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Review

Carrying Capacity and Adaptive Visitor Use Management for Sustainable Parks and Protected Recreation Areas: A Critical Narrative Review

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Abstract

This study examines carrying capacity in parks and protected recreation areas as a measurement, monitoring, and adaptation component of sustainable visitor use management. For a concept-focused critical narrative review, Scopus and the Web of Science Core Collection were searched, and 2493 records were identified. After removing 819 duplicates, 1674 unique records were screened. Overall, 370 records were evaluated as topically eligible. A 78-source critical-synthesis core, comprising central database records, foundational books, and institutional documents identified through citation chaining, was evaluated against seven common criteria. The findings demonstrate that carrying capacity is not a single, context-independent visitor count. Rather, it is an adaptive process requiring the definition of desired ecological and experiential conditions, the monitoring of indicators and standards, and management intervention when thresholds are exceeded. The study's contribution lies in comparing ROS, LAC, VAMP, CCAP, VIM, VERP, and IVUMF using common criteria, explaining the interdependence of physical, ecological, social, managerial, and economic dimensions, and jointly evaluating geographic transferability and digital data governance. In conclusion, sustainable management depends more on the organizational implementation of an indicator–standard–monitoring–action chain than on a numerical limit.

Keywords: carrying capacity; visitor use management; protected areas; sustainability; adaptive management; visitor impact management; indicators and standards

Academic Editor: Mark A. Bonn

Received: 25 June 2026
Revised: 3 August 2026
Accepted: 5 August 2026
Published: 7 August 2026

1. Introduction

The increased demand for outdoor recreation following COVID-19 has made it clear that visitor pressure in many parks and protected areas should be assessed not only by total use numbers but also by temporal concentration and spatial distribution [1,2]. Digitally mediated travel planning and the search for nature-based experiences can particularly influence site selection and pre-visit information use among younger visitor groups [3]. These developments have two consequences for management. Demand and concentration should be monitored more frequently, and social media and user-generated geographic data should be used in conjunction with counter, observation, and survey data, while

 https://doi.org/10.3390/su18168037

accounting for representational bias [4,5]. Thus, the pandemic and generational change are considered not as independent trend descriptions, but as a management context that alters indicator selection and monitoring frequency.

This current trend is a continuation of the mass demand for longer-term recreation, fueled by industrialization, urbanization, changes in working hours, and the expansion of transportation options. The fundamental challenge of park management is to prevent unacceptable degradation of vegetation, soil, wildlife, trail systems, and cultural values while maintaining accessibility and a quality visitor experience [6,7].

Visitor pressure is particularly concentrated in foregrounds close to infrastructure and services, protected areas near city centers, popular viewpoints, camping and hiking hotspots, and during seasonal peak periods. This concentration should be assessed not only by total visitor numbers but also by the spatial distribution of use, visitor behavior, type of activity, and the biophysical sensitivity of the area [8,9]. Overcrowding and misuse have failed to meet the expectations of visitors. Nonetheless, the aim in the use of protected areas is to protect the natural and cultural resource values and to pass them on to future generations without deterioration [10]. Therefore, the management problem is not to find a single, immutable maximum visitor density that the area can allow. Carrying capacity is the process of defining desirable conditions for ecological resources, cultural values, and visitor experience under specific management objectives. It monitors them through indicators and standards, and implements appropriate interventions, including the level of use, when thresholds are exceeded [6,11]. Numerical limits may be a valid tool in cases of security, physical facility capacity, or mandatory allocation. Notwithstanding, they are not proof of sustainable conditions alone.

In this study, sustainability is operationalized as the simultaneous maintenance of ecological integrity, acceptable quality of experience, equitable access, local community well-being, and institutional capacity to monitor these outcomes. Thus, carrying capacity is positioned as a tool that links indicators for measuring and monitoring sustainability to management action [6].

The established literature has detailed the critique of interpreting carrying capacity as a fixed number and the shift towards indicators, standards, and adaptive management [6,11]. Ajuhari et al. [12] systematically classified capacity assessment methods in recreation and tourism destinations. Da Mota et al. [13] examined the methods and global trends in measuring visitor capacity in natural areas through a quantitative literature synthesis. Rather than repeating the scope of these reviews, this study focuses on three gaps. These gaps are a comparison of ROS, LAC, VAMP, CCAP, VIM, VERP, and IVUMF using the same critical criteria; an explanation of the reciprocal feedback of physical, ecological, social, managerial, and economic capacity; and a combined assessment of geographic transferability and digital data governance. Therefore, the contribution is not to reaffirm the thesis that "carrying capacity is not a static number," but to develop a comparative decision-making logic that shows which framework is applicable under which problem, data, and organizational capacity conditions.

This study seeks to answer the following research questions:

RQ1: How has the concept of carrying capacity evolved in the literature on parks and protected recreation areas from a quantitative understanding of capacity to an approach based on indicators, standards, and adaptive visitor use management?

RQ2: What key indicators, data types, and management decisions are associated with the physical, ecological, social, managerial, and economic capacity dimensions?

RQ3: What are the strengths, limitations, and transferability issues of models such as Recreation Opportunity Spectrum (ROS), Limits of Acceptable Change (LAC), Visitor Activity Management Process (VAMP), Carrying Capacity Assessment Process (CCAP), Visitor Impact Management (VIM), Visitor Experience and Resource Protection (VERP), and Interagency Visitor Use Management Framework (IVUMF) in terms of application?

The answers to these questions will shift the contribution of the article from merely reiterating carrying capacity as the maximum number of visitors to critically synthesizing the concept's role within normative decisions, monitoring indicators, social acceptance thresholds, and adaptive management.

The following section of the article describes the search, selection, and evaluation protocol for the concept-focused critical narrative review. Section three presents the conceptual evolution and the theoretical break that became evident with LAC; section four presents the five capacity dimensions and the feedback loops between them; section five provides a comparative evaluation of seven visitor management frameworks. Section six integrates the findings, section seven presents conditional managerial implications, section eight discusses limitations and future research, and the last section presents the key conclusions.

2. Methodology

This study is a concept-focused, critical narrative review examining the conceptual development of carrying capacity, capacity dimensions, and visitor use management frameworks in parks and protected recreation areas. This design is suited to comparing the assumptions, theoretical tensions, and application conditions of concepts, rather than combining heterogeneous empirical studies, theoretical works, and institutional guidelines into a single effect size [14]. The study does not claim to be a systematic review or meta-analysis. Nevertheless, databases, full search strings, filters, search dates, suitability criteria, deduplication rules, and record-based decision logs have been reported to enhance the traceability of the selection. The justification and reporting adequacy of the narrative review have been checked against SANRA principles [15].

Bibliographic searches were conducted on 23 July 2026 in Scopus and 28 July 2026 in the Web of Science Core Collection. The TITLE-ABS-KEY field was used in Scopus, and the Topic field in Web of Science. No starting year limit was applied, and records indexed up to 2026 were considered. English-language articles and reviews were selected in both databases; the Scopus search was also limited to the final publication stage. Subject area, country, source title, and open access filters were not applied. Full queries are given in Supplementary Table S1.

A total of 2493 records were identified, including 1259 in Scopus and 1234 in Web of Science. Overall, 819 duplicates were removed using DOI, title-year-first author, and title-year-source fields. In addition, 1674 unique records were screened using title, abstract, and keywords. Studies on biological or resource carrying capacity not related to visitor/recreational use, studies lacking a focus concept, those outside the context of park/protected area/nature-based recreation, those only incidentally mentioned, and retracted studies were excluded. At this stage, 1304 records were excluded, and 370 records were found to be topically eligible. The 78-source critical-reading core comprised central database records, foundational books, and institutional documents identified through backward and forward citation chaining. All record-based decisions are presented in Supplementary Table S1.

The synthesis core was evaluated under seven common criteria: (1) clarity of normative decision; (2) integration of physical, ecological, social, managerial and economic dimensions; (3) operational nature of indicators and standards; (4) monitoring and adaptive feedback; (5) institutional applicability and data load; (6) stakeholder engagement, equity and accessibility; (7) geographical, cultural and digital transferability. These criteria enabled not only a description of the frameworks but also a comparison of the issues and the data/institutional capacities under which they could operate. Figure 1 summarizes the identification, dedu-

https://doi.org/10.3390/su18168037

plication, screening, topical eligibility, and critical-prioritization stages used to construct the review corpus.

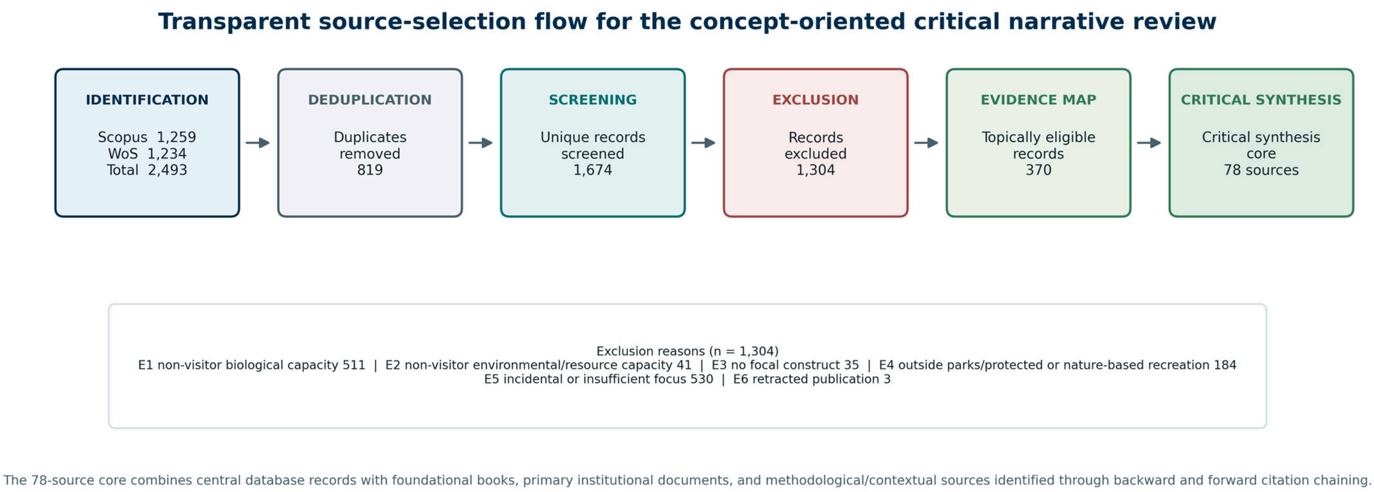

Figure 1. Transparent source-selection flow for the concept-oriented critical narrative review. Note: The 78-source synthesis core combines central Scopus and Web of Science records with foundational books, primary institutional documents, and methodological or contextual sources identified through backward and forward citation chaining. This is a transparency flow for a critical narrative review and should not be labelled as a PRISMA flow diagram.

3. Conceptual Evolution of Carrying Capacity

The term "carrying capacity" has a longer and more controversial genealogy than its contemporary use in park management implies. Before becoming a concept in recreation and visitor use management, the term circulated in various fields such as shipping, biology, rangeland management, wildlife management, and population ecology [16,17]. In rangeland and pasture management, carrying capacity refers to the level of animal use that can be sustained without causing unacceptable damage to pasture resources, although early range scientists cautioned that this capacity could not be defined with complete numerical precision [16,17]. In wildlife management, Leopold [17] applied carrying capacity in the context of animal populations and game management. In the field of recreation, Wagar [18] reframed the problem for wildlands by relating biological impacts to social conditions such as crowding, user conflict, and visitor satisfaction. Later frameworks such as Limits of Acceptable Change (LAC), Visitor Impact Management (VIM), Visitor Experience and Resource Protection (VERP), and the Interagency Visitor Use Management Framework (IVUMF) have moved the concept away from a single numerical limit and towards indicators, standards, monitoring, and adaptive management [19–22].

The concept of carrying capacity was initially used in the natural resource management and recreation literature to describe the extent to which a particular area could sustain a certain level of use. However, in park and protected area management, the concept has increasingly evolved into a normative and managerial framework that seeks to answer not just the question of "how many people?", but also "what resource and visitor experience conditions are acceptable?" [23,24]. The historical development of the concept is not linear, as it has acquired different meanings in different disciplines. Sayre [24] shows that the concept of carrying capacity is used with different normative assumptions in the literature of ecology, rangeland management, wildlife management, and human-environment relations. In the context of recreation and park management, the main importance of the concept stems not from producing an absolute and universal capacity number, but from enabling the simultaneous definition of acceptable resource conditions and visitor experience standards [12,24]. Comprehensive studies on carrying capacity, which deeply concern park management, began in the 1960s [25]. Initially, the focus of carrying capacity studies was the relationship between visitor use and environmental conditions [26].

Researchers argued that carrying capacity is not an absolute value but can be determined according to the natural and cultural characteristics of the area. Its capacity depends on the quality and quantity of recreational experiences. The carrying capacity consists of two components. These are physical (environmental) and perceptual (psychological) ones. This concept is a mixed system used by outdoor recreation areas, especially natural areas, shaped according to their unique structure [27]. Early recreation literature often defined carrying capacity as the maximum number of people that an area could accommodate without unacceptable resource degradation or decline in experience quality; subsequent frameworks demonstrated that this formulation was insufficient as a complete management system [28].

LAC is a theoretical turning point because it shifts the management question from "how many people can the site accommodate?" to "what ecological and experiential conditions are acceptable, and what action will be taken when these conditions deteriorate?" While the traditional approach seeks number as an objective characteristic of the site, LAC makes it clear that standards are value-laden management decisions. It considers the level of use not as the sole cause of effects, but as one of the manageable pressures, and places monitoring-action feedback at the center of the process [11,19]. However, LAC does not technically eliminate value conflict: who determines acceptable change, how monitoring is financed, and whether there is authority to enforce when the threshold is exceeded determine the success of the implementation. Table 1 organizes the development of carrying-capacity thinking around changes in the dominant management problem rather than around chronology alone.

Table 1. Conceptual shifts in carrying-capacity thinking and their unresolved management problems.

Period/Phase	Dominant Framing	Conceptual Shift	Unresolved Issue/Representative Sources
1900s–1950s	Ecological or range upper limit	Sustainable use was framed as a maximum level compatible with specified resource conditions.	Numerical precision and transfer across species or settings remained problematic—Sampson (1923) [16]; Leopold (1933) [17].
1960s	Recreation carrying capacity	Biophysical impacts were linked to crowding, conflict, satisfaction, and experience quality.	No single optimum number; use–impact relationships are context-dependent—Wagar (1964) [18].
1970s	Opportunity spectrum and zoning	A single desired experience was replaced by differentiated setting and experience classes.	ROS supplies planning context but not a direct threshold or capacity decision—Clark and Stankey (1979) [29].
1980s	Limits of Acceptable Change	LAC made desired conditions, indicators, standards, and management actions the central decision architecture.	Standards remain normative and require monitoring, authority, and enforcement—Stankey et al. (1985) [19].
1980s–1990s	Activity, impact, and experience frameworks	VAMP, CCAP, VIM, and VERP operationalized the problem through different planning entry points.	Performance depends on data quality, institutional continuity, and causal diagnosis—Graham et al. (1988) [30]; Graefe et al. (1990) [20].
2000s	Critique of numerical certainty	Carrying capacity was explicitly reframed as a value-laden decision and monitoring process.	Renaming the concept does not by itself close the implementation gap—McCool and Lime (2001) [11]; Manning (2007) [23].
2010s	Integrated visitor-use management	IVUMF positioned capacity as one component of a broader adaptive visitor-use management cycle.	Continuous monitoring, interagency coordination, and stable resources are required—IVUMC (2016) [22]; Leung et al. (2018) [6].
2020s	Social–ecological and digital layer	Resilience, distributional effects, and multi-source visitor data entered the management debate.	Privacy, representation bias, equity, and transferability remain unresolved—Tenkanen et al. (2017) [5]; Heikinheimo et al. (2017) [4].

Most scientists who have studied this subject argue that carrying capacity is a management system that enables the setting of appropriate management goals for the sustainability or restructuring of ecological and social conditions [31].

Social–Ecological Context

Carrying capacity, resilience, adaptive capacity, and socio-ecological systems are not the same concepts. Carrying capacity operationalizes acceptable conditions and intervention thresholds under specific management objectives. Resilience is the capacity of a system to absorb disruptive impact without losing its core identity and functions. Adaptive capacity is the ability of actors and institutions to learn and adjust. The socio-ecological systems approach integrates visitors, local communities, institutions, and ecosystems into the analysis unit through their mutual feedback [32,33]. Therefore, capacity indicators are not synonymous with resilience, but rather status and pressure signals within resilience-focused governance. When indicators are linked to longitudinal monitoring, explicit decision-making authority, and a learning cycle, carrying capacity analysis can function as an early warning and intervention component [34].

Figure 2 integrates the historical change in the dominant management question with the five interdependent capacity dimensions and the indicator–standard–action–monitoring–adaptation cycle. Visual logic in Figure 2 can be explained as follows: "Fixed/maximum number" → "use–impact and social norms" → "LAC/VIM/VERP: desired conditions + indicators + standards" → "IVUMF: adaptive visitor use management". The cycle at the bottom: Management objective → Indicator → Standard → Monitoring → Threshold overshoot → Action → Re-evaluation. In the outer framework: ecosystem, visitors, local community and institutions; intersecting principles: sustainability, resilience, equity and data governance.

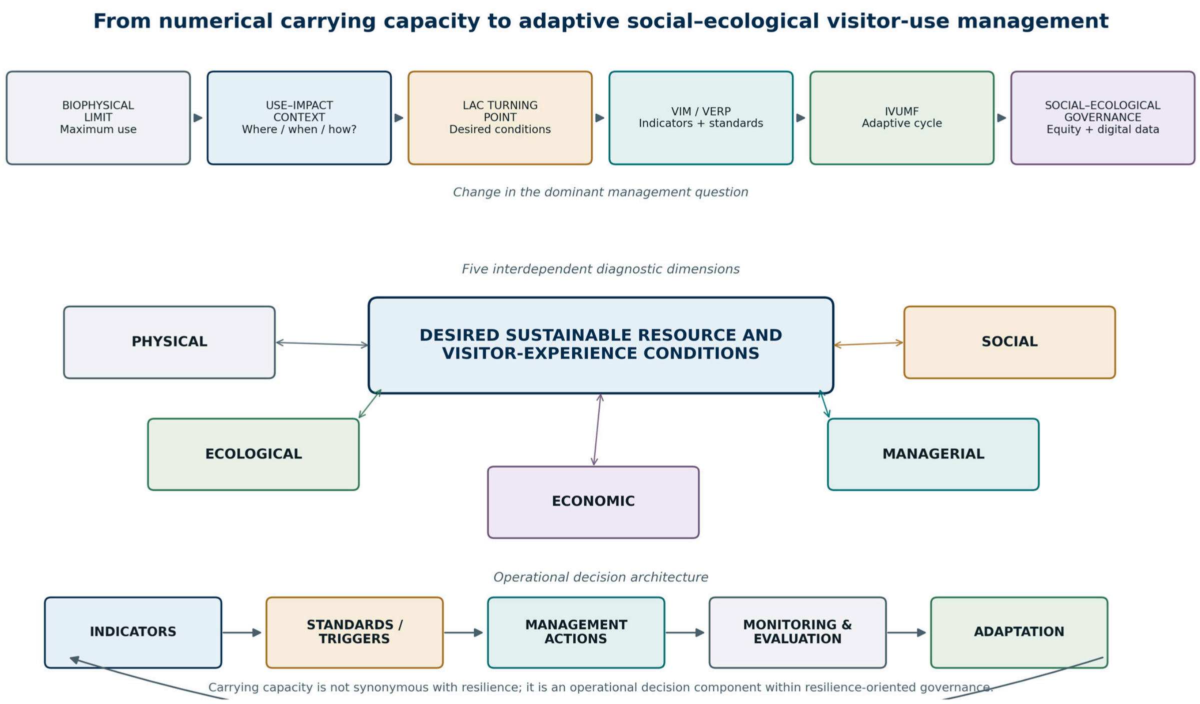

Figure 2. Conceptual transition from numerical carrying capacity to an adaptive social–ecological visitor-use management architecture.

4. Dimensions and Indicators of Carrying Capacity

In the literature, carrying capacity has been classified by different authors using physical, ecological, social, economic, managerial, perceptual, or infrastructural dimensions.

Although these classifications differ terminologically, the common issue for park management is how each dimension should be monitored using various indicators and how this information should be translated into management decisions. Therefore, this study synthesizes these scattered classifications into physical capacity, ecological capacity, social capacity, managerial capacity, and economic capacity. Table 2 distinguishes observable indicators from decision standards and shows why each capacity dimension must be evaluated together with at least one cross-dimensional safeguard indicator.

Table 2. Capacity dimensions, indicators, standards, and cross-dimensional feedback in sustainable visitor-use management.

Dimension	Key Management Question	Example Indicators	Standard/Decision Rule	Principal Cross-Dimensional Feedback
Physical	Are spatial and facility flows safe and functional?	Parking occupancy; queue time; trail or facility throughput; access-point load.	Hourly occupancy or safety threshold; timed entry; circulation rule.	Additional infrastructure may stimulate demand and shift pressure to ecologically sensitive sites.
Ecological	Are resource conditions within acceptable limits?	Soil compaction; vegetation loss; trail widening; wildlife disturbance; water quality.	Zone- and season-specific resource standard; closure or restoration trigger.	Impact depends on activity type, spatial concentration, behavior, and management—not only on total use.
Social	Are experience, conflict, and access conditions acceptable?	Encounters; perceived crowding; displacement; satisfaction; norms; distribution of access.	Experience-zone- and user-group-specific normative range.	Restrictions may displace use or costs to other sites, times, or user groups.
Managerial	Can the institution maintain the desired conditions?	Authority; staffing; budget; monitoring coverage; maintenance; enforcement; coordination.	Minimum monitoring and intervention service level; defined decision authority.	Low institutional capacity weakens measurement quality, implementation, and legitimacy.
Economic	Are benefits, conservation costs, and distributional burdens sustainable?	Visitor expenditure; local value added; leakage; management cost; revenue; housing and infrastructure burden.	Fiscal or investment decision conditional on ecological and social standards.	Revenue pressure may increase use, while earmarked conservation investment may improve resource and management conditions.

Physical capacity is the maximum number of visitors that recreation areas can carry in a certain period. It is about physical characteristics and physical facilities. A number of parameters related to the physical characteristics and physical facilities of the area are used [35]. These parameters vary according to the characteristics of the recreation location and type of recreation. Physical capacity refers to the level of use that a recreation area can accommodate. It is supported by its spatial layout, access system, and facility infrastructure. This dimension can be assessed by using indicators such as parking area, car park and transport capacity, trail width, picnic and camping units, beach access areas, climatic constraints, sensitive zones, and topographic limitations. Nonetheless, physical capacity alone is insufficient. The same number of visitors can yield different results in areas with varying ecological sensitivities, social norms, and management capacities [25,36].

Cifuentes [36] developed the recreational carrying capacity method with three dimensions named as physical, real, and effective [37]. The dimensions in this method are based on parameters related to the physical characteristics of the area and management possibilities. The method does not include ecological and social parameters and is lacking in terms of determining the management dimension. Nonetheless, it is effective in determining the physical carrying capacity.

Social Capacity can be defined as the upper level of visitor density in a recreational area where each visitor has equal opportunities in terms of the services offered. Social capacity is related to the effects of visitor density on experience quality, crowd perception, satisfaction, and acceptable encounter norms. Therefore, social capacity should not be evaluated as a single "highest tolerance" level, but rather as a tolerance range that varies according to visitor profile, experience level, activity type, trail or area conditions, and cultural norms [9,38].

More explicitly, the following questions are being sought [39]: What is the relationship between the level of visitor use and visitors' perceptions of crowds? To what extent is the effect of crowds on the quality of visitor experience acceptable? At what level of crowding does management intervention require [40]? Researchers who have examined the relationships between crowd perception and the personal characteristics of visitors have concluded that nationality, age [41], experience [42] and visiting the recreational area for the first time [43] are influential factors in crowd perception [44]. The characteristics of the recreation area, its topographical structure, and the type of recreation are also influential factors in crowd perception [45].

In assessing social capacity, visitor surveys, direct observation, encounter counts, crowd perception scales, photo/video simulations, spatial use data, and norm curves can be used in combination. Visitor surveys measure perceived crowding, satisfaction, displacement, visitor norms, and tolerance ranges. Direct observation records actual behavior, spatial concentration, queuing, and rule violations in specific areas and time periods. Encounter counts quantitatively determine the frequency of contact between visitors or groups and are particularly useful for trails, campgrounds, viewpoints, and water-based recreation routes. Crowd scales transform subjective evaluations of density into comparable social indicators, while photo and video simulations allow managers to test visitor responses to alternative use levels before implementing restrictions. Norm curves help identify preferred, acceptable, and unacceptable conditions. Thus, they support the definition of standards and thresholds. No single technique should be considered universally superior. The most robust social capacity assessments use multiple techniques in conjunction through triangulation and relate the results to clear indicators, standards, monitoring protocols, and management actions [23,25].

Ecological capacity refers to the effects of recreational activities on the ecosystem. Ecological carrying capacity is based on the determination of ecosystem parameters. It is based on monitoring the impacts of visitor use on soil, vegetation, water resources, wildlife, trail systems, and habitat integrity. Recreation ecology studies show that there is not always a linear relationship between the amount of use and the level of impact. The impact varies with the type of use, spatial concentration, biophysical sensitivity of the area, and existing management measures [7,8,28]. Although the ecosystem parameters vary according to the physical and ecological structure of the recreational area and the type of recreation, some parameters are generally examined in previous studies.

Studies that examine, evaluate, and monitor visitor impacts in natural areas to determine ecological capacity are called recreational ecology studies [7,45]. Vakhlamova et al. [46] addressed the effects of recreational uses on fauna, vegetation, soil, and water, and how these effects can be managed, establishing general principles. Each ecological capacity parameter has been examined by different methods by the relevant professional disciplines. Therefore, the subject needs to be evaluated within the scope of multidisciplinary and long-term studies.

Managerial capacity should be assessed at two related levels. Institutional capacity encompasses legal duties and intervention authority, interagency task sharing, decision legitimacy, stakeholder engagement, sustainable funding, and accountability. Operational capacity refers to the number and qualifications of personnel, budget, equipment, visitor and ecological monitoring systems, maintenance, communication, enforcement, and emergency procedures. The first level answers the question, "Who can make decisions and allocate resources?" The second level answers, "Can the decision be implemented and monitored in the field?" If either of these levels is insufficient, the defined standard or visitor limit cannot be implemented. Therefore, managerial capacity should be considered as the ability to maintain the desired resource and experience conditions [22,36,47,48].

Economic capacity should not be reduced to a single indicator of "visitor spending." At the first level, the regional impact of visitor spending on employment, income, and local added value can be examined by using input-output or multiplier approaches. At the second level, the non-market welfare value of recreation can be estimated through travel costs, contingent valuation, or choice experiments. At the third level, whether entry/permit revenues cover the costs of monitoring, conservation, maintenance, transportation, and visitor services is evaluated in terms of financial sustainability [6,49].

Economic benefit is not a capacity measure that replaces ecological and social standards. While local employment and income increase, leakage, housing and service costs, seasonality, labor pressure, or conservation costs may be borne by specific groups. Hence, economic indicators, resource status, visitor experience, and distributional impacts should be monitored. Income growth should not unjustifiably relax predefined ecological thresholds [50,51].

The five capacity dimensions are not independent "ceilings," but rather interdependent conditions that react differently to the same management intervention. For example, increasing parking or pathway capacity may reduce physical bottlenecks while increasing aggregate demand and ecological pressure. A reservation system may reduce social crowding but affect accessibility and local business revenues. Insufficient staffing may render monitoring and enforcement unsuccessful, even if ecological and social standards are correctly defined. Therefore, at least one cross-dimension conservation indicator should be identified in addition to the primary indicator for each capacity decision. The management cycle should be based not on the question of "which dimension yielded the lowest number?" but rather on the questions of "which condition is being disrupted, what is the mechanism, and what other condition is being affected by the intervention?" [6,34,47].

5. Visitor Management Frameworks

Since the mid-1960s, studies on carrying capacity have rapidly become widespread, and the impacts of recreational activities in national parks and other nature reserves have begun to be evaluated through carrying capacity analyses. There is an agreement that the intense demands faced by national parks and natural areas in the context of recreational uses inevitably lead to deterioration in natural and cultural resource values. However, researchers have raised questions about what constitutes the acceptable limit [52]. Developments in carrying capacity analyses suggest that these questions can be answered through the development of management models and the definition and determination of quality indicators and quality standards related to this issue. This approach has become one of the fundamental starting points for carrying capacity studies in the recreation field in the last twenty years. Numerous visitor management models have been created based on recent research within this framework [12].

There are three main reasons why the traditional carrying capacity approach has long been questioned. First, the relationship between the amount of use and the impact is not linear in most areas; initial units of use can create disproportionate impact, and behavior and spatial concentration can be more descriptive than the total number. Second, "unacceptable impact" is a normative decision before scientific measurement. The same evidence can translate to different standards under different experiences or conservation goals. Third, since capacity varies with season, site zone, user group, infrastructure, and management response, presenting a single, context-independent number as the objective characteristic of the area produces false certainty [11,23]. Numerical limits may be necessary under conditions of safety, limited facilities, legal allocation, or irreversible sensitivity. The criticism is not directed at the number itself, but at its use as if it were the entire decision-making system.

ROS, LAC, VAMP, CCAP, VIM, VERP, and IVUMF address different parts of these problems. Notwithstanding, no framework automatically selects acceptable conditions, creates a monitoring budget, resolves interagency conflicts of authority, or guarantees enforcement if a threshold is exceeded. Implementation failure often stems not from the framework's name, but from unmeasurable indicators, vague standards, data discontinuity, insufficient participation, and lack of authority to act [6,22,47].

Recreational Opportunity Spectrum (ROS) was developed by employees of the US Forest Service and Bureau of Land Management. As a result of concerns arising from growing recreational demands and the use of scarce resources, a set of parameters and rules for recreational opportunity management was determined by examining the physical, biological, and social conditions of the area and the relationships between them. Consequently, a comprehensive and integrated "natural resource planning approach" was developed [29,53].

The ROS inventory system includes six areas. These are Primitive (P), Semi-Primitive Non-Motorized (SPNM), Semi-Primitive Motorized (SPM), Roaded Natural (RN), Rural (R), and Urban (U). These classifications are determined by core physical and spatial factors including remoteness (distance from roads) and the degree of naturalness (level of human modification) ROS is defined as a regional recreation planning tool to help managers and planners to create inventories, design target management standards, decide among alternative management activities, and provide broader context in planning recreation resources for multiple uses [54].

Acceptable Limits of Change (LAC) is a planning system developed by Stankey et al. [19] in response to concerns about visitor management within the US National Nature Reserve. The LAC process focuses on the collection and interpretation of data on appropriate and acceptable resources and social conditions. It identifies recreational opportunities that need to be sustained or new recreational opportunities to be created [55]. In this method, a strategic and tactical management plan is created for each location. The places are separated according to the types of recreational opportunities offered by the area. While creating these plans, social and ecological data obtained from each location are defined and analyzed in line with quality indicators [56].

Visitor Activities Management Process (VAMP) was developed by Graham et al. [57] to assist the Natural Resources Management Process within the Canadian Parks Management Planning System. It was developed through work conducted with the Canadian Parks Service. The model serves as a guide in the planning of new and developing parks as well as parks that have completed their development. The basic principles of VAMP are to create a guide to principles and implementation policies, a management plan guide, and a visitor activity guide [6].

Shelby and Heberlein [57] worked on the CCAP (Carrying Capacity Assessment Process) model to determine the carrying capacity of Grand Canyon National Park, located on the Colorado River. This model is particularly focused on determining social capacity. In the CCAP model, it is argued that the concept of sociology is important in determining visitor satisfaction. Therefore, questionnaires prepared according to certain criteria were used to measure users' preferences. In addition, empirical data related to the evaluation and decision-making phase of the process were obtained. CCAP is a method that organizes and clarifies a set of concepts, variables, and procedures to establish carrying capacity [51,52,57].

VIM (Visitor Impact Management) emerged as a result of a study conducted by the US National Parks and Conservation Agency (NPCA) with Graefe et al. [20] for use by the US National Park Service. The VIM process basically focuses on three main issues. They are listed as the existing conditions causing the problem, the possible factors causing the problem, and the possible management strategies. The possible factors causing the problem are evaluated in three groups of physical, biological, and social factors. In the VIM method, matrices are used in the classification and the evaluation of management strategies [58].

The Visitor Experience and Resource Protection (VERP) framework was developed by the U.S. National Park Service as part of a planning process that integrates resource protection with visitor experience quality. This framework defines desired future resource and social conditions and operationalizes them through management zones, indicators, standards, monitoring, and adaptive actions [21]. It is a process developed regarding carrying capacity in terms of resource quality and visitor experience quality. This method is a prescription for desired future resource values and social conditions, defining where, when, why, and at what level use is appropriate [58]. VERP attempts to bring together management planning and operational planning. In this system, a series of management zones and the desired future state are defined through established standards and indicators [21]. The summary of visitor management models is listed in Table 3.

Table 3. Comparative decision profile of major visitor-use management frameworks.

Framework	Primary Management Question	Most Suitable Problem/Context	Principal Strength	Principal Limitation or Required Capacity
ROS	Which diversity of settings and experiences should be provided, and where?	Large, heterogeneous landscapes; zoning and recreation-opportunity planning.	Provides spatial context and differentiates desired experience settings.	Does not itself establish thresholds, monitoring rules, or corrective actions.
LAC	Which conditions are acceptable, and what action follows when a standard is exceeded?	Ecologically or socially sensitive zones requiring explicit standards.	Creates a clear indicator–standard–action chain.	Requires normative agreement, sustained monitoring, and authority to implement corrective action.
VAMP	Which visitor activities, services, and experience opportunities should be planned?	Activity and service planning within an established park-planning system.	Connects visitor demand and activity opportunities to management planning.	Empirical implementation literature is limited and the approach depends on the host planning system.
CCAP	Which use intensity or encounter level is socially acceptable?	Crowding, encounters, user conflict, and social-capacity questions.	Operationalizes social norms and experience quality.	A single threshold may misrepresent differences across cultures, activities, groups, and displaced users.
VIM	Which use, behavior, environmental, or infrastructure mechanism produces the observed impact?	Sites where impact is visible but its cause is uncertain.	Supports causal diagnosis and targeted intervention selection.	Requires intensive data and credible separation of competing causal mechanisms.
VERP	Which resource and visitor-experience conditions should be protected?	Parks with strong planning, zoning, and monitoring capacity.	Integrates resource and experience indicators, standards, and management zones.	Requires continuous monitoring, institutional continuity, and a capacity to escalate management actions.
IVUMF	How should complex visitor-use decisions be managed adaptively?	Large, multi-actor, multi-jurisdictional, or rapidly changing systems.	Offers an integrated and iterative decision, monitoring, evaluation, and adaptation cycle.	May remain procedural without interagency coordination, data sharing, budget continuity, and explicit decision authority.

As a more contemporary approach, the Interagency Visitor Use Management Framework offers an adaptable planning process that addresses visitor use in conjunction with resource conditions and visitor experience goals. The framework consists of four main elements as establishing the management need and project approach; defining the desired visitor use direction with the conditions to be maintained; determining management strategies; and implementation, monitoring, evaluation, adaptation as needed [40]. This approach positions carrying capacity not as a mere number, but as a visitor use management component that works in conjunction with indicators, thresholds, monitoring, and decision-making processes. Table 3 compares the frameworks according to the management question they answer, the context in which they are most useful, their principal strength, and the institutional or analytical capacity they require.

Abbreviations: ROS, recreation opportunity spectrum; LAC, limits of acceptable change; VAMP, visitor activity management process; CCAP, carrying capacity assessment process; VIM, visitor impact management; VERP, visitor experience and resource protection; IVUMF, interagency visitor use management framework.

The common contribution of these models is that they move the discussion of carrying capacity beyond simply calculating maximum visitor numbers and link it to desired resource conditions, visitor experience standards, indicators, thresholds, and management interventions. Nevertheless, three key limitations remain. First, while capacity numbers often appear technical and objective, the acceptable level of change is a normative decision. Second, capacity values are tightly context-dependent, as the same level of use can produce different ecological and social outcomes in different areas. Third, the success of the models depends not only on the correct selection of indicators but also on long-term monitoring, inter-agency coordination, stakeholder engagement, and the applicability of management decisions [24,25,57]. When the literature on the subject is examined, it has been observed that the reason for these failures is that the indicators and parameters that play an important role in determining the carrying capacity vary according to the characteristics of the recreational areas and recreation types, and there are deficiencies in the interpretation, synthesis and decision-making stages [49].

More clearly, the ecological impact and degrees resulting from intensive use in a recreational area vary according to the biophysical and ecological characteristics of that area [56]. Hence, the capacity values of areas catering to the same recreational activities may differ from each other in the context of characteristics. There is not always a linear relationship between the intensity of use and the level of impact in recreational areas. The level of impact varies depending on the spatial concentration of use, the type of activity, visitor behavior, the biophysical sensitivity of the area, the existing infrastructure, and the management measures implemented. Therefore, capacity assessments should not be reduced to the number of individual visitors. Area inventories, indicators, threshold values, and monitoring results should be interpreted together [7,27].

Geographical Transferability and Digital Data Governance

It is not necessary to propose an entirely new, named framework for the digital age. Existing adaptable structures can be updated with layers of digital monitoring and data governance. Social media, mobile location, and user-generated geographic data can complement spatial/temporal patterns of visitor flow. Nonetheless, the user base is not representative and raises issues of privacy, data ownership, algorithmic visibility, and digital exclusion. This data should be triangulated with counters, observations, and probabilistic surveys. Decision-making standards should not be based solely on platform data [4,5].

Many frameworks have been developed within the strong tradition of public agency, planning, and monitoring in North America. Therefore, transferability should be assessed not by simply transferring the model's name to another country, but by re-evaluating legal authority, local crowd norms, funding, data infrastructure, local livelihood dependencies, and forms of participation. Cultural crowding norms and park practices in Turkiye [59], forest recreation in Indonesia [35], spatial risk and ROS classification in China [54], perceived crowding in Bangladesh [42], and ecological–social–economic–biophysical capacity applications in Greece and Portugal [50,60] should be used as comparative testing grounds.

6. Critical Synthesis

This review does not contribute to reaffirming the thesis that carrying capacity is not a static number. This transformation is established in the LAC, VERP, and visitor use management literature. The contribution is threefold. First, by comparing the seven frameworks using common criteria, it demonstrates that the difference between them is not a chronological "old-new" ranking, but rather complementary responses to different decision problems. Second, it integrates physical, ecological, social, managerial, and economic capacity as a diagnostic system fed back under desired sustainability conditions, rather than separate ceilings. Third, it positions carrying capacity as an operational decision component linking status and pressure indicators to organizational learning and intervention, without equating it with resilience.

The comparison shows that no single framework solves all normative, ecological, social, organizational, and digital problems. ROS is strong in zoning and diversity of experience; CCAP in social norms; VIM in cause diagnosis; LAC and VERP in indicator–standard architecture; and IVUMF in inter-organizational adaptive looping. The appropriate choice depends on the type of pressure, ecological reversibility, visitor experience objective, data quality, legal authority, and monitoring resources.

7. Managerial Implications

The management tool should be selected not with the aim of generally reducing visitor numbers, but according to the mechanism that disrupts the defined resource or experience condition. First, the type of problem and spatial/seasonal scale should be identified. Then, the appropriate framework, measurable indicator, intervention trigger, and cross-dimensional protection indicator should be determined together [6,23]. Table 4 provides a problem-first decision (problem selection) matrix. It does not identify a universally superior framework, but links recurring management conditions to a defensible starting framework, intervention, monitoring set, and safeguard check.

Table 4. Matching management conditions with frameworks, interventions, indicators, and safeguard checks.

Diagnosed Management Condition	Suitable Starting Framework	Management Intervention	Primary Indicators	Conservation/Equity Safeguard
Predictable peak pressure and discrete entry points	IVUMF + VERP	Timed entry; reservation; dynamic quota; transport management.	Hourly entries; queue time; occupancy; frequency and duration of standard exceedance.	Digital and income access; no-show rate; displacement to adjacent sites.
Sensitive habitat or seasonal species pressure	LAC + VERP	Zoning; seasonal closure; group-size rule; restoration.	Zone- and season-specific vegetation, soil, wildlife, or water standard.	New impacts on alternative routes; local livelihood dependence; recovery rate.
Large, multi-agency park system	IVUMF	Shared data standard; responsibility protocol; staged action plan.	Interagency data coverage; decision time; action completion; monitoring continuity.	Authority gaps; budget continuity; balance of stakeholder representation.
Heterogeneous experience demands and site types	ROS + VAMP	Opportunity classes; zoning; activity and service portfolio.	Class-specific encounters; naturalness; service level; satisfaction.	Distribution of access and pressure across zones and user groups.

Table 4. *Cont.*

Diagnosed Management Condition	Suitable Starting Framework	Management Intervention	Primary Indicators	Conservation/Equity Safeguard
Localized impact with uncertain cause	VIM	Causal diagnosis; targeted surface, route, behavior, maintenance, or facility intervention.	Co-measurement of impact, use level, behavior, spatial concentration, and infrastructure condition.	Test alternative causes before applying a general quota.
Crowding, conflict, or displacement	CCAP + LAC	Norm study; time or group differentiation; information; allocation; quota if warranted.	Encounters; norm curve; conflict; satisfaction; displacement.	Minority-user norms; cultural differences; disability access; procedural fairness.
Management capacity below the required standard	IVUMF-based institutional diagnosis	Clarify authority; increase staffing or budget; joint monitoring; external partnership.	Monitoring coverage; staffing; maintenance delay; enforcement capacity; response time.	Do not set higher visitor-growth targets before minimum management capacity is secured.

Each intervention should be initiated with an initial measurement, a pilot application, and a predetermined review date. Reservations, quotas, or timed entry may be effective at foreseeable peak pressure. Notwithstanding, they should not be considered sustainable solutions without monitoring access equity, the relocation of use to neighboring areas, and the impact on the local economy. At threshold overshoot, the cause diagnosis should be updated first. The conditions for transitioning from less restrictive tools such as information and guidance to more restrictive tools such as zoning, seasonal closure, or quotas should be clearly stated.

8. Limitations and Suggestions for Further Research

This study is not a systematic review or meta-analysis, but a concept-focused critical narrative review. Limiting the search to Scopus and Web of Science and to records indexed in English may introduce database and language bias. Filtering based on title, abstract, and keywords may have excluded some contextual contributions that would have been visible in the full text. Conceptual prioritization does not imply complete coverage of the literature universe or an estimate of the frequency of findings. The fact that many of the core frameworks were developed within the North American institutional context limits evidence relating to other legal and governance arrangements. However, sharing full queries, deduplication rules, and record-based decisions makes the selection process controllable.

Future research should focus on comparative and longitudinal designs that follow the same indicator–standard–action chain across different continents and governance systems. Interventions such as reservation, zoning, and restoration should be evaluated not only in terms of total use or satisfaction, but also in conjunction with ecological recovery, displacement, access equity, local economic distribution, and management cost. Issues such as representation bias and privacy in digital data studies; leakage and cost distribution in economic studies should be dealt with. In institutional studies, whether a management decision is actually implemented after a threshold is exceeded should be treated as a key outcome variable.

9. Conclusions

This critical narrative review demonstrates that the key decision-making unit in sustainable park and protected area management is not visitor numbers, but clearly defined conditions for ecological resources, visitor experience, equity, local welfare, and institutional feasibility. Numerical limits may be necessary in security, physical facility, or high-sensitivity conditions. Nonetheless, they alone do not prove sustainability due to the nonlinear use–impact relationship, the value-laden nature of standards, and the variability of management capacity. Effective implementation should link context-specific indicators to decision standards, standards to intervention triggers, and interventions to learning through regular monitoring.

The study's contribution is to compare seven frameworks with common critical criteria, integrate five capacity dimensions within a feedback-driven socio-ecological diagnostic system, and management tool selection to the issue, sensitivity, data, and institutional capacity. This approach does not equate carrying capacity with resilience. It transforms into transparent decision support for measuring, negotiating, and implementing sustainability goals. Global feasibility depends on the explicit testing of local norms, legal authority, monitoring resources, and the representation/privacy conditions of digital data.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su18168037/s1, Supplementary Table S1 (Excel file).

Author Contributions: Conceptualization, Y.E., G.S.E. and O.A.; methodology, Y.E., T.C. and O.A.; software, Y.E., T.C. and G.S.E.; validation, Y.E., G.S.E., T.C. and O.A.; formal analysis, Y.E. and G.S.E.; investigation, Y.E. and G.S.E.; resources, O.A.; data curation, Y.E.; writing—original draft preparation, Y.E.; writing—review and editing, G.S.E., T.C. and O.A.; visualization, Y.E., T.C. and G.S.E.; supervision, O.A.; project administration, O.A.; funding acquisition, O.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Scopus and Web of Science search strings and filters, record-based inclusion/exclusion decisions, duplicate matches, exclusion justifications, subject-specific record map, and a critical synthesis core of 78 sources are presented in Supplementary Table S1. No personal or sensitive data was generated in this study.

Conflicts of Interest: The authors declare no conflicts of interest.

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