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Assistive System for Smart Tourism in Smart Environment: An ICT Approach for Over-tourism and Tourism Crisis Management

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Tourism is a significant global phenomenon of our contemporary society. Its ongoing evolution in terms of quality, diversity of offer, efficiency, and other key aspects is a natural and inevitable process. Information and communication technologies (ICTs) are playing a pivotal role in this evolution, primarily through digitalization. This digitalization concern primary data management for transportation, stays, entertainment events reservation, constitutes an open-ended list of situations. It is possible to increase this approach by digitalization of information situated in the environment. This approach is known as coupling Smart City/Tourism and Smart Environment. An Assistive System is in charge to provide appropriate management support to this approach. The objective of this paper is to justify this Assistive System approach, to describe its architecture and adaptation process in order to take into account each particular context. A modelling language expressing elements of concerned situation is also presented as well as open-endedness needed. We discuss also the use of this approach in the context of sustainable tourism and its contribution to avoiding over-tourism. A case study related to crisis management in mountain skiing environment concretizes our contribution.

Keywords: *Smart tourism, smart environment, assistive system, over-tourism, crisis*

Introduction

Tourism is an important activity which that requires a range of support to evolve appropriately and accommodate an increasing number of actors. While digitalization is already present in data management, its potential for use in field problem management is a relatively new area that requires further investigation.

We view it as Smart Tourism in Smart Environment. To ensure the effective management of this orientation, an Assistive System is required. This system should support all aspects of management, and must be interactive, integrated, distributed, mobile and collaborative.

Tourism represents a significant activity in contemporary society, with an estimated impact on over one billion and 250 million individuals across the globe in 2023 (McKinsey & Company 2023). It is also important to consider another perspective: 95% of tourists expressed a desire to visit only 5% of the places offered (Gidebo 2021). The recent developments concerning tourism are of great importance, as they

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involve the provision of solutions to an ever-increasing number of consumers and the consideration of constraints that are becoming increasingly prevalent. Two key concerns currently occupy the minds of those engaged in the field of tourism: the evolution of sustainable tourism and the avoidance of over-tourism in areas that are highly sought after (European Commission 2022). A third aspect that should not be overlooked is the management of crises, particularly those of a climatic nature, which are inherent to this area and which must be considered, prevented, and managed in situations that arise (Rasethuntsa 2023).

It has been demonstrated that Information and Communication Technologies (ICT) can make a significant contribution to the resolution of issues pertaining to the aforementioned aspects (Rosario & Dias 2022). Indeed, the concepts of smart tourism or e-tourism express a similar approach to the steps aimed at introducing digitalization into the context (Jones 2023b). The objective of digitalization is to provide services utilizing information and communication technologies (ICT), with a particular focus on the Internet, to facilitate the reservation of various services, including accommodations, transportation, dining, entertainment, and other activities. These services can be booked, paid for, and modified through digital channels. This dimension primarily concerns data management (DATA), which has reached a relatively advanced and satisfactory level, at least with regard to the data in the main flows. It is clear that further enhancements are possible, which will be demonstrated subsequently.

The phenomenon known as "smartification" is undergoing a second, more recent and evolving dimension. The objective is to transcend the data dimension and concentrate on the locations where actions are carried out. This entails considering the environmental context in which the various activities occur. This concept received the label "smart environment" or "e-environment." In this context, the digitalization of the environment is of concern, not only in terms of the data that are manipulated, but also in relation to the insertion of sensors and actuators that enable the monitoring of the environment and the implementation of actions within it. The integration of objects into the natural environment can be static, fixed in place, or dynamic, following the movements of the supporting entity. The supporting entities may be a physical object, such as a car, bicycle, boat, windsurfer, or other vehicle; an animal; or even a human. In all cases, the interactions between these objects and the central system, which may or may not be centralized, occur via a computer system known as the Internet of Things (IoT) (Mouha R 2021). It provides communication mechanisms between these disparate objects and the Assistance/Support System, which is responsible for the implementation of these novel operating principles for the benefit of users.

In the context of tourism, this approach can contribute appropriately to three key aspects of tourism management: sustainable tourism, over-tourism and the associated crisis prevention and management. The objective of this article is to describe main principles of the Assistive System in a generic approach, its architecture, design and implementation, and its adaptation to particular situations/contexts. A case study related to crisis management in mountain skiing environment concretizes our contribution. Our objective is not to answer the question of possible contributions of our approach to sustainable tourism and over-tourism. As ICT specialists we offer a range of generic possibilities, allowing tourism specialists to assess the suitability of our approach for their specific needs.

The remainder of this article is organized as follows: Section 2 presents a review of the current state of the art of reached aspects. Section 3 presents the architecture of the proposed assistance system. Section 4 outlines Assistive System adaptation methodology. Section 5 provides an overview of the cases studied and presents the use case Mountain Station Winter Smartification. Section 6 is dedicated to a discussion. Section 7 provides a conclusion to this article and presents future orientations.

State-of-the-art

Tourism is a multifaceted activity that can be defined as a desire of citizens to engage in leisure activities during periods of inactivity, such as short breaks, vacations, and retirement. Tourism can be defined as a state of being in which an individual is completely stationary (i.e., in one place), partially relocated (to a chosen destination that is relatively close or distant), or completely mobile in the form of excursions (Medlik 2023). The stays can be either individual (i.e., undertaken by one person or a family) or collective, depending on the size of the group. Travel may be undertaken by automobile, bus, train, or airplane or even by bicycle, by horse and on foot. The locations in question may be family residences, hotels, or holiday resorts, campervans and even cruise ships. The organization of these stays can be conducted individually or through organizations whose role is to suggest, assist, or manage these solutions. In the past, the primary actors in this field were travel agencies. As the diversity of solutions becomes increasingly apparent, other actors are also emerging, including transporters, rental companies, accommodation providers, and so forth. These actors are either working for travel agencies or directly for final users (clients). In this context, three concerns have emerged as increasingly pertinent and potential targets of our studies: the promotion of sustainable tourism, the avoidance of over-tourism and management of tourism crises (World Economic Forum 2017a). The digitalization of tourist activities, which encompasses the use of information and communication technologies (ICT), represents a potential and even significant response to these issues. We will first explain these different aspects and examine the different orientations already used before formulating our hypotheses, methodology, and contributions. Given the readers of this Journal's comprehensive understanding of all aspects of tourism, we will provide only a brief overview of the definitions and potential references.

Characteristic of Sustainable Tourism

Sustainable tourism, also known as responsible tourism, is an approach that aims to minimize the environmental, social, and cultural impact of tourism while promoting economic benefits for local communities and the preservation of natural resources and cultural heritage in the long term (Xu et al. 2023). The following characteristics are indicative of sustainable tourism: respect for the environment and the conservation of natural resources. The objective of sustainable tourism is to reduce the consumption of resources, such as water, energy, and construction materials, through the implementation of eco-efficient practices (Morelli 2011). The respect for local cultures is evidenced by the encouragement of the preservation of traditions, customs, history, and cultural heritage. Furthermore, it is important to consider the protection of human rights, equitable economic benefits, and sustainable job creation, as well as the well-being of host communities (Chivandi et al. 2023) (World Travel and Tourism Council 2022).

Definition of Over-tourism

The term "over-tourism" is defined as an excessive influx of visitors, which places pressure on local resources, such as water, energy, and food resources, as well as local infrastructure, such as roads, public transport, and sanitary facilities. This can have negative consequences on the environment, local culture, infrastructure, and the quality of life of residents. Furthermore, it can lead to environmental deterioration of the natural environment, including air, water, and land pollution, loss of biodiversity, destruction of natural habitats, and overconsumption of resources (Gidebo 2021). In reality, over-tourism is a complex and multifaceted phenomenon that can have significant negative impacts on tourism destinations. We will present our contribution to this issue.

Crisis Management in the Tourism Context

We address, as third aspect, the issue of crisis management in the context of tourism (Wut et al. 2021) (Faulkner 2003). What is the nature of environmental crisis management? Environmental crisis encompasses unforeseen events or disasters that threaten the environment, populations, and human activities. Such crises may be caused by natural phenomena, such as storms, floods, earthquakes, volcanic eruptions, forest fires, or by human behaviors, technological incidents, industrial accidents, severe pollution, or pandemics.

The following are the principal aspects and steps of environmental crisis management (Pizam & Mansfeld 2006):

- Planning and preparation, which includes the following aspects: identification of potential risks, development of emergency plans, training and exercises.
- Alert and communication, which encompasses early warning systems, emergency communication, resource mobilization, rescue operations for people in danger, protection of critical infrastructure, and so forth.
- Crisis management, which involves operations coordination and continuous communication.
- Recovery and reconstruction, which includes damage assessment, reconstruction and restoration.

We will present our contributions to this problem.

Digitalization

Digitalization and virtualization are two of the most active and important approaches in a wide range of activities, including marketing, sales, enterprise management, and logistics (Chanias & Hess 2016). The objective is to replace physical documents and face-to-face contacts with digitalized documents shared worldwide and remote virtual access to their exchange and manipulation. The human face-to-face interaction is replaced by independent manipulation of these documents (data support). Furthermore, the tourism industry is also significantly affected by this evolution, not only in the stages of trip preparation, but also and primarily in mobile situations during trips.

Digitalization is the transformation of current working principles in the physical world to a new world that is more or less digital and virtual (El Saddik 2018). This evolution commenced at least 15 years ago and has been ongoing, rather than occurring in a linear fashion. This phenomenon can be observed in various fields, including marketing, customer relationship management (CRM), production, public services, logistics, and so on (Abdel-Aziz et al. 2016). While information-based services can be entirely digitized, physical object-based activities, production, and manipulation integrate physical and virtual activities with the Internet of Things (IoT) approach (Mouha R 2021). The digitalization of information can result in significant enhancements to data management, including enhanced quality, reduced processing times, and reduced associated costs.

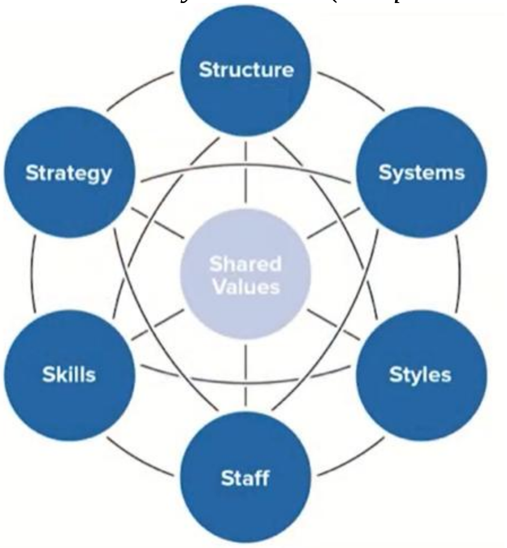
The process of digitalization is often presented as a three-step process, beginning with digitization. This refers to the transformation of physical documents (such as texts, drawings, etc.) into digital ones, which can be transported and modified more easily. The subsequent stage, designated as "digitalization" is characterized by the incorporation of manipulation tools (for these digital documents) that facilitate the sharing and presentation of data on diverse websites. The transportation of digital data between different locations of use is facilitated by computer networks and commonly accessible stores, either in specific servers or increasingly more in no-location cloud infrastructures. The final and most significant stage is known as digital transformation. This stage is concerned with the proposals of new organizations that consider the previously explained elements. This process leads to what is commonly referred to as “informatization” (Firican 2023).

Consequently, economic, social, and cultural relationships and barriers are re-examined and significantly altered. As previously stated, the methodological processes employed are distinct from the scope of actions undertaken. Nevertheless, there exist generic digitalization processes that can be employed directly or adapted to suit the specific requirements of a given field.

Globally, digitalization can be defined as a transformation process with the objective of proposing new practices, a new ecosystem, new stakeholders, a new business model, and new management in order to provide better customer services.

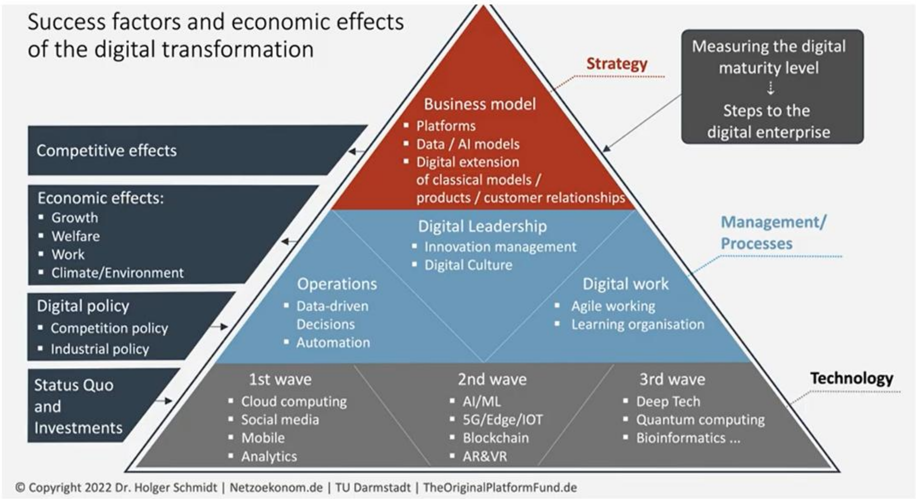
For this purpose, a variety of more or less elaborate processes are proposed. We shall mention only two models. The McKinsey 7S model (Shaqrah 2018), which provides an overview of the main components of an appropriate digitalization approach, including Strategy, Structure, Supportive Systems and Managing Styles, Working Staff, and Members' Main Skills, as well as Shared Values (Figure 1).

Figure 1. *McKinsey 7S Model (Shaqrah 2018)*



Further refinement of the model is proposed in The Big Picture of Digital Transformation (Big Picture), which synthesizes all aspects, elements, and methods (Figure 2). These approaches facilitate the organization of the design and development stages.

Figure 2. *Digital Transformation - The Big Picture (Edition 2022) (Big Picture)*



The Influence of Digitalization on Tourism

The advent of digital technology has had a profound impact on the global tourism economy. The digital revolution has transformed the operations of urban centers, tourist bureaus, and travel professionals. Cities are investing in the development of tangible and interactive media (Frolov & Strekalova 2021). In tourist offices, it is becoming increasingly common to utilize dynamic displays and other tactile supports that enhance the presentation of expected vacancy locations to potential clients (Camilleri 2018). In addition to tourist offices, museums, shopping malls, fairs, festivals, and other tourist sites are also equipped with these technologies in order to offer travelers an unforgettable and rich experience (Ionita 2017) (Massari & Del Vecchio 2022).

The tourism industry is undergoing a period of significant transformation. The advent of new technologies has given rise to novel forms of tourism.

- M-tourism, also referred to as mobile tourism, is the act of reserving holidays directly via a mobile or touchpad device (Chen et al. 2021).
- Social tourism entails selecting accommodations based on social networks (Minnaert et al. 2009).
- E-tourism is the convergence of the Internet and tourism, resulting in a multitude of digital experiences (Hamid et al. 2021).

The immersive and interactive travel agency of the 21st century is already a reality and continues to expand via the Metaverse approach (Metaverse), which we will discuss in greater detail later.

The term "tourism digitalization" refers to the integration and utilization of digital technologies across the entirety of the tourism industry, encompassing all stages of the travel planning and booking process, as well as the on-site traveler experience.

Tourism Digitalization Tools

The array of digitalization tools utilized in the tourism industry is diverse and encompasses various facets of the tourist experience, encompassing both the planning and execution phases of the trip. The following is a list of the principal tools utilized in the digitalization of tourism. Online reservation platforms represent a significant advancement in the field of digitalization of tourism. Similarly, mobile travel apps have become invaluable resources for travelers. Digital marketing and social media, which utilize digital marketing strategies, have also played a pivotal role in the digitalization of tourism. These strategies encompass online advertising campaigns, social media platforms and virtual and augmented reality technologies. These digital tools for the tourism industry facilitate the planning, booking, and enjoyment of trips in a more efficient, convenient, and personalized manner. At the same time, they enable tourism businesses to better meet the needs and expectations of their customers.

This digitalization approache has been designated as "Smart Tourism". The aforementioned activities are computerized. In order to clarify this approach in a structured manner, we will examine it successively, as follows: The concept of Smart Tourism is defined as the integration of digital technologies into the tourism sector, with the aim of enhancing the efficiency, convenience, and personalization of the travel experience for travelers, while simultaneously improving the ability of tourism businesses to meet customer expectations.

Smart Tourism in Smart Environment

The concept of the "Smart Environment," also referred to as the e-environment (Gretzel et al. 2015), pertains to the utilization of information and communication technologies (ICT) in order to encompass a range of activities, including environmental monitoring, natural resource management, optimization of waste and recycling, transport and mobility management, smart public lighting, prevention of natural disasters, and awareness raising and citizen participation.

The junction of "Smart Tourism" and "Smart Environment" refers to the utilization of information and communication technologies (ICT) to advance sustainable tourism practices that are environmentally conscious and integrated into broader development initiatives for intelligent territories. This entails integrating smart tourism principles into a destination's overarching environmental management strategies. The following items will present some of the key aspects of this concept: The integration of digital technologies in tourist attractions, the implementation of sustainable mobile applications and booking platforms, the intelligent management of tourist flows, the fostering of environmental awareness and traveler education, the establishment of public-private partnerships for sustainable tourism, and the utilization of data for environmental management are all aspects of the integration of smart tourism into smart environment initiatives. By integrating smart tourism into smart environment initiatives, tourism destinations can offer more sustainable, attractive, and environmentally friendly travel experiences. It is not only limited to data access, integration and manipulation, but takes into account data localization as source and destination of users' behaviors in relation with the perception, respect and understanding of in the field behaviors.

Management of Crisis in the Context of Smart Tourism in Smart Environment

Crisis management encompasses the processes of planning, preparation, response, and recovery from unforeseen events or disasters that threaten the environment, populations, and human activities. Such crises may be caused by natural phenomena, such as storms, floods, earthquakes, volcanic eruptions, forest fires, or by technological incidents, industrial accidents, severe pollution, pandemics or by human actions (Wut et al. 2021) (Faulkner 2003) (Standing et al. 2012).

In more specific terms, environmental crisis management in the context of smart tourism and smart environment naturally involves the use of information and communication technologies (ICT) to anticipate, manage, and mitigate the effects of natural disasters and environmental incidents on destinations, tourism, and local ecosystems. We can list a number of ways in which Smart Tourism in Smart Environment can contribute to the management of environmental crises (Standing et al. 2012):

- The use of environmental sensors and real-time monitoring systems to detect warning signs of crisis, such as pollution levels, climate variations, and natural hazards, is essential for effective surveillance and prevention. The integration of geospatial and meteorological data into Smart Tourism platforms allows for a more comprehensive understanding of risk areas and the implementation of preventive alerts for travelers and local residents.

- The development of emergency and crisis management plans that integrate real-time data, simulation models, and predictive analytics for a more rapid and effective response. The use of computer modeling to simulate different crisis scenarios and assess potential impacts on tourism infrastructure, ecosystems, and populations.
- Communication and Alerts: The establishment of ICT-based early warning systems is essential for informing travelers, residents, and tourism stakeholders of impending emergencies and safety measures to take. The utilization of smart tourism mobile applications to provide real-time updates on environmental conditions, alternative routes, evacuations, and other pertinent information is recommended. The utilization of online platforms and crisis management applications is essential for the coordination of relief efforts, the allocation of resources in an efficient manner, and the facilitation of communication and collaboration between local authorities, response teams, and relief organizations.
- Sustainable recovery and reconstruction: Planning for post-crisis reconstruction by integrating sustainable practices, such as restoring ecosystems, building resilient structures, using renewable energy, etc. The promotion of sustainable recovery tourism is achieved by the highlighting of environmentally friendly reconstruction initiatives, the showcasing of eco-responsible products and services, and the raising of travelers' awareness of the importance of supporting affected destinations.

Assistive Systems

It has been the case since at least the 19th century that tourist trips have required the provision of supportive assistance (Bhatia 2012). This assistance was initially provided in a physical and paper-based format, and was provided prior to the trip. The evolution of assistive systems is a permanent and ongoing process, and it is likely to continue in the future. It is possible to cite the evolution of physical agencies to virtual technologies through the emergence of the Internet (Kautson 2004). It is crucial to highlight the evolution of one-off contact to continuous access to appropriate information, contextualization by geolocation, and the Internet of Things. In this new context, the success of this evolution is contingent upon the efficacy of user interfaces and the satisfaction of users with regard to their interactions with these interfaces. The evolution is characterized by utility, usability, and user satisfaction. Given the ongoing complexity of these factors, ensuring their guarantee is challenging.

As previously stated, the context of smart tourism in a smart environment necessitates the implementation of an assistive system that enables all categories of users to access available information, modify it, collaborate with others, and share it. The assistance system provides users with the capacity to act as either customers or professional providers. It enables them to manage reservation activities, including transportation, accommodation, and various rentals, as well as their modifications, cancellations, and support in difficult cases of malfunctions and errors.

Assistive System Objectives

In order to provide appropriate services in an organized assistive system, it is essential to identify the key elements of this system. Globally, information and communication technologies (ICT) are responsible for data collection, storage, and management, as well as for appropriate manipulations in different working situations. They also provide communication over short and long distances by wireless and wired networks, in mobility, and interact with the environment in which active and passive things are organized in the Internet of Things (IoT). Two crucial aspects are human-computer interaction (HCI) and the development of new services based on artificial intelligence (AI). The primary objectives of HCI are related to multimodal and multi-channel communication with various devices and interaction styles, including touch-based and speech-based interactions (chatbots), as well as AR (augmented reality) approaches and the imminent Metaverse. These interactions may occur on a desktop computer or with mobile devices, including smartphones, connected watches, and tablets. This allows for individual and collaborative situations, as well as large, in-the-field screens or in-vehicle HCI devices, such as those found on vehicle dashboards.

From the perspective of artificial intelligence, big data, open data, and machine and deep learning are primarily employed to identify pertinent information within the vast quantity of data available and to synthesize observed behaviors derived from typical data. An illustrative summary is presented in Figure 3, which initially addresses the concept of a smart city. This framework can be readily adapted to encompass the domain of smart tourism, as evidenced by the work of (Liu & Peng 2014).

Figure 3. *Smart City Architecture summarized by Liu and Peng (Liu & Peng 2014)*

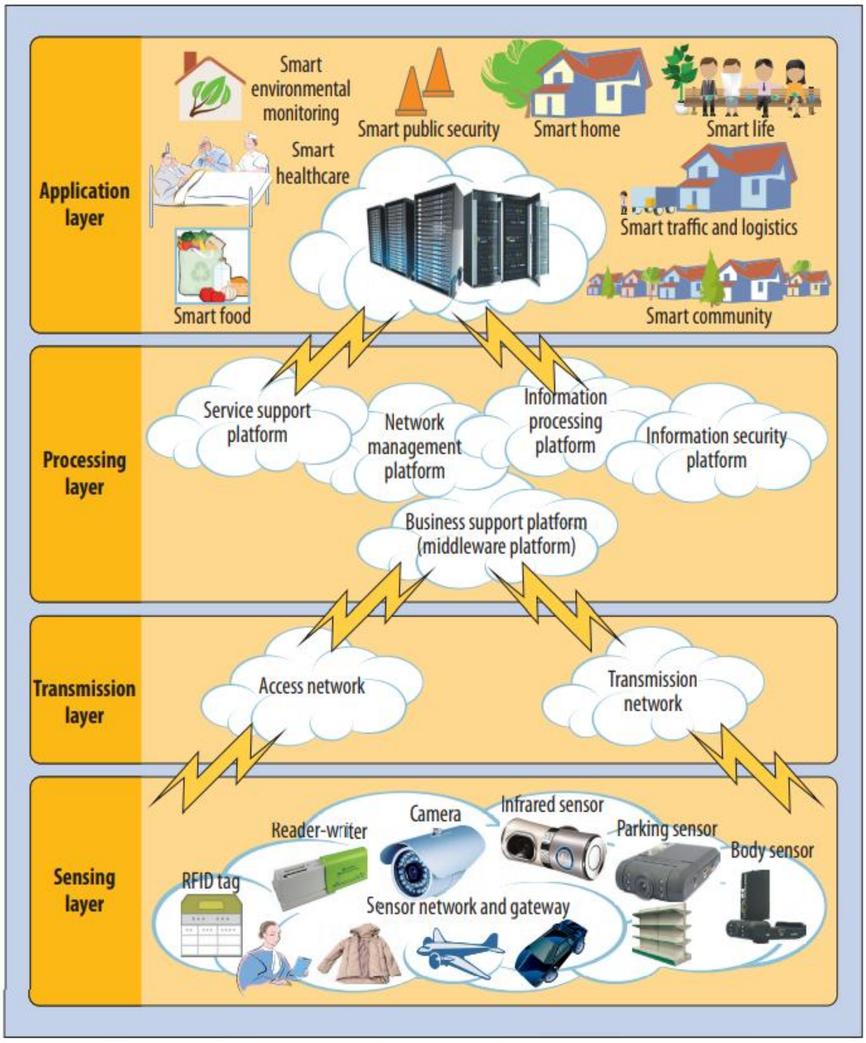
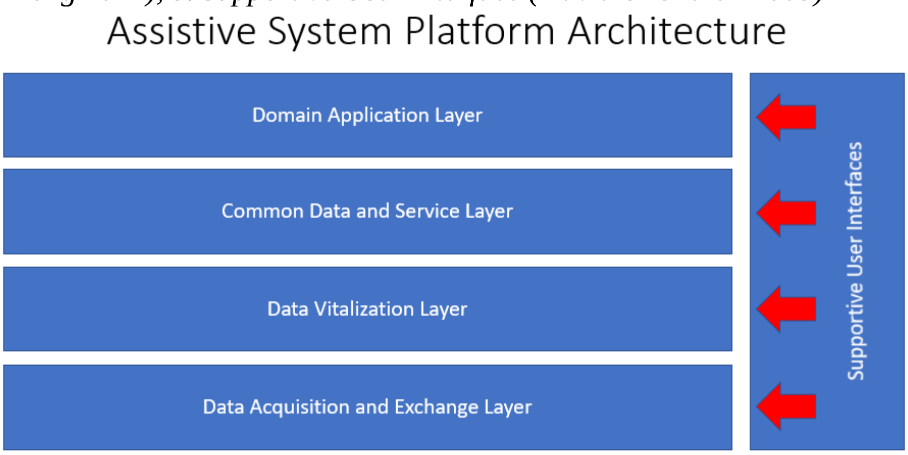


Figure 4. *a. Assistive System Architecture of a Supportive Platform with Data Vitalization (Xiong 2012), b. Supportive User Interface (David & Chalon 2009)*



Assistive System Platform

In order to organize these disparate elements, it is necessary to create or utilize a supportive platform that facilitates connections between people, services, and even objects in ways that were previously inconceivable. In order to organize and manage these aspects, it is necessary to implement a system that groups the different services and their applications, the data on which they work, and the relationship, if needed, between the field and the system. The system is structured in four layers (Figure 4):

- The first layer is dedicated to applications,
- The second layer is focused on the management of common data and the provision of general services.
- Layer 3 is concerned with the process of data vitalization (Xiong 2012). The objective is to work on data and develop new constructions based on it that can be utilized in new applications. One example of this necessity is the ability to collect and associate data in order to manage situations that were not predictable, such as multiple instances of rescue in situations that were not necessarily easily predictable.
- Layer 4 is designed to facilitate the acquisition and distribution of data essential for the optimal functioning of all applications.

In order to accommodate the evolving needs of the assistive system, an appropriate user interface, called the Supportive User Interface, has been implemented. This interface enables maintenance staff to facilitate the modifications requested. The "mashup" technique can be employed for this purpose (Grammel & Storey 2008).

A generic intermediation platform must be adapted to different working situations. The objective is to provide an appropriate collection of data, services, and acquisition sensors and valuators that are capable of working together in a vitalization approach and creating adapted user interfaces that facilitate appropriate interactions. The mashup approach represents an intriguing methodology for facilitating these adaptations. Mashups are defined as "the software engineering approach, which is able to construct new applications by assembling and combining several existing functions" (Atrouche et al. 2015).

The Mashup architecture is comprised of three fundamental elements, as elucidated by Merrill (cited in (Atrouche et al. 2015)). The three elements of the Mashup architecture are data, services, and user interface. The objective of a mashup is to create a three-tier application, comprising the following components: (1) data integration, (2) application logic, and (3) user interface. The integration of heterogeneous data sources employs two principal technologies: web services and mashup.

In the context of intermediation platforms, application mashuping represents a highly valued approach for the creation of appropriate applications based on the reuse of existing ones. The architecture is based on a four-layer model (Figure 4a). To update or adapt data and services, a particular user interface is employed, designated as the "Supportive UI." The objective of this interface is to facilitate the introduction of appropriate adaptations concerning data, services, IoT exchanges, and HCI. The supportive user interface, which is also oriented towards the creation or evolution of mashup applications, proposes a programming interface for experienced developers and a visual programming-oriented approach for experienced users (Figure 4b).

Data Identification and Dynamicity Management

In order to identify the data needed for all identified activities and applications, it is important to determine their evolution, or dynamicity. A total of five levels and providers of data dynamicity were identified.

The initial, fundamental level is entirely static, which means it is not intelligent but is nevertheless useful for a significant proportion of city users (in total or by category). This includes physical panels, boards, and signs, as well as circulation signs. A case in point is the use of city maps, circulation signs, and so forth.

The second level, which exhibits minimal dynamicity, is based on boards with QR codes. In this instance, the information indicator is static, whereas the dynamicity is provided by the information sent to the user’s smartphone from the website address encoded in the QR code. This approach is well-suited to the dissemination of optional information, which is accessed exclusively by interested users and known only to them. This may include historical information, as well as commercial and advertising materials.

The third level of dynamicity is characterized by the need to disseminate information that is of general interest and needs to be commonly known. One solution is to disseminate the information directly to users' smartphones or to GPS vehicle screens. An alternative solution is the utilization of public active screens and information boards (Wang et al. 2015). This kind of dynamicity is typically determined by external decision-making centers that work with data that has been collected or that has been predefined.

The fourth level of dynamicity is contextual dynamicity, which is defined as the ability of a system to produce particular cases or situations in response to an action on a local device, whether manually or automatically. A classic example is a remote control located on a bus, which the driver activates to open a barrier, allowing access to a restricted portion of the road. This type of sender (or remote control) can be either integrated into the vehicle (e.g., bicycle, automobile, bus, boat, etc.) or operated manually by the user, frequently in emergency situations. Such devices are duly registered with the relevant authority. The actuator associated with the remote control can be either monolithic or mono-selective, acting on a single door, barrier, etc., or integrated in a system that assists in the execution of more sophisticated behaviors. The management of this dynamicity necessitates the establishment of an appropriate association between the sender(s) and the receiver(s) in order to organize the corresponding behaviors.

The fifth and highest level of concern pertains to the dynamicity of emergency and rescue situations, which are primarily related to weather and environmental conditions, such as floods, landslides, tsunamis, ecological and industrial problems, and fires. In such circumstances, the objective is to collect pertinent information and disseminate it to the relevant authorities, who are responsible for determining the most appropriate actions and informing those who are affected (both those who are required to take action and those who are impacted).

As previously stated, it is crucial to deploy sensors in a strategic manner throughout water, air, and other environments for fire detection. These sensors must be capable of transmitting accurate data to the rescue center in a timely manner. The synthesis of these data is then elaborated, and an emergency signal is propagated to all information media, both individual and collective, in the city with vocal and/or visual announcements indicating the actions to be undertaken.

To achieve greater levels of dynamism, three distinct approaches can be employed. The first approach is entirely contingent upon the local context. The objective of local senders addressing local receivers is to elicit responses that are both local and appropriate. A more general solution would be to enable the sharing of available data that is collected by communication devices, namely senders and receivers, on site in the field, the city, and its neighborhood. This data would be open to external users for their applications and services. This approach ultimately leads to the creation of what is referred to as Open Data (Auer et al. 2007) (Kitchin 2014), which represents a significant advancement in the general accessibility of large-scale data of interest.

Another intriguing approach is based on the evolution of collected data through the acquisition of more recent data and their integration into the elaborated behavioral model. This approach is based on a research field known as machine and deep learning, which aims to aggregate collected data and create a progressively more accurate behavioral model synthesizing observed situations. This process of data aggregation is referred to as data vitalization (Xiong 2012), which enables the adaptation of collected data to new observed situations.

Data Model Structure, Access Management and Integration Approaches

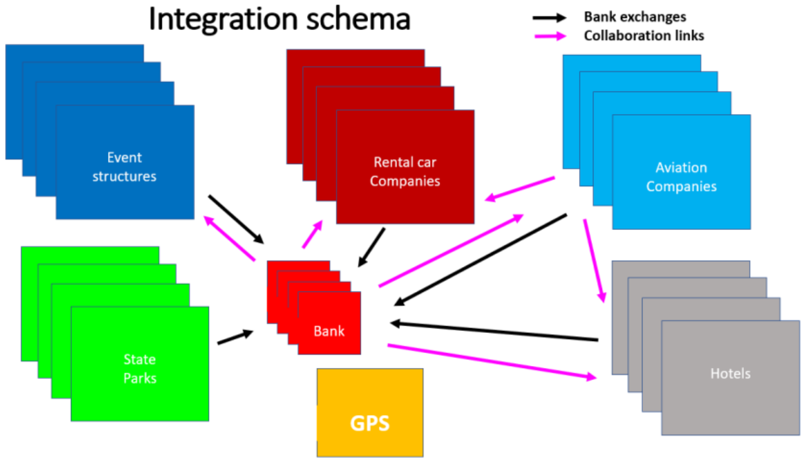
All assistive services must utilize, generate, or evolve data, which may be personal, ephemeral, long-lasting, public, or a combination of these characteristics. These services are employed in a variety of settings, including elementary and more sophisticated multi-services. In the event that ephemeral data are collected, elaborated, and utilized on a regular basis, it is necessary to store data with a long-term duration in order to facilitate their use. Such data may be stored individually or collectively, according to a specific theme, in what is known as a data silo. A more general integration is also a possibility, but for the purposes of smartification, it seems important to maintain the ability to receive new applications using existing or new data. In this manner, partial integration represents an appropriate solution when considering the use of thematic silos and the implementation of appropriate application programming interfaces (APIs) for the management of data access. The inter-silo relations are similarly situated with respect to the necessity of implementing major exchanges and the requirement to enhance the efficiency of less frequently utilized operations. It seems that total integration is unattainable, as the global system is not closed but rather open-ended, capable of receiving new services and applications on a daily basis, which support new visions of digitalized and virtual tourist activities.

From the standpoint of integration, we identify two primary categories of configurations: elementary configurations, which are limited to a single issue, and more or less integrated multi-issue configurations. It is evident that this is not an integrated system, but rather a partially integrated approach. It is evident that banks are connected or interfaced with the majority of proposed services, primarily for the purpose of facilitating payment transactions. Additionally, banks propose related activities that necessitate integration or, at the very least, data exchange with other applications (e.g., hotel reservations, rental cars, etc.). Similarly, airlines also offer ancillary services such as hotel reservations and rental cars.

Hotel reservations can be classified into three categories: homogeneous, heterogeneous, and generic. Homogeneous reservations are made through established hotel chains, such as Hilton or Best Western. Heterogeneous reservations are made through independent providers, such as Choice Privilege. Generic reservations are made through online booking platforms, such as Booking or Hotels. Each category has distinct management of reservations, modifications, and other services. Individual services are also employed for purposes such as access to state parks, museum visits, and even the operation of specific structures.

As illustrated in Figure 5, GPS (or other GNSS) represents an independent digitalized service, whereas banking is a more prevalent digitalized service, primarily utilized for financial transactions. The integration of services allows for the concurrent use of multiple services, such as the reservation of a hotel through an airline digital service. It would appear that integration based on systematic data standardization is not an appropriate solution, as the data used by different services are at least partially different, and their integration could be too complicated, necessitating complex exchanges between services. A mixed approach, with a local data store for specific data and a shared store in a chosen location for shared data, would appear to be an appropriate solution (payment data stored in a bank service).

Figure 5. *Silo and Inter-silo Exchanges and Collaborations*



The introduction of a new digitalized service can be either independent or contingent upon collaboration with other services that are already present. In order for these services to be compatible with one another, they must provide an API

(Application Programming Interface), which is a standardized approach for their interconnection.

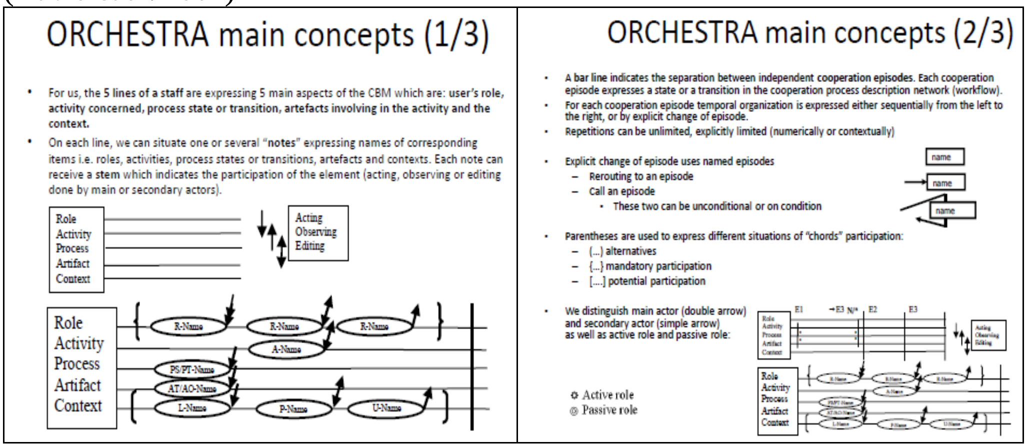
Assistive System Adaptation Methodology

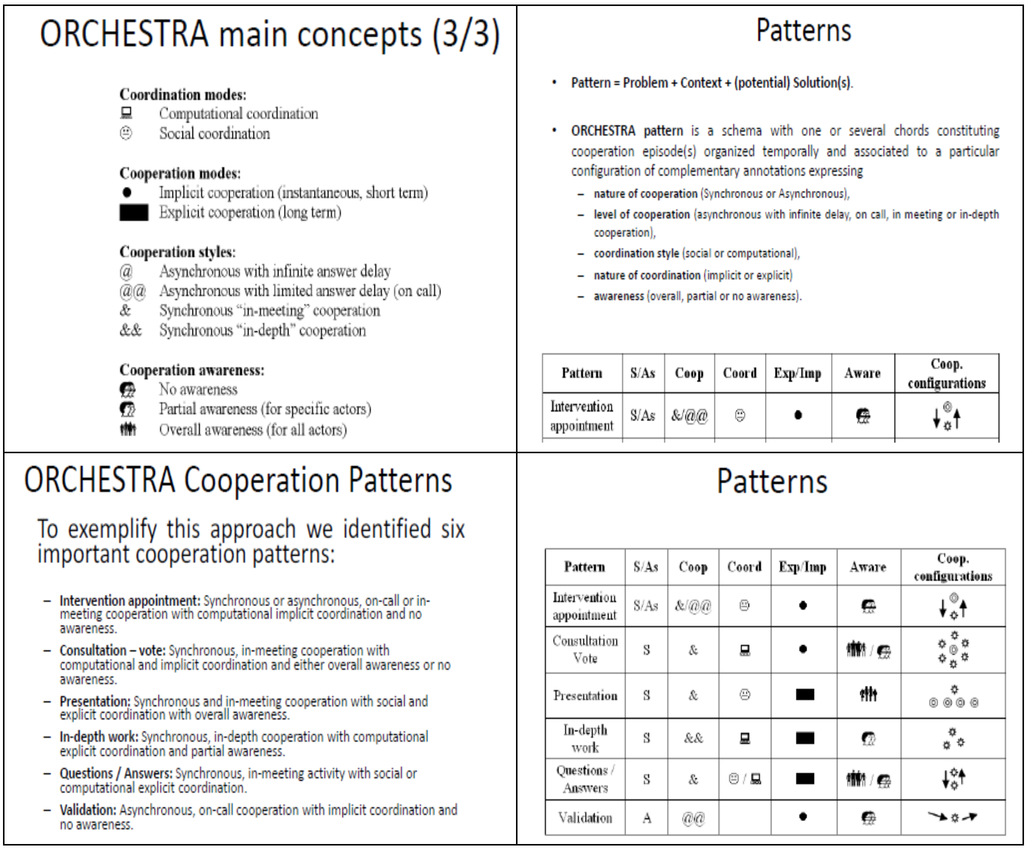
One crucial aspect of the design of a novel assistive system is devoted to contextual modeling. The objective of this process is to identify all actors who are affected by the system, the activities they perform, the data they use, and the geographically distributed objects with their behaviors.

Modeling Formalism - ORCHESTRA

We proposed a language called ORCHESTRA (David et al. 2006) (David et al. 2007), which facilitates the expression of the working conditions of an assistive system. This system is interactive, collaborative, integrated, distributed, and mobile, and it is adapted to the studied cases. The musical score expresses all of the collected characteristics of the Cooperative Behavior Model (CMS), which are as follows: the user's role, the activity concerned, the process state or transition, the artefacts involved in the activity, and the context, which is mainly location or mobility.

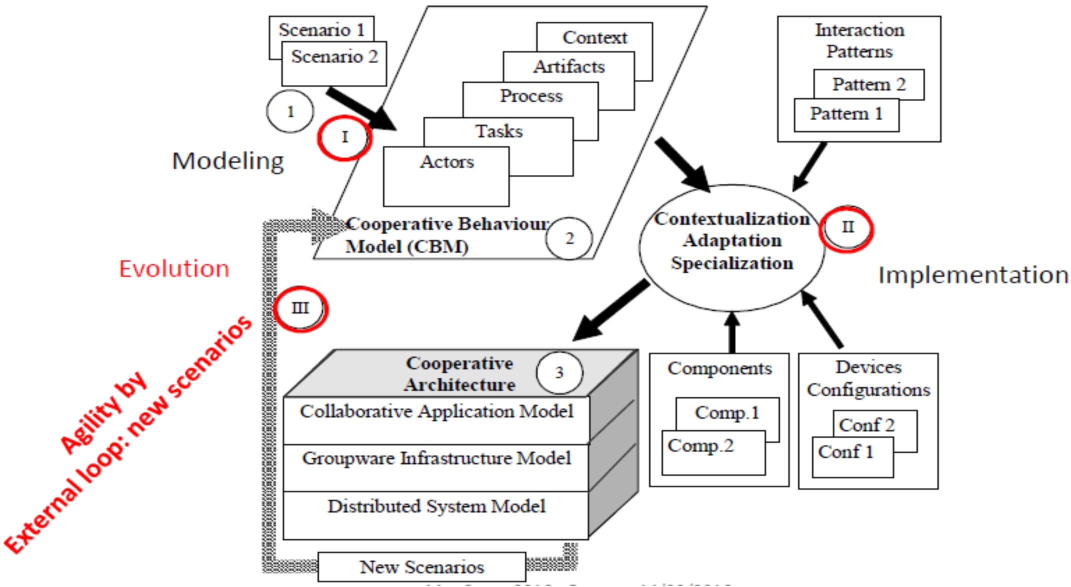
Figure 6. *ORCHESTRA Modeling Formalism Explanation* (David et al. 2006) (David et al. 2007)





Following the completion of the modeling work, the elaborated model is then projected into the assistive system platform architecture (Figure 7). We give in the section "Case studies" an example of this modelling.

Figure 7. *ORCHESTRA Modeling Projection on Assistive System Platform (David et al. 2006)*



Design and Deployment Approaches for an Assistive System Creation and Evolution

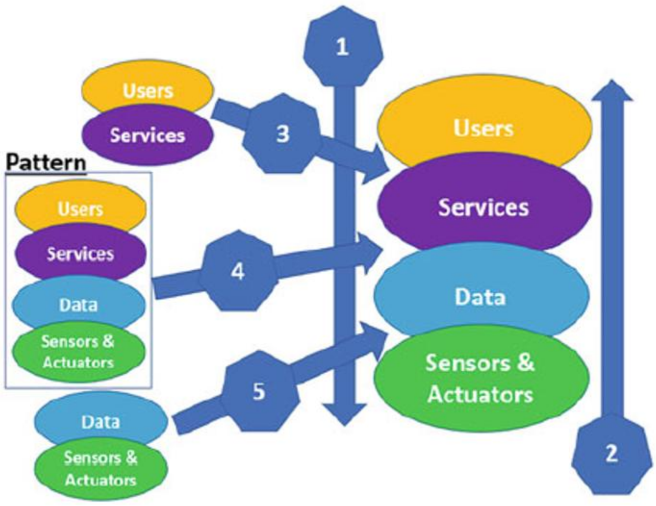
In order to develop an Assistive System for Smart Tourism, there are a number of potential ways that can be pursued (Figure 8) (David et al. 2022). The simplest approach is to develop a new application from the scratch and deploy it. When multiple applications are proposed, a more system-oriented approach is recommended, whereby they are integrated to varying degrees.

In this case the design of a system can be approached in a number of different ways, depending on the context in which it is being developed. In the context of a system design for Smart Tourism, the top-down approach (1, in Figure 8) appears to be the most appropriate. In this case, the study starts with the identification of potential users and corresponding services through a discussion with them. This enables the identification of their wishes and expectations. The subsequent stages of the process involve the identification of data on which the selected services can operate and, finally, the sensors and actuators required to establish an appropriate relationship with the field. These disparate elements are integrated in a sequential manner and incorporated into the Assistive System Platform previously presented.

Conversely, the bottom-up approach (2, in Figure 8) may be more appropriate if the objective is to identify which services can be provided to potential users based on available data. In this instance, the operational process begins with the identification of field-based devices and the data they provide. Additionally, the determination of services and potential users is conducted at a later stage. This environment-based approach is most suitable when the initial focus is on a broad range of issues and the potential user base and available services are not limited.

It is also possible to adopt an extension-oriented approach between these two extremes. This approach is likely to be the most commonly used. Its defining characteristic is its capacity for adaptation to extension-oriented situations, which encompasses the consideration of new users, new services, and/or new data integration into an existing Smart Tourism Assistive System (3, in Figure 8).

Figure 8. *Design and Deployment Approaches*



In this case, two sub-approaches can be distinguished, in the same way as for the "from scratch" approach. These are the top-down and bottom-up approaches, which utilize different starting points. The former is based on users and services, while the latter is based on data, sensors, and actuators. In these two cases, the objective of this integration process is to identify the new set of actors and homogenize services, data, sensors, and actuators in order to avoid redundancy and incoherence, which are difficult to manage during the life of the platform.

An alternative approach is based on the integration and reuse of off-the-shelf applications, which have been previously created and proposed as pattern solutions (4, in Figure 8). In this instance, the integration process may also encompass homogenization, taking into account the characteristics of all the patterns. The objective is to achieve a homogeneous system by integrating the users, services, data, sensors, and actuators.

The final approach is based on open data as a starting point (5, in Figure 8), with the integration or elaboration of appropriate services using them.

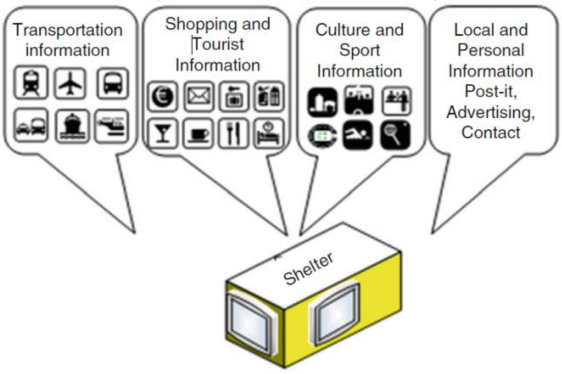
Case Studies

Case Studies: Previously Studied

In our previous projects and published papers, we have primarily focused on the context of smart cities, with the following examples illustrating our work in this area:

- Goods and parcel distribution rounds based on parking reservation (Patier et al. 2014).
- Parcel transportation based on subway passengers with human-human transmission or using individual boxes (Li et al. 2021).
- Accompanying children or disabled persons in public transportation (Li et al. 2021).
- Management of route lanes in relation with transportation traffic prioritizing public vehicles (buses, emergency and firefighters' vehicles) asking lane reservation by in-vehicle transmitter and informing other drivers either by in-field boards and/or on in-vehicle dashboard screen (Wang et al. 2015).
- Beach management in the context of the ongoing pandemic (with reservation and rescue services) (Chalon et al. 2022).
- Smartification of a coastal city, an extensive approach (David et al. 2024).
- Finally, the installation includes a bus shelter with integrated information and support for carpooling. This shelter displays transportation solicitations and proposals on a large screen (Figure 9) (David & Chalon 2010).

Figure 9. *Bus Shelter (David & Chalon 2010)*



Case Study: Mountain Station Winter Smartification

The objective of this study is to examine the transformation of a mountain station into a smart mountain station during the winter season. The primary characteristics of the weather conditions are snow and frost, which have both positive and negative consequences. The positive consequences include the opportunity for skiing activities and the prevention and management of avalanches. The negative consequences include circulation problems and the organization of rescue operations. This case study will be presented in conjunction with the previously described design and deployment approaches.

Top-down Approach: Mountain Station Winter Smartification

In order to gain the most comprehensive understanding of this complex issue, a top-down approach is the most suitable methodology. All issues related to tourism can be considered as a starting point for analysis: Transportation from and to the station, including internal circulation for all actors (buses, supplying trucks, cars, pedestrians, and stay reservations), etc. It is of course necessary to include all aspects of mountain station winter tourism (skiing, on-sledge circulation, etc.). In this comprehensive analysis, it is essential to consider the principles of sustainable tourism, the avoidance of over-tourism, and crisis management. It is evident that skiing and other snow and ice activities are of particular concern in this context. It is therefore appropriate to start this process by engaging in discourse with potential users and collating their anticipated services. The next step is to identify the data that is needed, to collect it using appropriate devices, and to manage it over an extended period. This data must then be disseminated to users in an appropriate format, such as through wireless networks.

From the perspective of the application, it is a top-down design, beginning with a general discussion and progressive refinement of all necessary aspects (treatments, data, user interfaces, in-city devices, etc.).

Extension-oriented Approach: Traffic Management in the Winter Mountain Station

The organization of traffic is a crucial aspect of any transportation plan. It is evident that during the low season, a static allocation of the circulation map is a viable option. However, in the high season, the objective of dynamicity is to ensure better traffic speed by introducing various restrictions at different times of the day, with either authorized or prohibited vehicles. Such dynamicity is either based on collected and preprocessed data (behavioral patterns) or on real-time data, including temperature, snow level, wind speed, and snowstorm intensity. Furthermore, the management of the circulation related to the use of snow removal engines is also to be considered. This information is then disseminated to the driver assistance system and drivers in an appropriate manner. This may be done electronically via signs or by transmitting the relevant information to in-vehicle screens, smartphones, and GPS applications. From the perspective of the application, we consider it to be an extension-oriented approach, whereby new functionalities and behaviors are added to the system.

Open Data as Starting Point

The Open Data (Auer et al. 2007) as Starting Point approach involves the collection of generally available data, which is then filtered and integrated or elaborated into appropriate messages for distribution to interested users. In the context of our case study, it is necessary to consider a number of factors related to winter conditions, including temperature, snow levels, wind direction and intensity, the likelihood of snow storms and the potential for avalanches. These factors must be disseminated to relevant institutions, including hotels, tourist agencies, clients and professionals, through appropriate channels, such as light panels, bulletin boards, emails, SMS and social networks.

Pattern Use: Access Control to Protected Areas

The control of access to restricted areas is a widely employed strategy to mitigate the adverse effects of over-tourism. One particularly well-known solution is employed in numerous US National Parks. A digitalized service is necessary to obtain a timed entry reservation to enter the park, even if one already possesses a pass. Annual passes entail the payment of entrance fees, thus exempting holders of annual or senior passes from the additional $2 reservation fee. The timed entry reservation is employed to regulate the influx of visitors to the parks during the summer season, when access is particularly congested (Figure 10). A website has been created for the distribution of timed entry tickets in relation to the number of potential visitors (Plan Your Visit).

Figure 10. *Arches National Park access control*

A similar service was identified for museum access management at the Getty Villa and Getty Museum in Los Angeles.

In the case of the winter mountain, over-frequency can provide interesting solutions. A number of adaptations can be implemented in order to facilitate a wide range of potential uses. Access restrictions may be based on temporal factors, such as exceeding the global daily capacity or a specific time slot (e.g., AM, PM, or hourly). Alternatively, they may be related to specific conditions (e.g., temperature, water or snow level, wind, animals' or birds' special period).

It may be beneficial to adapt these restrictions to slope access limitations, city access limitations, and off-road skiing control. The control of the level of ski required for each category of ski slope is essential. This approach can also be employed to regulate the cost of ski passes in relation to the ski level and slopes utilized.

Bottom-up Approach: Emergency and Rescue Services in Ski Area

The convergence of ICT (Information and Communication Technologies), Smart Tourism, and Smart Environment enables the creation of Assistive Systems that can make a significant contribution to the management of environmental crises (Figure 11).

For the effective management of crises, a more complex solution is required, and an appropriate process must be in place. As previously stated in the section on the state of the art, crisis management is based on four phases, which occur in a sequential order:

1. Creation of an Appropriate Working Context
2. Activation of the Operational Period
3. Activation of Appropriate Rescue Level
4. Activation of Post-Crisis Management

The case presented here is limited to that of a skiing area, as the problem of emergency management in urban areas is a common occurrence. The optimal approach to addressing crises related to skiing is to equip both skiers and mountain professionals, including ski patrollers, pole operators, and groomers, with appropriate movement and rescue transceivers. It is imperative that the area be secured by protecting the chairlifts and ski lifts. The marking of trails and the placement of avalanche detectors represent an important method of protection and information dissemination. It is also imperative to install intrusion detectors in areas deemed dangerous. It is necessary to equip snow groomers for ski slopes with GPS and rollover sensors, among other devices, in order to be able to follow their movements and to identify any navigation mistakes that they may make. All skiers traversing areas deemed dangerous must be equipped with transceivers and registered in the Assistive System. This is the content of the initial phase of the Assistive System's operational functionality.

The subsequent phase is devoted to observations, which are conducted over a specified period of time. It is to be expected that the sound communication system, comprising information panels and light beacons, will be operational throughout this period. Furthermore, the reception system for all communications provided by in-area transceivers, whether originating from humans or from in-environment senders, will be fully functional. During this operational phase, the Assistive System is capable of receiving and responding to informative messages with geolocation data for the senders.

The subsequent phase is dedicated to the activation of the rescue organization. Upon receipt of a corresponding message, the Assistive System and its users (rescue managers) are able to determine the level of emergency and organize appropriate treatments and actions. In the case of a ski injury, for instance, ski patrollers can determine the level of emergency and organize appropriate treatments and actions. This may involve activating a rescue team and providing information to concerned persons (clients, ski professionals, etc.). In the case of an avalanche, a rescue team is activated and appropriate information is provided to concerned persons via selected information channels. In the event that a rescue team is required, or if a helicopter is needed, these resources will be deployed. In this instance, the system is capable of establishing a specific communication link between team members and victims. The establishment of an appropriate communication connection between all actors in mobility is essential for the effective management of emergencies.

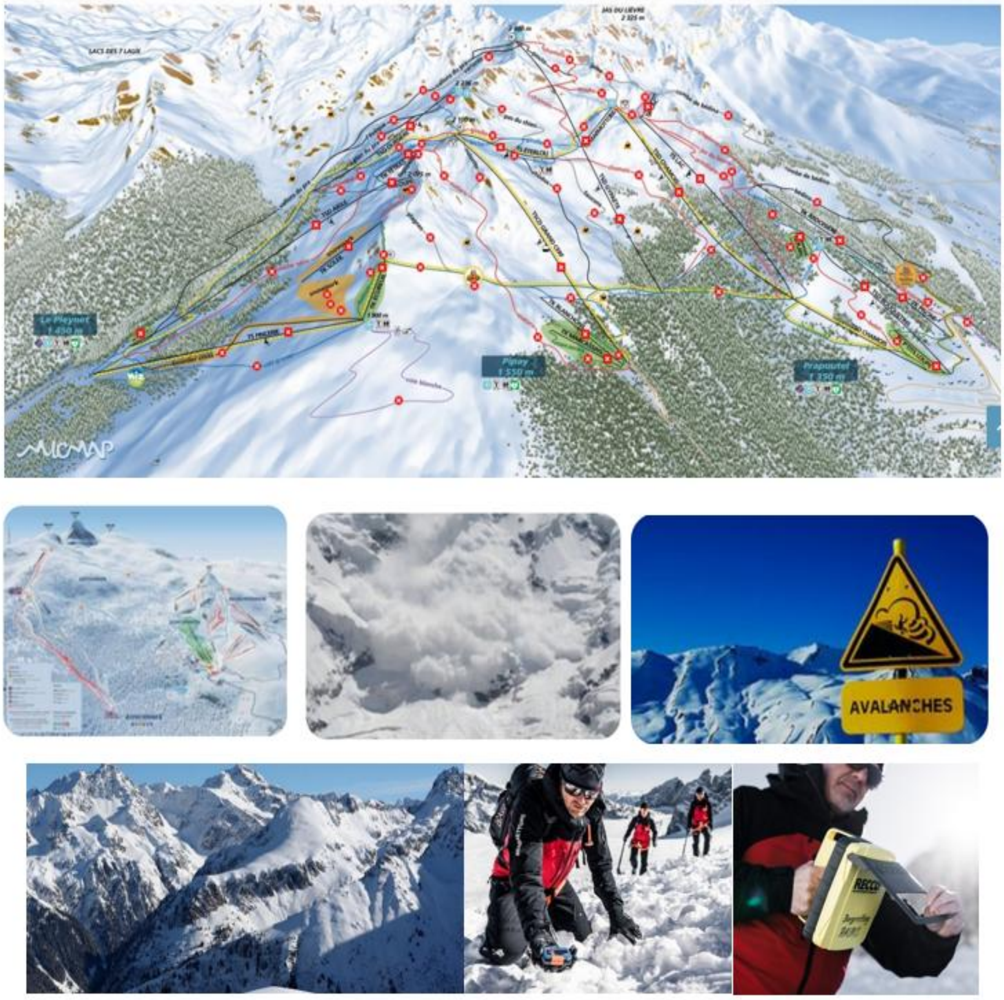
In the event of an avalanche, the transceiver worn by the skier is an essential item in conjunction with other equipment used for locating buried skiers. The detector, carried by the rescuer, emits a search beam that is reflected by RECCO® reflectors (RECCO) integrated into various types of clothing, helmets, ski boots, and other equipment. This enables the precise location of buried individuals. In a professional mountain rescue operation, the search for avalanche victims using an AVD (avalanche victim detector) is of the utmost importance. In the event that an AVD signal cannot be detected within the avalanche cone, the RECCO® detector is employed as an additional electronic search tool. In this manner, individuals who have become buried can be located with remarkable precision. The RECCO® detector can be utilized for searching both on the ground and from a helicopter.

The final phase of the Assistive System's operational cycle is dedicated to post-crisis management. The system is designed to undergo a process of reinitialization, which involves the appropriate reactivation of all system components and their in-environment elements (protections and transceivers) in order to prepare them for a new operational phase.

It should be noted, however, that a summer mountain crisis situation is not identical to the aforementioned scenario. The evolution from snow to water, from skiing to mountain biking and paragliding, may result in a change of customers, but the underlying needs remain the same.

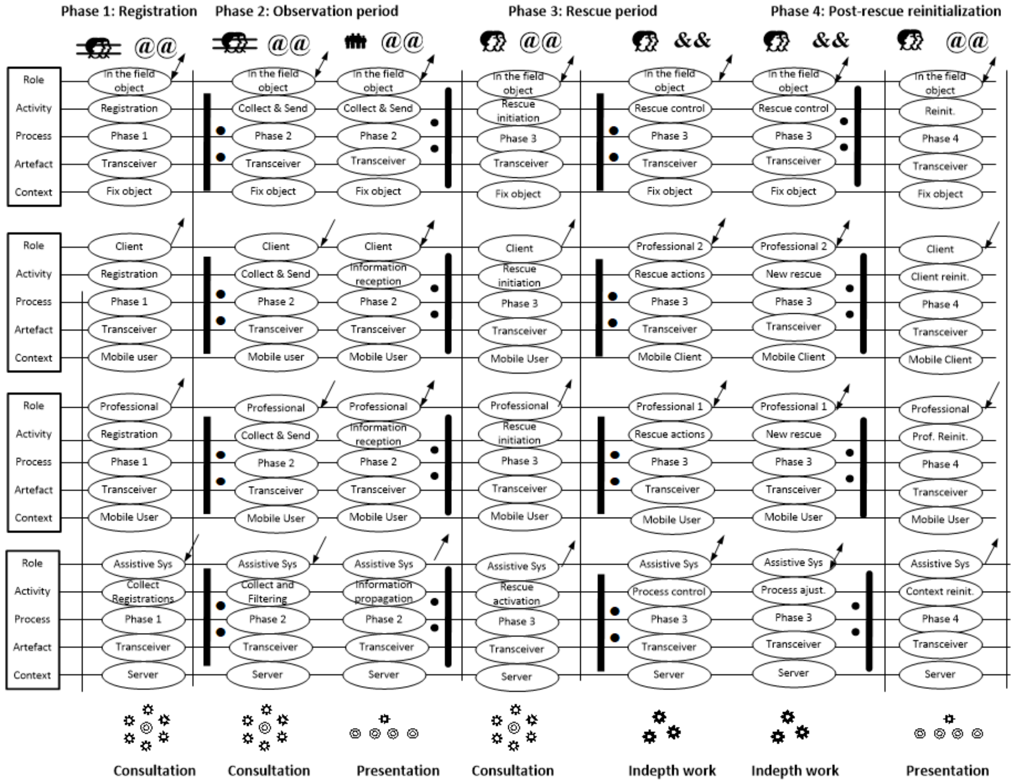
From the perspective of the design process, this final case can be considered a bottom-up approach, with the capacity of the environment serving as the primary source of information. It is evident that, should this preliminary stage prove unsatisfactory, it will be necessary to proceed by a more or less top-down approach in order to complete it.

Figure 11. *Ski Area Emergency and Rescue Services*



The in-gate limitation approach is relatively straightforward in terms of its working principles, collaboration, and modeling. In contrast, crisis management, with its various phases, is a more complex undertaking. A preliminary model is proposed for the first level of modeling with ORCHESTRA, as illustrated in Figure 12.

Figure 12. *ORCHESTRA (David et al. 2006) (David et al. 2007) modeling of Ski Area Emergency and Rescue Services*



Discussion

In order to address the issue of over-tourism, it is necessary to implement limitations on the number of tourists in a sensitive area. As described earlier (Access Control to Protected Areas) (Figure 10). This should apply to access to the station, as well as to the duration of their stay in hotels, flat rental, or resorts. In addition, it would be beneficial to implement environment gates with different parameters. At this time, no additional proposals have been put forth to address this issue. It is evident that more semantic solutions, such as the proposal of alternative destinations, are to be considered. However, it is not necessarily the case that technological improvements are required.

In the context of crisis management in the tourism sector, our proposal is based on a close relationship between smart tourism and smart environment. This approach takes into account the use of distributed transceivers that are able to observe and propagate the current situation. Consequently, our assistive system is capable of implementing appropriate actions or reactions and organizing rescue interventions.

Concerning sustainable tourism; we have not finalized proposition. As ICT specialists we are proposing different mechanisms, which can be used to take into account appropriate sustainable tourism characteristics presented previously, which can be retain by the designers.

Conclusions

This paper examines the digitalization and virtualization of operations related to tourism in the context of smart tourism in a smart environment. We presented the tourism needs, developments, and principal objectives to substantiate the need to provide all actors (consumers and providers) with suitable conditions that would permit the achievement of substantial results, particularly in two key areas: the avoidance of over-tourism and the management of tourism crises.

The main characteristics of the proposed assistive system, its actors, its architecture, and the design and development aspects were presented. A formalism called ORCHESTRA was presented in a cursory manner to illustrate its role in the modeling of work conditions. Five approaches to the construction and/or evolution of the system were presented in order to propose appropriate approaches which are needed in order to support the evolution of working conditions and users' and professionals' claims.

As demonstrated, total integration is not a solution. Conversely, an open-ended approach could be preferred in order to integrate new services that can be utilized on a daily basis and would communicate easily with existing ones. The modularized approach represents an appropriate solution.

In order to demonstrate the potential applications of our Assistive system in the context of over-tourism limitation and crisis management, we have compiled a list of several previously studied situations and provided a description of the system's functionality in a winter season setting at a mountain station. The objective was not to resolve all identified issues related to over-tourism and crisis management; rather, it was to provide a foundation for further studies and projects.

The next step in the evolution of this kind of assistive system is the integration of the Metaverse approach (Kouroupi and Metaxas 2023) (Koo et al. 2022) (Go 2022) (Yaqoob 2023), an approach to virtual and augmented reality that allows for an interesting and rich contextualization, as well as in-sofa sitting tourism. Its recent evolution from a purely virtual approach, which avoided over-tourism, to a more appropriate one that provided supplementary information through a 3D augmented reality interface, thus enhancing users' understanding of the places they visited. Another way to improve users' understanding of suggested destinations is through generative intelligence, a machine learning and deep learning-based approach inspired by ChatGPT and AI generative approach (Gursoy et al. 2023) (Hsu at al. 2024).

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