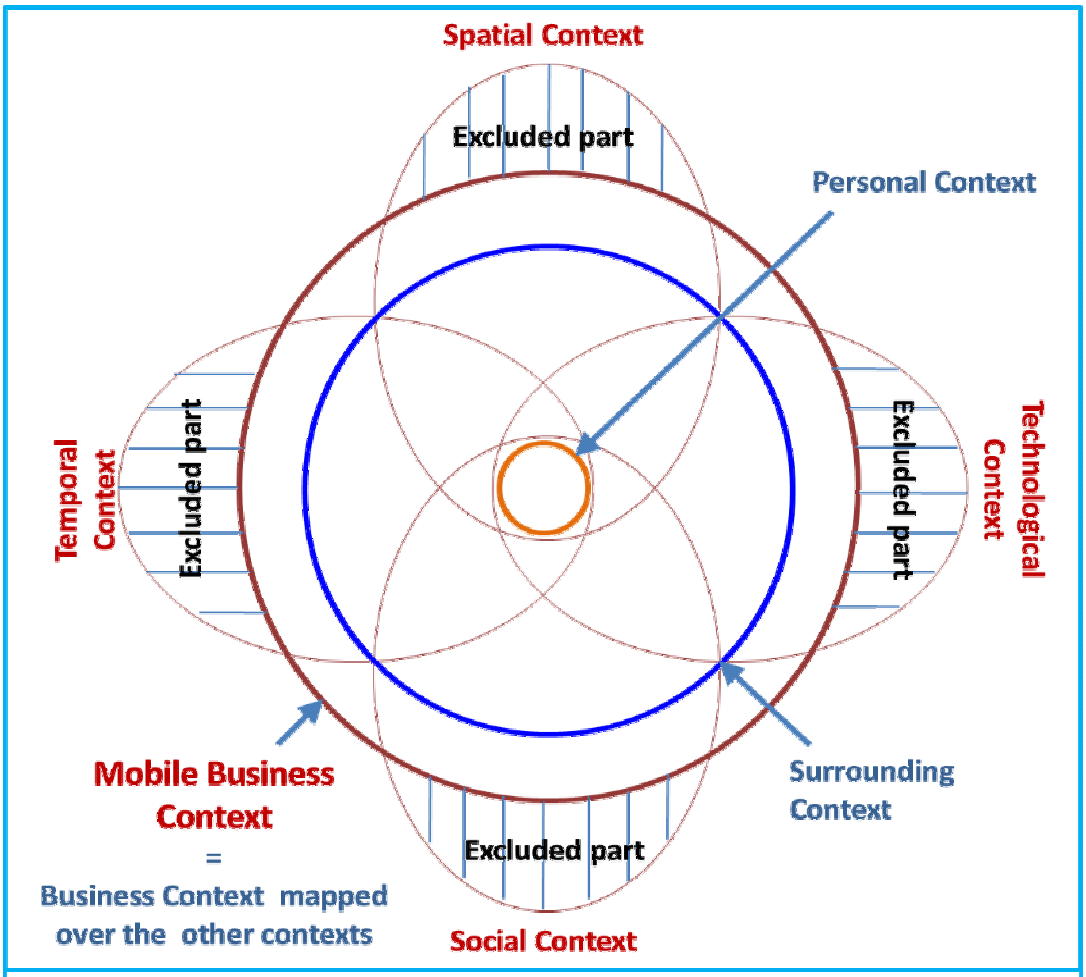

Fig. 8 : Mapping (limiting) mobile context to business context : Typical model

Spatial, temporal, social, technological and business contexts as elements of a mobile context are not unconnected entities. They can refer to each other, exchange information. For example, a given mobile salesman (personal context) necessary sells his products (business context) somewhere (spatial context) at some time (temporal context), to some people (social context), and can use a mobile phone (technological context) to analyze his business and determine his potential customers within his surrounding environment (environmental context). Furthermore, the connection between these entities may not involve all the context components. For instance, an organization operating only in North America will not have to deal with spatial areas or social considerations others than those prevalent in this geographic region. Therefore, from a boundary standpoint, the business context includes the personal and surrounding contexts while delimiting sub-areas of the temporal, spatial, technological and social contexts, as illustrated in Figure 8.

4. CONCLUSION AND FURTHER WORKS

This paper dealt with mobility and mobile context in the scope of geospatial business intelligence (GeoBI). The notion of mobility has been explored and two taxonomies have been proposed to characterize mobility in the BI context: mobility as remoteness and remote access to resources (IT side), and mobility as dynamic change of context (user side). Elements that could structure the mobile context information have been explored (personal context, environmental context, spatial, temporal, social, technological and business contexts) and several models have been proposed to deal with contextual information awareness (GeoBI applications side) and situation awareness (decision maker side).

Further works will be dedicated to propose an UML diagram classes for mobile business context which should organize personal, spatial, temporal, social, technological and business contexts into packages. Next works will also deal with handling and integrating context-awareness (i) in the server side (sending adapted contextual data from data warehouses to the user through web services) and (ii) in the user side (rendering and representing sensed contextual information to the user through mobile devices) so that it can improve the user's situation awareness.

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