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The Concept of Comprehensive Tracking Software to Support Sustainable Tourism in Protected Areas

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Abstract: Visitor management in protected areas requires knowledge of visitors—their numbers, time-space curves, motivation, behavior, and satisfaction as an important input. The systematic analysis, comparison, and synthesis of visitor monitoring methods, with the focus on methods for individual tracking, is conceptualized in the form of a mind map. The map serves as a basis for managed dialogues with experts from several protected areas in the Czech Republic. The theory and experts' practical insight are processed by the means of systems analysis with the aim to formulate (1) a guideline for the integration of heterogeneous data about visitors and (2) the concept of an advanced intelligent software tour guide with an individual tracking function. The proposed concept aims to achieve comprehensive monitoring of visitors' time-space behavior in the context of their socio-demographics, goals, preferences, feelings, and the resulting impressions. In addition, the visitor flows may be interactively influenced in a personalized way by the application, leading to better individual impressions and satisfaction, with full respect for the carrying capacity of the territory. Related challenges, such as the stimulation of visitors to use the application, are discussed. The ongoing experimental implementation of the concept as a part of a comprehensive destination application is mentioned at the end.

Keywords: protected areas; monitoring; visitors management; intelligent software; carrying capacity

1. Introduction

Visitor management of protected areas [1–3] is supposed to keep the tourism intensity below the area limits while respecting the needs of the local economy and community as a multi-faceted goal of participative management [4]. It requires reliable, comprehensive, and detailed data about tourism intensity, including its impacts and practical methods and tools to exploit the data for the purpose of visitor management [2]. Numbers of visitors are commonly monitored in various geographical contexts, such as individual monuments, spatially limited localities, protected areas, or even countries or whole continents [5]. However, visitor monitoring is often not comprehensive enough in protected areas; also, the full potential of the resulting data is often not fully exploited. Both factors have a negative impact on the effectivity and efficiency of visitor management [4]. It is partly caused by the limitations of visitor monitoring methods and technologies, as discussed in the literature review below. Also, practically applicable methodologies for the integration and utilization of available heterogeneous data about tourism and its impacts in protected areas are missing. Both problems are addressed in the manuscript.

At first, a literature review (Section 2) is conducted in the areas of tourism impacts, tourism sustainability, visitor management, tourism modelling and simulations, visitor monitoring and tracking, and the utilization of data about visitors. Specific attention is paid to the promising method of individual tracking, its variants, and the challenges related to its deployment. Based on the review, a research gap is identified (Section 3), followed by the formulation of three research questions (Section 4). Regarding the original research methods (Section 5), the research area is conceptualized in the form of a mind map showing the broad spectrum of visitor monitoring approaches and relevant concepts in their logical relations. The mind map serves as a basis for consultations, managed dialogues, brainstorming, and the Delphi method, with tourism experts. The knowledge gathered from the experts, compared, analyzed, synthesized, and generalized in the context of the relevant literature, served as the main input for the subsequent systems analysis.

To pave a way towards the operationalization of concepts, such as the carrying capacity or limits of acceptable change (LAC), in the context of visitor management of protected areas, the results of the analysis (Section 6) include a novel set of recommended integration steps for heterogeneous visitor data in protected areas and a comprehensive and universally applicable concept of an intelligent tour guide for visitor tracking and visitor characteristics acquisition, reflecting the state-of-the-art of both tourism management in protected areas and advanced software technologies. Functional and qualitative characteristics of the proposed software concept are provided. Additionally, suitable architecture (broken down into modules, layers, and other logical parts) is recommended to help researchers with its implementation. The ongoing experimental implementation is briefly introduced. Limitations of the study and the implementation challenges of the proposed concept are discussed (Section 7), including human and technical factors; quality of the data collected by the proposed application; ethical, legal, and financial aspects; and the applicability of the solution in other protected areas in the world. Finally, the answers to the research questions are provided (Section 8), based both on the literature review and the original research.

2. Literature Review

Managements of touristically interesting and environmentally sensitive protected areas are under increasing pressure due to factors, such as rising tourism intensity, increasing visitor demands and changes in visitor behavior patterns, industrial pollution, climate change, and non-native and invasive species [4,6,7]. The ever-growing intensity of tourism cause a multitude of disturbances—trampling, widening of the trails, formation of parallel or completely new trails [8,9], disturbance of animal populations, pollution, changes in species composition, etc. [1,4,10]. Above all, the long-term interaction of those influences, as well as the gradual accumulation of their negative impacts, can lead to profound and sometimes even irreversible degradation of the protected natural heritage [1,4,10]. On the other hand, extensive restrictive measures (strict limits on the number of tourists, a radical increase in charging, total bans on zones, etc.) reduce the visitor's overall benefit and may adversely affect the local economy and community [11].

The LAC method [12,13], the carrying capacity [2,4,8,10,14–18], tourism sustainability indicators [8,10,19], or visitor management models [2,4,11] are some of the theoretical concepts and methods which the protected area visitor management may use to assess the effects of tourism and tourism infrastructure construction and maintenance. However, their full operationalization, leading to better strategic planning, space-time zoning [2,4], or other practical measures, often remains a challenge [1,3,20]. To find the optimal visitor intensity for a protected area, interactions between the visitors, local nature, the local economy, and local community, visitor flows modelling provides vital insight [11]. Visitor counts can be used to form a model reflecting the dynamics of the destination system, allowing visitor flow simulations [21–24]. However, the quality of such models is critically dependent on the extent, quality, and readiness of the entry data [21]. The use of real-time data in models of destination systems is not common [20]. Though some destinations are somewhat ahead [25], the utilization of the available technology in visitor management is generally below its potential [26].

On-site collecting, online collecting, tracking, and modelling are conceptually different *visitor flows monitoring approaches* [21]. Depending on the method [21,27,28], different data can be collected, e.g., visitors' count at a given locality and time (spot measurement), sum of visitors passing a given locality during a period of time (interval measurement), space-time curves of visitor flows (either of individual visitors or summary curves representing crowds), or profiles of individual visitors (e.g., socio-demographic characteristics combined with the motivation, decisions, and perception). Visitors' counts or sums, if gathered from a sufficient number of localities, may be used to approximate visitor flows, providing a basic qualitative overview of the distribution of the visitors during the day and during the year [29]. Validation may be necessary to assess the quality of such a model. Methods for deployment, data collection, and subsequent analysis are available [5,27,28,30–34], i.e., direct and indirect observation, counting of access permits and tickets, self-registration, traces of use, sensor-based visitor counters (at entrances and/or chosen localities within the area), capturing and subsequent analysis of aerial views [4,21], or usage of anonymized passive localization data from cellular network operators [21,35]. The most commonly used visitor monitoring methods concentrate on activities spatially constrained to the tourist infrastructure (trails, designated points of interest, etc.) [36].

Individual tracking methods are based on satellite positioning (e.g., The Global Positioning System known as GPS, or Galileo), active mobile positioning, Bluetooth positioning, Wi-Fi positioning, or indirect monitoring based on geocoded social media, or photo databases (comprehensive overviews, e.g., [30,37,38]). In particular, satellite positioning is a promising technology in tourism and recreation research [36,39,40]. The method is not bound to the tourist infrastructure [36,41], making it possible to capture tourist movement within the whole examined area. It can be precise and reliable [31,36,42,43] and its precision is often further improved on the level of a mobile operating system with active cellular and Wi-Fi positioning data. Individual tracking may be conducted on mobile devices provided to the visitors [44–46], sometimes called "loggers". On closed circuits, where an audio guide device is offered to the visitors, extending or upgrading the device to perform the tracking may be economically and logistically viable. In protected areas, however, organizing distribution and collection of the tracking devices may be difficult and expensive [22], so it is being used rather seldom and for time-limited studies [20,25,42,45,47,48]. Alternatively, visitors' own mobile devices, such as cell phones, smartwatches, or other wearables, may be used for individual tracking, which is more suitable for longitudinal studies in protected areas [49]. To ensure sufficient motivation for participation in individual tracking, visitors have to receive an appropriate benefit in return, such as the service of a software tour guide [50]. The benefits must be obvious, e.g., from the description and user ratings [21], and once tried, it should not disappoint expectations [51]. Visitor preferences may be initially identified, for example, with the help of local tourism experts, and then implemented in the application [52]. Personalization, communication, collaboration, and innovative interaction are among the key tour guide features [50].

Sometimes, only visitor counts are considered, though it may be a less important driver of ecological change than visitor behavior [46]; also, the efficiency of measures aimed to influence visitor behavior may depend on visitor characteristics. Thus, attention should be paid to the *categorization of visitors*, including their needs, motivations, limitations, and the resulting patterns of behavior. Such analysis may help to reveal which categories of visitors are desired, e.g., because of their positive impact on the local economy, and which should rather be discouraged from coming [11]. Questionnaires or satisfaction devices installed at entrances and/or exits may be used to acquire visitors' socio-demographics together with psychological data, such as preferences, goals, or perceptions [47], which may serve as a basis for psychographic segmentation. Indirect monitoring based on analysis of the digital footprint of visitors in the web, in social networks [7,53], or in specialized collaborative geographic information systems [54,55] may provide both visitor count estimates and contribute to visitor profiles or segments (e.g., if area-related content and interactions are assessed in the context of the socio-demographics reflected in visitors' profiles).

3. The Research Gap

Summarily, visitor monitoring methods vary significantly regarding the character and range of data they provide (e.g., may involve all or only part of the visitors) or the difficulty and cost of initial deployment and subsequent utilization [5,27,28,30–35,38]. The use of visitor monitoring methods is a common part of visitor management practice, however, monitoring is often not implemented systematically enough and data is often available with a significant delay (for example, from offline people counters installed in the terrain or when using data from mobile operators), making the assessment of the destination system state in real-time impossible [4,20]. Visitor monitoring may be hindered by the lack of signal coverage or the low density of the relevant infrastructure in protected areas. Some methods may not be applicable at all (e.g., drones would cause disturbances to nesting birds), while other methods do not provide data sufficiently up-to-date and detailed for comprehensive modelling and assessment of the destination system state in real-time (e.g., counts from offline sensor-based counters). The measuring error may limit usability—e.g., the passive localization data from cellular networks contain only the location of the connected base station, leading to geolocation error up to several kilometers; also, the record is stored only if the mobile device is used for a call, message, or data transfer, leading to an unpredictable sampling frequency. Budget limitations have to be considered too.

So, full exploitation of as much available heterogeneous visitor data as possible (collected by a variety of methods, considering the specific limitations of each of them) is a recommended first step of a cost-effective strategy [36]. Correct and efficient data integration requires a systematic and consistent approach. However, a relevant methodology for the utilization of heterogeneous data is not available, which may be one of the reasons why comprehensive visitor monitoring is so rare.

So, to pave a way towards the operationalization of concepts, such as carrying capacity or LAC, in the context of visitor management of protected areas, (1) the recommended steps for the integration of heterogeneous data about visitors in protected areas and (2) the universally applicable concept of an intelligent tour guide for visitor tracking and for visitor characteristics acquisition are introduced in the results section of the manuscript. The ongoing experimental implementation of the proposed concept is mentioned, and relevant challenges are discussed at the end.

4. Research Questions

4.1. Question 1 Regarding the Data Integration

The first research question focuses on the appropriate way to integrate heterogeneous visitor data as one of the basic conditions for effective visitor management:

Which steps should be taken to integrate and utilize visitor monitoring outputs and other available data, information, and knowledge in an affordable and socially acceptable way to provide a sufficiently detailed real-time and rich insight into visitor behavior, including both space-time curves of visitor passage through the protected area and relevant characteristics, such as socio-demographics, motivation, and perception?

4.2. Question 2 Regarding the Concept of Intelligent Visitor Tracking Software

Secondly, because the practical applicability of individual tracking using visitors' own mobile devices turned into an intelligent tour guide as a promising source of rich data is limited by the lack of relevant systems analysis, the following research question was formulated:

Which characteristics should an individual tracking software applied on visitors' own mobile devices possess, considering both visitor management needs and visitor preferences?

4.3. Question 3 Regarding the Architecture and Implementation Challenges of the Tracking Software

Finally, because the software concept, in order to be implemented and deployed in a protected area, has to be considered within the context of the area characteristics, involved humans, and other related systems, the following research question was formulated:

How does the method of individual visitor tracking by their own mobile devices fit the architecture of an integrated visitor monitoring solution, what potential does such complex software bear, and what challenges affect its implementation and how to deal with the challenges?

5. Materials and Methods

5.1. Initial Conceptualization of the Research Area

The integrated visitor monitoring approach, as well as the relevant concept of an intelligent software tour guide able to monitor visitors and purposefully influence their passage through the protected area and their other behaviors, is built upon (1) the systems analysis of the area of visitor monitoring methods, (2) dynamic concept of visitor flows, and (3) the dynamic and multi-dimensional concept of the carrying capacity. Secondary research draws from the fields of sustainable tourism concepts [8,10], informatics [24], psychology, or sociology focusing on the visitor monitoring and their motivation and behavior, the LAC/carrying capacity concept [4,12–14,16,17], and utilization of information and communication technology in visitor management [24]. In the initial stage of the research, thorough analysis, comparison, and subsequent synthesis of knowledge from the relevant literature on visitor monitoring among managerial activities dealing with tourism sustainability in protected areas were conducted. The research was focused on the literature, covering both the theoretical foundations of visitor monitoring methods and their practical evaluations. The study involved both online and offline visitor monitoring as well as the resulting data utilization.

The research followed the steps:

1. Choose representative publications considering their relevance and scientific value.
2. Identify and record relevant concepts in the involved resources (mainly the monitoring approaches, their main defining characteristics, the resulting data, and its typical utilization).
3. Arrange the concepts in logical clusters.
4. Identify relations between clusters.
5. Apply cognitive synthesis to simplify the resulting map (i.e., remove duplicities, concepts not central to the research area)

The resulting mind map was conceptualized in the IHMC CmapTools environment (Figure 1). It captures the identified concepts, both verified (repeated by various authors) and promising innovative ones, in their logical relations. So, it illustrates the broad spectrum of visitor monitoring approaches (online and offline, in-situ and ex-situ) and their importance for effective and efficient measures for the sustainability of tourism in protected areas.

5.2. Acquisition of Knowledge from Protected Area Management Experts and the Systems Analysis

The mind map served as an input for the subsequent primary research, which involved representatives and experts from the management of several protected areas, national geoparks, and protected area destination organizations in the Czech Republic (Table 1 and Figure 2).

Table 1. Basic characteristics of the Bohemian Switzerland National Park and the protected areas Bohemian Paradise, Broumovsko, and the Iron Mountains involved in the research. Source: [32,56].

The Area	Type	Size [km^2]	Established	Key Features
Bohemian Switzerland (České Švýcarsko)	national park	79	2000	the unique geology and geomorphology of sandstone rocks, the broken topography and the rich biodiversity
Bohemian Paradise (Český ráj)	protected area	181	1955	sandstone rocks supplemented by dominants of eruptive rocks with conspicuous shapes and with folk architecture sights
Broumovsko	protected area	432	1991	cretaceous sandstone relief with the extensive rock-pillar landscape
Iron Mountains (Železné hory)	protected area	286	1991	among the most diverse geological structure in the Czech Republic

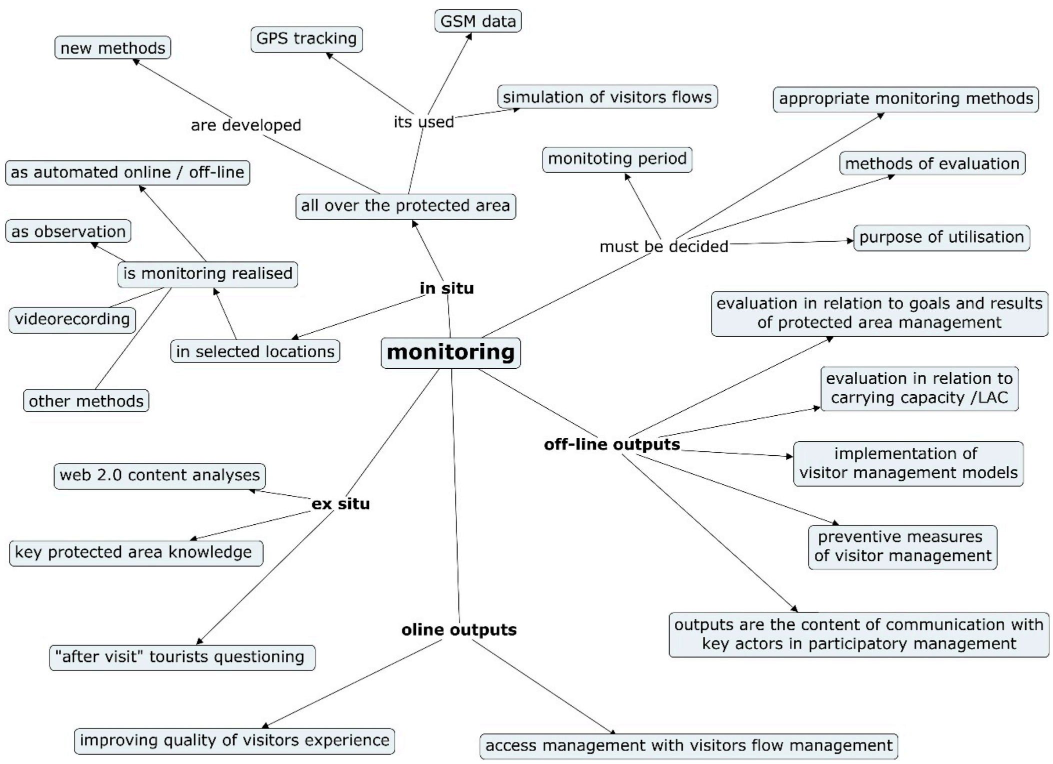

Figure 1. Mind map of the role of visitor monitoring among managerial activities dealing with tourism sustainability in protected areas. Created in IHMC CmapTools 6.03.01 version, based on the literature review [2–4,7,9,21,22,27,43,53].

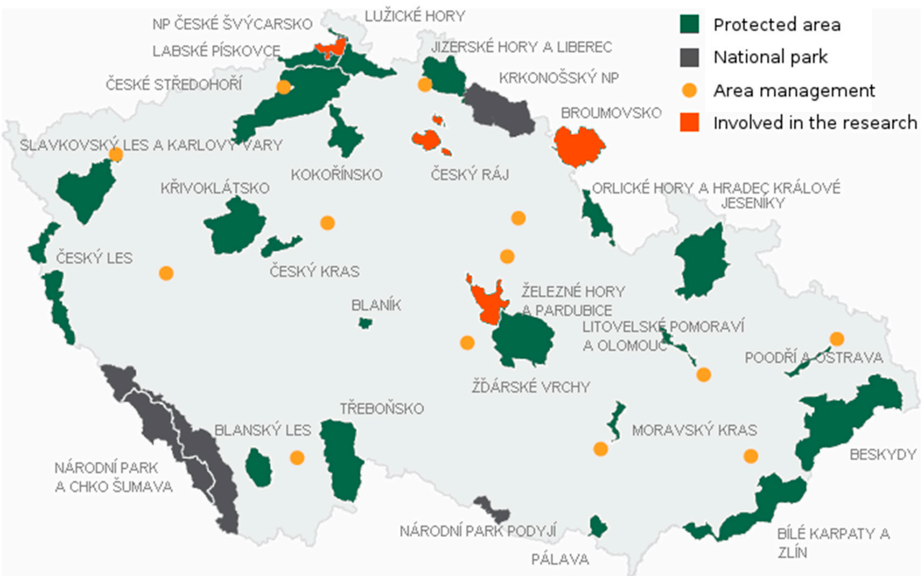

Figure 2. Map of the protected areas in the Czech Republic; the areas involved in our research are marked red. Source: [57].

Gradually, five representatives and experts from protected area management, six destination organization experts, and four geopark experts were involved. None of the protected area experts involved in the research had any previous experience with systematic visitor data integration or with using the concept of the intelligent software tour guide. Summarily, seven individual consultations and managed dialogues followed by four focus groups with brainstorming and the Delphi method were arranged with the experts concerning the research questions and as an input for intelligent tour guide systems analysis. The brainstorming and focus group were used to raise new ideas, and the Delphi method was used to reach a consensus when needed. Based on the questions raised in the previous research and the context of the conceptual mind map, the theme and the program of each meeting was outlined in advance; sets of directed questions, relevant examples from the literature review, and analogies to support creative thinking were prepared, depending on the specific methods chosen for each meeting. From each meeting, a detailed record was made for further analysis. Each record was also shared among participants as a form of feedback and as input material for subsequent meetings.

The combination of methods applied in several iterations during the course of the meetings revealed the experts' knowledge about the natural features; visitors, their characteristics; tourism impacts; current practice of influencing visitors' behavior; the role of information systems; other tourism actors; visitor management and nature protection processes; the role of the time factor, including trends and accumulation of impacts; data and data acquisition methods, including visitor and impacts monitoring; goals, visions, and strategies; and problems, challenges, constraints, and conditions in each of the involved protected areas. The knowledge gathered from the experts was compared, analyzed, synthesized, and generalized in the context of the relevant literature. The intermediate findings were also consulted with the representative of the central office of the Nature Conservation Agency of the Czech Republic, the central agency responsible for the coordination of nature protection and with the department of tourism and spatial planning department of Hradec Králové region, where most of the involved areas are located.

The knowledge gathered from experts served as an input for systems analysis, leading to the design of a computer program—an intelligent tour guide for each involved protected area. Namely, use cases, functional requirements, and other characteristics of the software were identified and discussed. Specific attention was paid to the heterogeneity of the available data and data sources, including differences in the quality and extent of the data (e.g., the coverage of the deployed visitor monitoring methods, the length of timelines, different summation approaches, etc.). Finally, the analysis of both the specifics and similarities between the areas resulted in generalized results (Figure 3)—the formulation of (1) recommended steps for the integration of heterogeneous data about visitors in protected areas, and (2) the concept of an intelligent tour guide for visitor tracking and visitor characteristics' acquisition, introduced in the following results section.

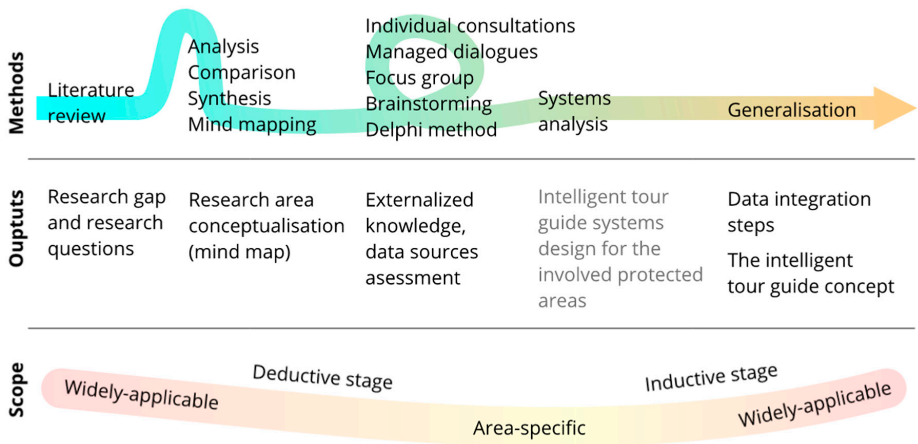

Figure 3. Summary of the methods and their outputs (results) along the course of the research. The literature review is followed by the sequence of steps resulting in the mind map; combination of methods applied in several iterations resulted in externalized experts' knowledge and assessment of data and data sources in each involved protected area; systems analysis resulted in an intelligent tour guide design for each involved area (a result beyond the scope of the manuscript) and set a ground for the widely applicable results—the recommended heterogeneous data integration steps and the concept of an intelligent tour guide.

6. Results

6.1. Recommended Integration Steps for Heterogeneous Visitor Data in Protected Areas

Because meaningful visitor flow and visitor impact modelling require sufficiently comprehensive and accurate data [21], systematic exploitation of all available relevant heterogeneous data about visitors (collected by a variety of methods, each with its specific limitations, e.g., visitor profiles, numbers of sold tickets, counts from sensors, space-time curves of individual visitors) is a recommended [36] and cost-effective approach. Such integration leads to deeper insight and may serve as a basis for more effective communication strategies, more relevant tourist information/navigation systems, or better tourist software [58]. The resulting integrated set of historical data, real-time data, mutual relations, and relevant knowledge provides a foundation for a better understanding of the destination system, including its dynamics. As inferred from the interviews with experts by the means of systems analysis, the process of data integration and exploitation can be described as a set of successive steps (Figure 4):

1. *Purpose/objective clarification.* Define specific visitor monitoring objectives in relation to the protected area's specifics. Purpose clarification may help to decide which inputs are necessary (e.g., visitor counts, space-time curves, structure, behavior and motivation, and impact specifics).
2. *Available inputs mapping.* Reveal which data, sources of data, or knowledge are readily available. Relevant knowledge may be acquired by the means of managed dialogue, brainstorming, the Delphi method, etc. from experts across protected area management, destination organization, and other local tourism actors.
3. *Available inputs assessment.* Evaluate and interpret the available data in regard to the objective pursued. Examine whether the available inputs are sufficient to reflect the destination system and analyze the relations between them and their mutual compatibility. Statistical methods, including deterministic and stochastic modelling, may be used. Hypotheses about the data formulated in this step (e.g., expert assumptions about visitor characteristics) may be further evaluated in the following step.
4. *Inputs extension.* Decide which additional inputs are necessary. Consider the relevance, reliability, budget limitations, etc. Small-scale research to validate patterns appearing in the available inputs may be necessary. Questionnaires among visitors may be used to stratify them into distinctive categories characterized by the purpose of the visit, behavior, impacts on local nature, etc. Necessary additional data sources may be identified, such as people counters or satisfaction devices.
5. *Integration.* Adjust, clean up, or transform the inputs to make them mutually compatible (e.g., same units, compatible intervals), exhaustive (e.g., approximations to fill gaps in the data), and synergistically interlinked (may require, e.g., averaging, calibration).
6. *Exploitation.* Utilize the integrated inputs in harmony with the defined purpose. It may result in a model of the destination system, which reflects the state of the destination system in real-time and allows simulations.

Sample scenario: Visitor management of a protected area requires tourism impact estimates depending on its intensity (step 1). Estimates of proportions of various visitor categories depending on days of the week, holidays, weather, or season, or other factors together with expert estimates of specific impacts of these categories of visitors are available (step 2). Thus, the summed visitor impact can be simulated; or with real-time visitor monitoring data, the summed visitor impact can also be projected in real-time (step 3). However, because the coverage of the area by real-time visitor monitoring is not sufficient, new monitoring devices have to be deployed (step 4). Based on the expert knowledge (proportions of visitor categories, conditional impact estimates) and available data (visitor counts, accumulated impacts), a model has to be constructed (step 5) and used in visitor management practice (step 6).

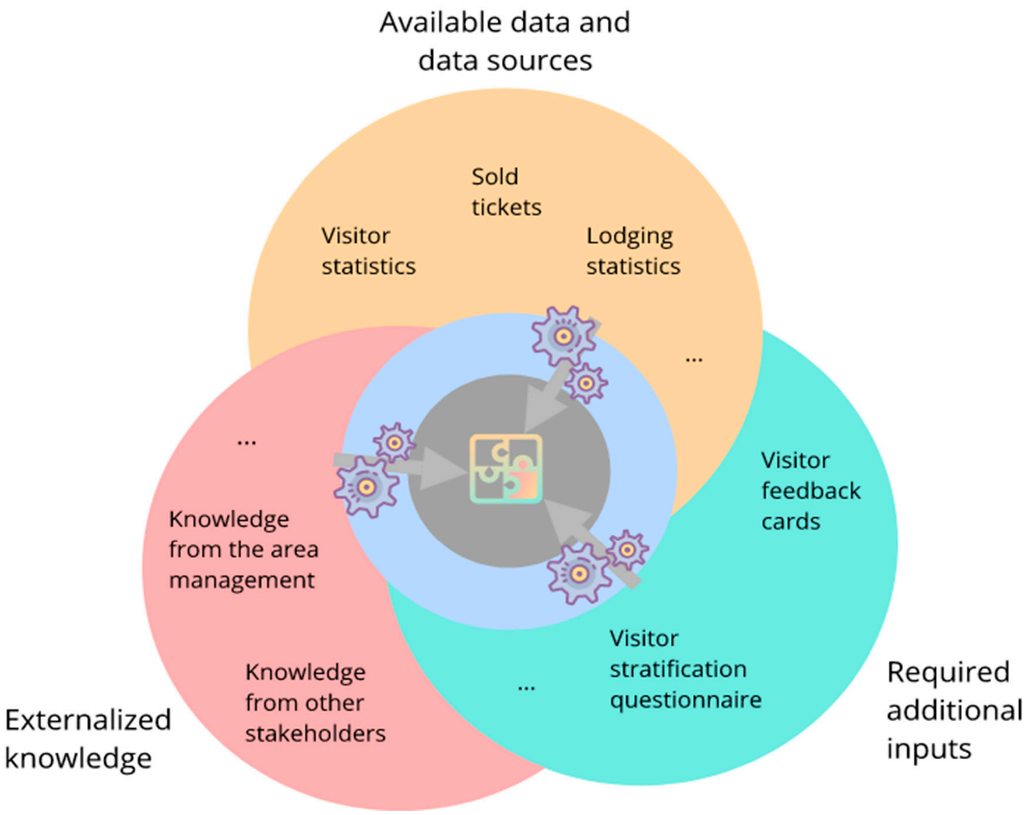

Figure 4. Utilization of inputs for a better understanding of the destination system as a process, starting with mapping (step 2) and assessment (step 3) of clusters of inputs, such as data and knowledge, followed by their extension (step 4) leading through integration (step 5) to their systematic exploitation by the integrating software (step 6) according to the defined purpose or objective (step 1).

6.2. The Concept of an Intelligent Tour Guide for Visitor Tracking and Visitor Characteristics' Acquisition

The following paragraphs summarize the key results of systems analysis based on the knowledge from protected area experts involved in the research as an extension to previous works [50], respecting the proposed dual purpose of the application (serving visitor management and visitors themselves), and technological and scientific state-of-the-art, including users'/visitors' expectations and cognitive approaches. The concept is meant to be generic enough to fit a variety of geographic areas (size, protected features of the local nature, local community, tourism intensity, division of roles in participative management between organizations, etc.) and the variety of available data sources, connected as described in the previous section. The intelligent tour guide has to be:

Reliable, accessible, compatible. Consistent user experience upon varied conditions has to be provided, including device-related differences (operating systems and their versions, display sizes, performance and memory, storage, signal sensitivity, browsers, libraries, etc.), locality related differences (e.g., varying cellular network and satellite locality coverage), and user heterogeneity (different skills and experiences, support for disabilities, etc.). Namely, the user interface has to be consistent, reliable, accessible, usable (both easy-to-understand and easy-to-operate), and reasonably fast in all contexts. Installation and operation have to be almost effortless [59]. The progressive web app [60,61] is one of the recent technologies which might help to facilitate the qualities.

Personalized. The application should know and reflect, e.g., the means of movement, group size, the planned or actual length of the visit; also, the specific needs of physically impaired visitors should be considered [62]. Personalization should build upon the area-specific visitor typology and reflect different motivations, cognition, and perceptions. Not just content (e.g., recommendation selection, selection and level of presented information), but also functions and user interface should be personalized. In addition to the autonomous data collection (tracking the position and interactions with the application), the application may proactively inquire users about their preferences, goals, and perceptions, at defined stages of the visit, for example, using a variant of the Dynamic Real-Time Ecological Ambulatory Methodology (D.R.E.A.M) for subjective data acquisition in participants' natural setting [63].

Location-sensitive. The application should be aware of the current spatial position of the user device, match it with the model of the protected area, and adjust the content and functions accordingly. Location services provided by mobile operating systems, typically relying on satellite, Wi-Fi and cellular network location for increased accuracy, may be used, such as Activity Recognition API of Google, geofencing, and iBeacons [21]. For better point-of-interest or direction recommendations, not just the current position, but the whole recorded space-time curve, including the speed and visitor's stops at previous points-of-interest, should be considered in the context of his preferences and known plans.

Destination-system-aware. The intelligent software tour guide should be aware of the structure and the state of the underlying destination system and should adjust its behavior accordingly, which goes beyond the earlier software tour guide concepts [50,52]. The functionality requires a connection to relevant real-time data sources or, preferably, to a live destination system model reflecting the state of significant localities within the destination system. It involves measured, approximate, and predicted numbers of visitors in relation to the capacity of the tourist infrastructure (parking, accommodation, restaurants, monuments, famous localities, etc.) and to the ecological and psychological carrying capacity in time. With such a model, points-of-interest, directions, and other recommendations may respect not only personal preferences (personalization), the spatial structure of the destination (localities, infrastructure, trails, etc.), and the current position, including the recorded speed and frequency and length of stops (location-sensitiveness), but also the current or predicted state of localities. Visitors at the beginning of their visit may be informed about estimated numbers of visitors at various localities within the destination; such information may help them to adjust their plans and prevent disappointment. The information may be conveyed, e.g., as a histogram, or for stronger impression and impact in a more graphic way as a photograph of the locality captured earlier under similar conditions (visitor intensity, season, weather). If such pictures are not available, generating them artificially (e.g., rendering the estimated number of visitors) may be considered [64].

Interactive and collaborative. Visitors should be motivated for participation by suitable means for interaction and collaboration [50], including integration with common social media [65,66]. The communication may involve fellow-visitors, either those who visited the same destination in the past, those who are present, or those who are planning to come. Sharing experiences, impressions, recommendations, pictures, videos, etc. may be enjoyable, can deepen the visitor's experience, or lead to new relationships. The descriptive content (texts, pictures, videos) used by the software guide may also be co-created or enhanced by visitors themselves, following the wave of volunteered geographic information, or VGI [67,68]. Rules and responsibilities for the content and relevant workflows might be necessary, but with help from visitors, the descriptive content may gradually grow for a minimal cost as in other geosocial networks.

Dialogue-wise. The application should serve as a communication channel between visitors and visitor management. Visitors may be informed about alerts (e.g., a wildfire), events (e.g., a festival in a nearby town), or be educated; visitors should be also given means to comment, recommend, or give feedback to management, which may have a positive psychological effect of being treated as partners and make the visit more engaging. Well-informed visitors are more likely to adjust their behavior to minimize their negative impact [69]. Various interaction mechanisms may be purposefully applied as direct or indirect vectors of influence on visitors' behavior, and thus on the behavior and state of the destination system itself [70].

Decently gamified. Gamification may further increase visitors' motivation and participation [71–73]. It involves concepts, such as reward points, levels, quests, competitions, or contests. Such features will not suit everyone, but for some, the gaming elements may become an essential part of the visit experience.

6.3. Intelligent Tour Guide Implementation Recommendations

Implementation involves the areas of (1) destination system modelling based on the spatial structure, (2) available data and relevant knowledge, (3) descriptive content preparation (texts, pictures, sounds, videos, etc.), and (4) software development, testing, and deployment. It is recommended that the intelligent tour guide is implemented as a component of a complex destination application, which may become a cornerstone of systematic visitor management (Figure 5). The intelligent software tour guide may use the concept of *software agent* [23,74], which at first identifies itself with the type of the visitor and then partly autonomously and partly in reaction on visitor's interaction seeks to maximize estimated enjoyment and experience, respecting the restrictive conditions, such as the carrying capacity. The concept of a persona may be used to differentiate the behavior of the software agent in accordance with the identified categories of visitors. The agent then communicates with the destination system model, e.g., about the current state of localities, and reports back about visitors' movement and interactions.

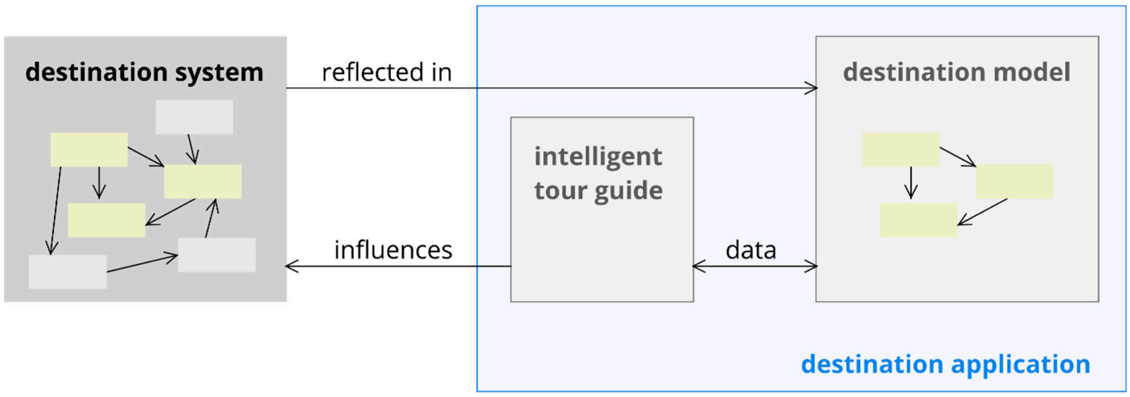

Figure 5. An intelligent software tour guide as a component of the comprehensive destination application. The destination model in the core of the destination application reflects the most important variables and functional relations, which characterize the protected area as a destination system (e.g., visitor counts in monitored localities in relation to the state of the protected features considered most vulnerable to visitor presence). The selection of the variables, relations, and the whole process of destination model construction, though of interest to the authors, exceeds the scope of the manuscript.

To make the destination application *maintainable and extensible*, it is recommended that distinctive functional layers are separated, for example, according to the model-view-controller pattern [75], and to divide functionality into smaller components interconnected through well-defined interfaces. Figure 6 illustrates the layers for presentation, application logic, persistence, and external services, together with the internal component-based structure and main communication flows.

From the initiative of the manuscript authors and with their full participation, an intelligent software tour guide in the context of a complex destination application (Figure 6) is being experimentally developed for the selected protected areas in the Czech Republic [11,69] (Figure 2), starting with the recommended data integration and exploitation steps. The stark differences between and within the involved areas (localities from overloaded to underutilized by tourism) allow the application to be implemented with respect to the specific needs of each area, but also distinguish its common parts. The goal is to design the application for as much code reuse as possible, with regard to possible further implementations also elsewhere.

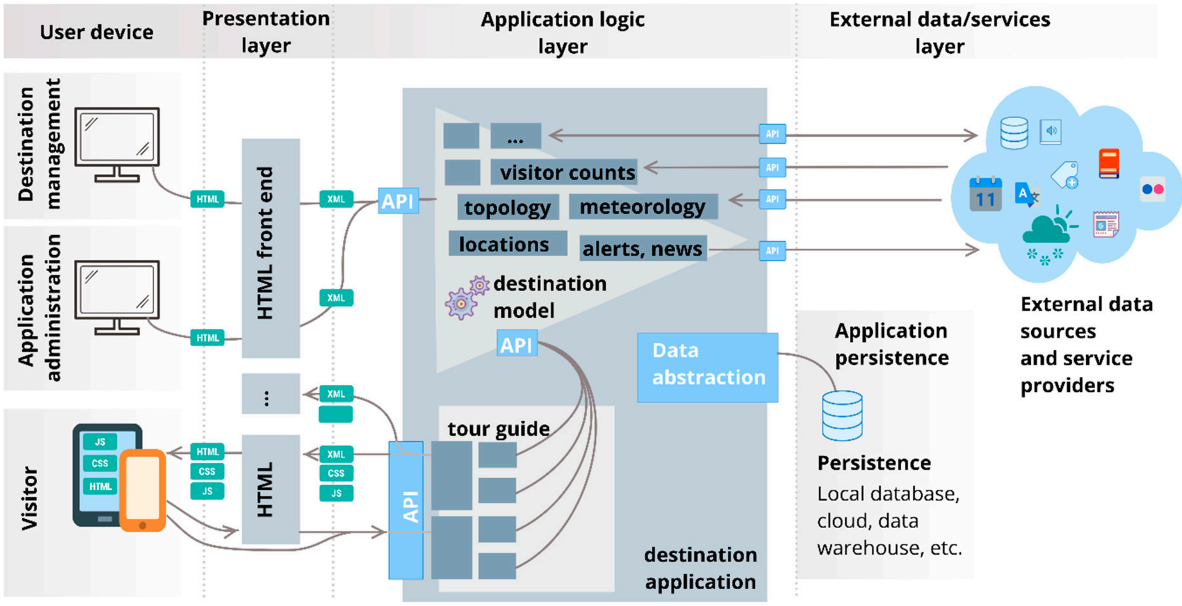

Figure 6. An intelligent software tour guide as a component of the comprehensive destination application is being experimentally developed for selected protected areas in the Czech epublic.

7. Discussion

Regarding *human factors*, the potential of individual visitor tracking to provide rich and valuable data may be hindered by the low motivation to participate [21,50,51]. Low participation may limit the usability of the resulting data and negatively affect the effects of possible attempts to influence the flow of visitors. To overcome the challenge, visitors have to understand the reasons for data collection and also the reward must be obvious, such as the tour guide function. A good understanding of the needs of relevant types of visitors in the analytical phase of its development and reflecting visitors' individual preferences, relevant and high-quality content, and easy-to-use and meaningful functions are necessary preconditions of success. The motivation may be further supported by gamification or involvement of social media. Usability testing, including tests in-situ, may be necessary to prevent as much user mistakes as possible [20,32,37,74]. In addition to the quality of the application, its existence and advantages have to be sufficiently communicated with visitors. Other tourism actors may have to collaborate to ensure effective and affordable propagation; relevant destination organizations and the local tourism industry may be involved. Word-of-mouth is among the most powerful ways of propagation, especially when the critical mass of users is reached. Support for the online recommendation (eWOM) may be an important component of the marketing mix [76].

From the *technical side*, active mobile positioning provides spatially accurate data collected with a sufficient sampling rate, for example, compared to passive localization data automatically recorded by mobile operators. However, still, the low satellite signal in rocks or under the canopy of a dense forest in combination with less-sensitive mobile devices may affect the quality of the data and even the function of the tour guide. The application cannot depend on a permanent Internet connection, considering the often limited cellular network coverage in protected areas and the fact that not all visitors are likely to have a data subscription in their plan. Providing free Internet access may be used as an additional factor motivating visitors to participate. The variety of target devices means that the software design has to deal with compatibility issues.

Regarding the *interpretation of the resulting data*, the bias caused by the selection of participants and the willingness and fitness of members of different visitor groups has to be considered. Also, individual tracking may have an unintended influence on visitors' movement and behavior [49], though the impact and resulting bias is usually acceptably low [31,36,43]. Additional small-scale research by personal interviewing and/or unobtrusive observation may assess the extent of such a bias.

Ethically and legally acceptable data collection may require the acquisition of informed consent from each participant. Credible explanation of the purpose and data protection policies has to be provided. Personal data retention and processing may require the setting of relevant rules and strategies to ensure fair use of the data and its protection. Digitization of visitor experience is also not necessarily desirable; some visitors have some desire for digital disconnection, though often ambivalently accompanied by the value of being connected [77–83].

An *inadequate budget* can lead to compromises, e.g., in the project management, analysis, or implementation, affecting the compatibility, reliability, or usability of the program, or the quality and extent of the underlying model and the set of descriptive data. Poorly designed or maintained applications may lead to disappointment among visitors and eventually abandonment when a critical mass of users is not reached. On the other hand, successful implementation of an intelligent software guide capable of visitor tracking may lead to a major shift in the quality of protected area visitor management. Such an application can increase the visitor experience and at the same time be a source of detailed information about the movement of visitors, their behavior, motivation, and experience. It can also become an effective tool for influencing visitor flows and behavior, all with low operating costs. Because the application serves both the protected area visitor management and visitors, a suitable cost-sharing scheme between area management and a destination organization, local service providers, or other actors may be negotiated.

The variability of the protected areas involved in the research (Table 1 and Figure 2) and the participation of members of protected area management, geopark management, and destination organizations allowed an examination of the problem from various perspectives and with *applicability* beyond the initial scope. Experimental verification of the individual tracking method, supplemented by visitors' feelings and experiences by means of an intelligent tour guide operated in the context of a complex destination application, currently takes place in all involved areas. The application is being carefully designed in harmony with all recommended principles. Namely, a clear distinction is being made between the universal part of the application and area-specific models, configurations, deployment choices, or custom pieces of code. Various research methods are planned, such as simulations, design probes, and usability testing. One of the goals is to evaluate how the growing insight into visitor behavior thanks to the collected data can lead to iterative improvements of the destination model and the potential of the application to purposefully influence the destination system. The research team is looking for other possibilities of verifying the concept presented elsewhere in the Czech Republic and the world. Further research will reveal if the concept is truly generally applicable, as hypothesized, or not.

8. Conclusions

Adequate visitor management requires a good overview of the visitors—their numbers, time-space curves of movement, other patterns of behavior, motivations, feelings, experiences, and impressions. The data collection methods cannot be universally recommended or rejected; their choice should be based on local targets and conditions. Visitor monitoring is a common part of visitor management practice, however, monitoring is often not implemented systematically and does not provide a real-time overview of the area as a destination system. Data from different sources are typically treated separately and management lacks a unified methodology for handling them. Regarding the first research question (Q1), as a result of research which analyzed the knowledge of experts from several protected areas in the Czech Republic, recommended *data integration steps* were formulated (Figure 3). They may serve as a basis of a generic data integration and exploitation methodology for protected areas. Systematic data and knowledge integration can provide a more comprehensive understanding of visitors and their behavior and can be used to implement a destination system model—a basis for an intelligent software tour guide or a complex destination application.

In the answer to the second research question (Q2), an intelligent software tour guide has to provide high-quality content, intelligible functionality, and a reliable, usable, and accessible user interface; it should be personalized, location-sensitive, aware of the structure and state of the destination system, able to facilitate interaction and collaboration between visitors and a dialogue between visitors and the protected area management, gamified and well-presented, and usable both in-situ and for planning a visit. Visitors may contribute their own interpretative content, such as photographs, textual descriptions, and comments.

In relation to the third research question (Q3), an intelligent software tour guide that is aware of the destination system structure and its current state would not only collect data but also guide visitors according to their preferences while fully respecting the dynamically changing ecological, physical, and psychological carrying capacities of individual localities within the destination. So, visitor management will be able to influence the visitor flow, with respect to the momentary carrying capacity of each locality and its current and predicted occupancy, and inform visitors about current events, alerts, and traffic in key localities. Treating visitors not just as a problem but also as an opportunity, and not merely consumers, but also partners [11,69]; an awareness of nature conservation issues and their participation could be raised among them, via education, motivation, and engagement in meaningful activities.

Summarily, the intelligent software tour guide is a promising concept of a tool for influencing the flow of visitors, patterns of their behavior and, as a result, the destination system as a whole. It also respects the digitalization of society and the related changes in cognitive and behavioral patterns of visitors and tourism actors [18,84]. However, cycles of experimental development and deployment in contexts of various protected areas, followed by the feedback assessment and analysis of its impacts are necessary to evaluate its practical value for both visitor management and visitors. It will allow the formulation of additional research questions and precise hypotheses regarding the concept itself, visitor behavior, visitor management methods, or tourism sustainability. The first round of such experiments is ongoing in the selected protected areas of the Czech Republic. Clear separation of universally applicable and area-specific parts of its architecture will allow the participation of other teams willing to implement the software concept elsewhere. The experimental implementation and deployment will allow an assessment of the limitations of the concept regarding its applicability in various types of protected areas, for different groups of visitors, and reveal additional technological and infrastructural requirements.

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