RECREATIONAL CARRYING CAPACITY CALCULATIONS: AN APPLICATION ON CAPPADOCIA ROCKY SITES

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Abstract

The Cappadocia region, which is crucially important in terms of history, nature and culture, hosts visitors of all ages from all over the world. In order not to lose its attractiveness and appeal and to pass on its continuity to future generations, it is of utmost importance to control demand in heritage areas that have been damaged or are vulnerable to damage. The main objective of this study is to identify the areas with the highest number of visitors to heritage sites in the Cappadocia region and to calculate the three recreational carrying capacity (physical, real and effective carrying capacity) and social carrying capacity in these areas. In this context, the areas with the highest density of visitors in the region were first identified based on the statistical reports published by the Nevşehir Provincial Directorate of Culture and Tourism (NPDCT). These areas are designated as Göreme Open-Air Museum (GOAM), Derinkuyu Underground City (DUC) and Kaymaklı Underground City (KUC). Then, the recreational and social carrying capacities for these areas were calculated. In accordance with the calculations, it was revealed that in Derinkuyu and Kaymaklı Underground Cities, both the physical and social carrying capacities were exceeded in all months of the year. In GOAM, it was found that the recreational carrying capacity was exceeded in all months of the year except in the winter months. The results differ according to the summer and winter periods. However, it was determined that the number of monthly visitors that Göreme Open Air Museum should host should be 51,450, DUC should host 27,500 and KUC should host 15,950 in the summer period, when more visitors are travelling.In addition, based on the results of the real carrying capacity, the number of expected daily visitors in the areas concerned was determined and both theoretical and practical contributions were provided in accordance with the results obtained.

Keywords: Demand Management; Sustainability; Carrying Capacity.

CÁLCULOS DE CAPACIDADE DE CARGA RECREACIONAL: UMA APLICAÇÃO EM SÍTIOS ROCHOSOS DA CAPADÓCIA

Resumo

A região da Capadócia, que é crucialmente importante em termos de história, natureza e cultura, recebe visitantes de todas as idades de todo o mundo. Para não perder sua atratividade e apelo e passar sua continuidade para as futuras gerações, é de extrema importância controlar a demanda em áreas patrimoniais que foram danificadas ou estão vulneráveis a danos. O principal objetivo deste estudo é identificar as áreas com o maior número de visitantes nos locais de patrimônio na região da Capadócia e calcular a capacidade de carga recreativa (capacidade física, real e efetiva) e a capacidade de carga social nessas áreas. Nesse contexto, as áreas com maior densidade de visitantes na região foram identificadas com base nos relatórios estatísticos publicados pela Diretoria Provincial de Cultura e Turismo de Nevşehir (NPDCT). Essas áreas são designadas como Museu ao Ar Livre de Göreme (GOAM), Cidade Subterrânea de Derinkuyu (DUC) e Cidade Subterrânea de Kaymaklı (KUC). Em seguida, as capacidades de carga recreativa e social para essas áreas foram calculadas. De acordo com os cálculos, foi revelado que nas Cidades Subterrâneas de Derinkuyu e Kaymaklı, tanto a capacidade física quanto a social foram excedidas em todos os meses do ano. No GOAM, constatou-se que a capacidade de carga recreativa foi excedida em todos os meses do ano, exceto nos meses de inverno. Os resultados diferem de acordo com os períodos de verão e inverno. No entanto, foi determinado que o número de visitantes mensais que o Museu ao Ar Livre de Göreme deve receber deve ser de 51.450, DUC deve receber 27.500 e KUC deve receber 15.950 no período de verão, quando mais visitantes estão viajando. Além disso, com base nos resultados da capacidade de carga real, o número de visitantes diários esperados nas áreas em questão foi determinado e foram fornecidas contribuições teóricas e práticas de acordo com os resultados obtidos.

Palavras-chave: Gerenciamento da Demanda; Sustentabilidade; Capacidade de Carga.

CÁLCULOS DE LA CAPACIDAD DE CARGA RECREATIVA: UNA APLICACIÓN EN LOS ROQUEDALES DE CAPADOCIA

Resumen

La región de Capadocia, que es de vital importancia en términos de historia, naturaleza y cultura, recibe visitantes de todas las edades de todo el mundo. Para no perder su atractivo y apelación y pasar su continuidad a las futuras generaciones, es de suma importancia controlar la demanda en áreas patrimoniales que han sido dañadas o son vulnerables a daños. El objetivo principal de este estudio es identificar las áreas con el mayor número de visitantes en los sitios de patrimonio en la región de Capadocia y calcular la capacidad de carga recreativa (capacidad física, real y efectiva) y la capacidad de carga social en estas áreas. En este contexto, las áreas con mayor densidad de visitantes en la región fueron identificadas en base a informes estadísticos publicados por la Dirección Provincial de Cultura y Turismo de Nevşehir (NPDCT). Estas áreas son designadas como Museo al Aire Libre de Göreme (GOAM), Ciudad Subterránea de Derinkuyu (DUC) y Ciudad Subterránea de Kaymaklı (KUC). Luego, se calcularon las capacidades de carga recreativa y social para estas áreas. De acuerdo con los cálculos, se reveló que en las Ciudades Subterráneas de Derinkuyu y Kaymaklı, tanto la capacidad física como la social fueron superadas en todos los meses del año. En GOAM, se encontró que la capacidad de carga recreativa fue superada en todos los meses del año, excepto en los meses de invierno. Los resultados difieren según los períodos de verano e invierno. Sin embargo, se determinó que el número de visitantes mensuales que el Museo al Aire Libre de Göreme debería recibir debe ser de 51,450, DUC debería recibir 27,500 y KUC debería recibir 15,950 en el período de verano, cuando más visitantes están viajando. Además, basándose en los resultados de la capacidad de carga real, se determinó el número de visitantes diarios esperados en las áreas en cuestión y se proporcionaron contribuciones teóricas y prácticas de acuerdo con los resultados obtenidos.

Palabras clave: Gerenciamento de la Demanda; Sustentabilidad; Capacidad de Carga.

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1 INTRODUCTION

Tourism has undergone many changes throughout history and has always been an attractive and popular industry. Consequently, tourism destinations have become a significant global phenomenon (Liu et al., 2015). The fact that countries offer incentives to the tourism industry has provided a basis for human mobility by encouraging tourism investments and tourism activities around the world. Tourism movements that were initially on a small scale began to develop into masses over time (Nunkoo, 2015). The continuous increase in tourism in the world and in Turkey over the years, both in terms of income and the number of tourists in general, has revealed the approach that tourism is a mass phenomenon (Demir & Çevirigen, 2006). However, mass movement is considered to be a situation that complicates the control and supervision of tourism activities as increasing mobility has a negative impact on the balance of protection and use, causing rapid destruction of resources (Pickaver et al., 2010).

The phenomenon of human mobility, particularly in the context of tourism, has the potential to negatively impact both the environment and sustainability. This is particularly evident when there is an excess of resources, which can lead to the exceeding of the carrying capacity (Chen & Tang, 2023).

At this point, demand management and the need to spread demand according to supply come to the fore in order to ensure sustainability (Çalık, 2014). The rise in income levels, the growth and diversification of transport options and the increase in tourism activities lead to a strong demand for tourism. As a result, the natural and cultural characteristics of the destinations are negatively impacted and the changing texture cannot meet the expectations of the visitors and begins to reduce the quality of the tourism experience.

In the studies conducted within the scope of demand management, it is found that there are different visitor and demand management strategies (Göktuğ & Arpa, 2015; Göktuğ & Kurkut, 2016; Mason, 2005). Carrying capacity calculations included in these are also considered as a strategy that can be used to spread demand according to supply and can provide tangible values (Gonson et al., 2018).

Examining the studies on demand management in tourism, it was found that visitor management models (Akten & Gül, 2014; Göktuğ & Arpa, 2015; Göktuğ & Kurkut, 2016; Proença & Soukiazis, 2005; Song & Li, 2008; Song et al., 2003) and the theory of recreational and social carrying capacity (Bera et al., 2015; Cengiz & Kaptan Ayhan, 2008; Dağ & Mansuroğlu, 2018; Göktuğ et al. , 2013; Khodkar & Özyurt Tarakçıoğlu, 2018; Saveriades, 2000; Sayan & Atık, 2011;Thomas et al., 2005; Tran et al., 2007) are mainly applied in national parks and protected areas.

The Cappadocia region, unique in the world with its churches, underground cities and fairy chimneys, hosts thousands of visitors every year with its natural beauty. In 2019 nearly four million tourists visited the city (Nevşehir Provincial Directorate of Culture and Tourism, 2020), and it was noted that some heritage sites in the city had more visitors than others. The accumulation of visits especially in spring and summer and their excess during these periods lead to an unconscious use of resources and the risk of destruction.

Göreme National Park and Cappadocia Rock Sites, which are also on the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage List, attract a large number of visitors as one of the most important tourism centers in our country. In 2019, only GOAM, KUC and DUC hosted approximately two and a half million domestic and foreign visitors (Nevşehir Provincial Directorate of Culture and Tourism, 2020).

In a tourism region that attracts so many visitors, it is felt that the pressures and the increasing negative impacts created by tourism are inevitable. In addition, archaeological sites within the World Heritage Area (WHA) are expected to welcome visitors within the framework of sustainable tourism principles. However, the long-term development plan for Göreme National Park and Cappadocia Rocky Sites, which are included in the UNESCO World Heritage List and constitute the largest part of the World Heritage Sites, has not yet been fully elaborated, approved and implemented (Somuncu & Yiğit, 2009).

Therefore, it was found that there is no area management plan and visitor management plan for the World Heritage Sites in the region. In this sense, there is no approach such as carrying capacity calculations for the area and the implementation of its results within the framework of a plan. The question of whether the carrying capacity of the Göreme National Park and Cappadocia Rocky Sites has been exceeded therefore constitutes the main problem of the study.

In this context, it is anticipated that the data obtained from the study will be crucial in the preparation and implementation stages of the plan for both field and demand management. For all these reasons, the objective is to carry out carrying capacity calculations within the scope of demand management and to provide some suggestions for all stakeholders involved in destination management.

In this context, first of all, the previous studies were first examined in the context of research, and then the data to be used in the calculation of the carrying capacity were collected, and three levels of recreational carrying capacity (physical, real and effective carrying capacity) and social carrying capacity were calculated. Also thought that the study will contribute to create the carrying capacity data that can be used in the tourism planning of the region and to the sustainability of the area.

2 THEORETICAL REVIEW

It is common knowledge that the factors that attract tourists to a destination are not indefinite and unlimited. Therefore, the attraction factors should be considered as limited and non-renewable resources. It is well known that great significance is granted to demand management in pursuing an approach that preserves the environment and is based on improving living conditions and in protecting destination-specific resources (Can, 2013). In tourism literature, demand management is usually based on the concept of carrying capacity and visitor management models (Björk et al., 2021; Li et al., 2021).

In order to determine and limit the capacity in tourism destinations and the extent of use of tourism activities, carrying capacity has proved to be an attractive tool, and it

has been pointed out that carrying capacity should apply to a certain period of time and a certain number of tourists. The fear of losing irreversible resources through misuse is gaining more significance in a world where natural and cultural resources are gradually diminishing. Carrying capacity is often used to determine how many tourists can be accommodated without harming a tourism destination and reducing tourist satisfaction (McCool & Lime, 2001).

The concept of carrying capacity in tourism was first used by Lucas in 1964 in a study in which he examined visitors' perceptions of wildlife in an area where canoeing was practiced. In the said study, the concept of carrying capacity is stated as a concept that concerns environmental elements (Fennell, 2002). In some of the studies on carrying capacity, this concept has been associated with the life stages of touristic regions and it has been argued that different carrying capacities of touristic regions should be determined in each life stage (Cornejo–Ortega et al., 2011).

Thus, it has been noted that carrying capacity studies in tourism are generally associated with physical and social carrying capacity calculations, since physical carrying capacity is generally an indicator of how many people an area can accommodate, and overcapacity is assumed to mean that the area will not be able to meet expectations (UNWTO, 2019).

Khodkar & Özyurt Tarakçıoğlu (2018), López-Dóriga (2019) and Zacarias et al., (2011) conducted research on the carrying capacity of the beaches, mainly related to the physical carrying capacity, and as a result of the studies conducted, it was found that the physical carrying capacity of the beaches was exceeded during the high season. In addition, within the scope of physical carrying capacity, for national parks (Aliyeva et al., 2020; Kang, 2023) were calculated by the researchers concerned and the optimal number of daily/monthly visitors was determined based on these calculations.

In the social carrying capacity, which is another type of carrying capacity calculated within the scope of the study, there are two major factors, namely “tourist” and “local people”. These two significant factors have led to the calculation of studies on social carrying capacity using different models and scales. Brandolini and Mosetti (2005), Gonson (2018) and Joshi & Dahal (2019) calculated social carrying capacity using the "Social Carrying Capacity Assessment Model", which refers to tourists. As a result of the study, each author determined that the social carrying capacity was exceeded in the research area in question and determined the number of groups/people that can be in the area at the same time in order to avoid the problem of exceeding it. Davis & Morais (2004) and Saveriades (2000), on the other hand, conducted studies on social carrying capacity models based on local population and requiring the use of scales.

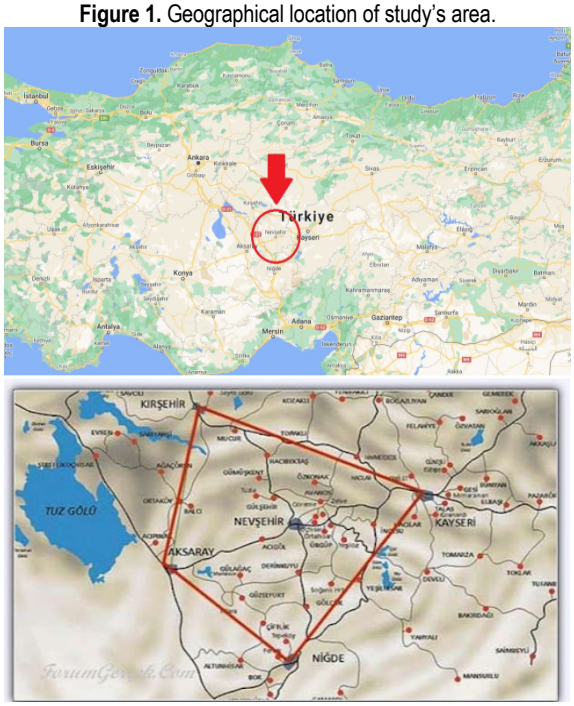
The types of carrying capacity are also calculated for the national parks. It is noted that the types of carrying capacity calculation for national parks are generally calculations of recreational carrying capacity. As a matter of fact, on recreational carrying capacity, Tran et al. (2007) examined Phong Nha-Ke Bang National Park, while Soylu (2013) examined Gallipoli Peninsula Historical National Park. Recreational carrying capacity calculations are also considered as a demand management tool. To this end, Cornejo-Ortega et al. (2011), Croxton et al. (2002), Melo & Alcantara (2014) and Saveriades (2000) have conducted various studies on carrying capacity calculations in national parks. In addition, López-Bonilla & López-Bonilla (2008) and McCool & Lime (2001) consider recreational carrying capacity in the context of sustainability, while Brylske & Flumerfelt (2004) consider it in the context of maintaining ecological balance.

Within the scope of the study, as mentioned earlier, physical carrying capacity, real carrying capacity, effective carrying capacity and social carrying capacity were calculated. The three levels of recreational carrying capacity (physical, real and effective carrying capacity) are the most fundamental point that distinguishes the study from other studies in the tourism literature that have been conducted in the context of carrying capacity.

3 METHODOLOGY

In the calculations of carrying capacity carried out within the scope of the study, three levels of recreational carrying capacity developed in the context of the "Carrying Capacity Estimation Method in Protected Areas" developed by Cifuentes (1992) and recommended by the World Union for Conservation of Nature (IUCN) and the “Social Carrying Capacity Evaluation Model developed by ”Shelby & Heberlein (1984) and implemented by Bergère & Le Berre (2011), Brécard & De Luigi (2016) were used. It was found that the areas for which carrying capacity was calculated are the most visited areas in Göreme National Park and Cappadocia Rocky Sites included in the UNESCO World Heritage List. National Parks are defined as *“areas of natural and cultural significance, encompassing both scientific and aesthetic values.”* The map and location area of the study are presented in Figure 1.

Figure 1. Geographical location of study’s area.



Source: ATLAS (https://basic.atlas.gov.tr/)

They serve as protected areas for the conservation of biodiversity and cultural heritage, as well as offering opportunities for recreation and tourism (van Chao et al., 2023). In this context, the visitor numbers published on the official website of the Directorate of Culture and Tourism of Nevşehir Province (DCTNP) were examined and it was found that the visitor numbers of GOAM, DUC and KUC were higher than those of other areas.

Based on the use of physical, ecological, climatic or management factors to limit visitor numbers in a formulation, the three levels of recreational carrying capacity consist of physical, effevtive real and effective types of carrying capacity (Cifuentes, 1992). Below are formulations and explanations for each type of carrying capacity.

"Physical Carrying Capacity" (PCC) refers to the maximum number of people who can physically fit within a defined space at a given time (Ceballos-Lascurain, 1996) and is calculated by the following formula:

PCC=AxDxRf
In this formula:
PCC: Physical Carrying Capacity
A: Area (Area or footpath available for visitors' use)
V/a: Visitor area (area or length of footpath per visitor) (1 visitor/m² in area, 1 visitor/m in the path)
Rf: gs/zs (Rotation factor: The time an area is open per day/ the average duration of a visit)
Rf: gs/zs (Rotation factor: The daily opening hours of an area / the average duration of a visit)

Based on the formula, the physical carrying capacity is calculated by multiplying the total area that can be used by visitors, 1 m² of area per visitor or 1 m of long path length, and the number of visits that are possible during the opening hours of the area in a day (Göktuğ, 2011).

"Real Carrying Capacity" (RCC) is based on the removal of recreational activities from the PCC by calculating various correction factors (Cf) that impede visitation. RCC numerically defines the impact of climatic conditions that are regarded as unfavorable in terms of recreation during the year and the physical characteristics that limit recreational activities on the amount of recreation (Göktuğ, 2011). In other words, it is the maximum number of tourists allowed by local conditions and management capacity without affecting the demand of tourists. Correction factors for national parks and open spaces are determined as temperature, precipitation and stormy days (Tran et al., 2007). These correction factors are derived from biophysical, environmental, ecological, social and managerial variables (Ceballos-Lascurain, 1996). RCC is expressed by the following formula:

RCC: PCC – Cf_1- Cf_2 - ..... – Cf_n
Cf: Vv/Vt x 100

RCC: Real Carrying Capacity
PCC: Physical Carrying Capacity
Cf_1,Cf_2, Cfn: Calculated correction factor for each variable
Cf: Correction factor
Vv: Delimiter value of variable
Vt: The total value of the variable

According to this formula, cf must be calculated first in order to find the RCC. Cf are determined as a result of the calculation of the relationship between the limiting values and the total values of the factors that prevent or restrict the visit by interpolation method. After all the cf applicable to the field are calculated, they are mathematically subtracted from the previously calculated PCC (Göktuğ, 2011). Cf, expressed as percentages, are placed in the formula as follows:

RCC: PCC x (100 – Cf_1 / 100) x (100 – Cf_2 / 100) x …….x (100 – Cf_n / 100)

"Effective Carrying Capacity" (ECC) is the maximum number of visitors that an area can handle according to its current management capacity (Ceballos-Lascurain, 1996):

ECC: RCC x MC

ECC: Effective Carrying Capacity
RCC: Real Carrying Capacity
MC: Management Capacity

According to the formula, ECC is the previously calculated RCC multiplied by the management capacity (MC). Management capacity is the sum of conditions needed for protected area management to accomplish its tasks and objectives. In the study, "MC" was formulated as follows:

MC: Number of Current Staff / Minimum Number of Staff Required x 100

Information on the social carrying capacity of the Derinkuyu and Kaymaklı Underground Cities was obtained through an interview with the guides who showed visitors around the region.
"Social Carrying Capacity" (SCC) is based on the number of groups and people who can interfere with the trip in closed areas, while social carrying capacity refers to the maximum number of people or groups that visitors want to meet in an area and it refers to a value that can vary depending on the specific characteristics of each area related to the visit (Göktuğ, 2011). The SCC is obtained by the following formula:

SCC: Gs x GEn x Rf

Gs: Average Group Size
GEn: Maximum Number of Groups or Individuals to Encounter (average)
Rf: Rotation Factor

The formula envisages visiting the area in groups. However, if there is a tendency for individual visits in the area, the Gs (Average Group Size) in the formula can be deducted.

In order to make the necessary calculations regarding the carrying capacities of the areas experiencing tourist density in the region, at attempt was made to reach the information contained in the formulas for measuring carrying capacity. In order to measure the physical carrying capacity of the GOAM, first of all, information about width of the site was needed.

This information was obtained from the General Directorate of Land Registry and Cadastre – Parcel Inquiry (General Directorate of Land Registry and Cadastre). From the determined area of 41.300m², the area measurements of the churches and chapels as well as souvenir shops in the museum, which are not accessible to visitors, were subtracted, and the measurement of the main area used by tourists was obtained.

This area was determined to be approximately 38.880m². The first of the other information required for the measurement of physical carrying capacity is the number of people that fall within 1 m². This information was obtained from the literature review. Hall & Page (2001) stated that space planning should be done so that 1 person occupy on 1 m² (scenario 1) or 1 person occupy on 2 m² (scenario 2). The second piece of information is the time the area is open to visitors and how long the visit lasts.

This information was provided by the NPDCT and by professional tourist guides who show tourists around the region. Information such as precipitation, storm and number of sunny days, which are necessary to calculate the real carrying capacity including factors affecting the visit in the open area, was obtained from the Nevşehir Meteorological Directorate.

The area measurements required for the physical carrying capacity calculation tool for Derinkuyu and Kaymaklı Underground Cities were obtained through the literature survey. Further information required for the calculation of the physical carrying capacity was obtained from the NPDCT.

The number of people per square meter is also referenced by the study of Hall & Page (2001). Since Derinkuyu and Kaymaklı Underground Cities are closed areas, the real carrying capacity was not calculated. However, as overcrowding and social distancing are believed to cause problems in closed areas, the social carrying capacity in these areas was calculated.

The information required for the implementation of the Social Carrying Capacity Assessment Model was obtained from the information provided by the professional tourist guides working in the region. In this context, the tourist guides were asked whether the waiting times and crowding in the underground cities pose a problem for tourists and how many groups of people should best be in the area at the same time in order to avoid this situation. Management capacity, which is another type of carrying capacity that can be calculated, was calculated based on the data received from the relevant museum directorates in all three areas.

4 RESULTS ANALYSIS

Three levels of recreational carrying capacity were calculated at GOAM and the results are shown below

GOAM's Physical Carrying Capacity (PCC):

The features required for the determination of the PCC of the GOAM are shown in Table1.

Table 1. PCC Features of Göreme Open Air Museum.

v_h: Open-Air Museum average visit time (hours)	2 hours
A: Open-Air Museum Area (m²)	38880m²
d_t:Day time during which the Open-Air Museum is open to visitors (summer period)	11 hours
d_t: Day time during which the Open-Air Museum is open to visitors (winter period)	10 hours
D: Optimal Outdoor Museum Area (person/ m²)	1 or 0,5

Source: own elaboration.

In accordance with this information, the Physical Carrying Capacity for the GOAM was calculated in two different ways by considering the scenarios of Hall & Page (2001) and the summer (April-September) – winter (October-March) periods. The PCC values calculated according to Scenario 1 and Scenario 2 are shown in Table 2 and Table 3.

Table 2. Göreme Open-Air Museum Summer PCC Values.

*Göreme Open-Air Museum PCC: (person/month)	213840 people
**Göreme Open-Air Museum PCC: (person/month)	106920 people

*Scenario 1: D= 1 person, **Scenario 2: D= 0,5 person
Source: own elaboration.

Table 3. Göreme Open-Air Museum Winter PCC Values.

*Göreme Open-Air Museum PCC: (person/month)	194400 kişi
**Göreme Open-Air Museum PCC: (person/month)	97200 kişi

*Scenario 1: D= 1 person, **Scenario 2: D= 0,5 person
Source: own elaboration.

According to NPDCT statistics on the number of visitors to museums and ruins in 2019, the distribution of the number of people visiting GOAM by months is shown in Table 4.

Table 4. Number of Visitors to Göreme Open-Air Museum in 2019.

Summer Term		**Winter Term**	
April	154.415	October	161.624
May	141.381	November	107.036
June	144.556	December	65.187
July	135.484	January	56.807
August	149.177	February	61.494
September	149.776	March	90.181
Total	**874.789**	**Total**	**542.329**

Source: own elaboration.

When Table 4 is taken into consideration and D=1 person according to Scenario 1, GOAM does not have any problem regarding the exceeding its physical carrying capacity in both the summer period and in the winter period. However, when S/a= 0.5 person in accordance with Scenario 2 is evaluated, it can be said that there was no problem of exceeding the physical carrying capacity for only four months (December, January, February and March) in both periods.

Nevertheless, considering the 2019 data, it is found that the number of visitors exceeded 90 thousand in March. Therefore, it can be assumed that there will be a problem of exceeding the carrying capacity in March as well. In addition, considering today's conditions, the significance of social distance is increasing and it is on its way to becoming a part of our lives. In this context, it is assumed that more accurate and healthier results will be obtained by taking Scenario 2 (D=0.5) into account in the calculations of the carrying capacity.

Calculation of Real Carrying Capacity of GOAM (RCC):

10 years (2008 - 2018) meteorological data of Nevşehir were used to calculate the correction factors required to determine the RCC. These data were obtained from Nevşehir General Directorate of Meteorology. In determining the temperature and precipitation correction factors, comfort levels (Türkoğlu & Çalışkan, 2011), which are generally determined for humans and created on the basis of bioclimatic conditions, were considered. Türkoğlu & Çalışkan (2011) indicated that the comfort level is between 18°C and 23°C.

There is no thermal stress between these degrees. Türkoğlu & Çalışkan (2011) considered it appropriate to use the following parameters for the most appropriate temperature, precipitation and wind; they assumed that the temperature factor should be 25°C, the wind factor should be 8m/s on average, and the precipitation factor should be 5 mm.

However, considering the climatic conditions arising from the geographical location of the sample and taking into account the 10-year meteorological data of the region, it was predicted that 8 m/sec wind intensity would not be an appropriate data since it occurs in the region during a large period of the year, and the number of days with the wind of 17.2 m/sec was used as the correction factor (Türkoğlu & Calışkan, 2011). The features of the RCC regarding the relevant field are shown in Table 5.

Table 5. Göreme Open-Air Museum RCC Features (Summer Period).

V_1: Number of days with temperature more than ≥25°C' (annual average)	99,1 days
H: The average time of the day when the sun is intense	4 hours (11.00-15.00)
R: The average number of days per year with precipitation ≥5 mm	107,5 days
R_h: Average rainfall duration (hour)	3 hours
S: Average number of stormy days (wind speed ≥17,2 m/sn)	38 days
S_d: Storm duration	4 hours
d_h: Daily time the Open-Air Museum is open (hours)	11 hours
V_t: The annual number of days that the Open-Air Museum is open to visitors	365 days

Source: own elaboration.

Disturbing temperature correction factor (Cft): The number of days when the temperature was ≥25°C was used to calculate the disturbing temperature correction factor.

Cft:

Cft = V_1 / V_t x 100

V_1 = 365 days - 99.1 disturbing hot days = 265.9 days/year

V_t = 365 days

Cft = 265.9 / 365 x100

Cft = 72.8 (72.8% limitation).

Precipitation Correction Factor (Cfp): In relation to the visit the GOAM, precipitation affects the visit in general. The ground getting wet and slippery on the excursion route can prevent recreational activities. The presence of precipitation is already a factor that hinders the visit. In calculating the precipitation factor, the average number of days when the precipitation was ≥5mm was considered.

Cfp = V_1 / V_t x 100

V_1 = 107.5 rainy days x 3 rainy hours = 322.5 hours/year

V_t = 11 visiting hours x 365 days = 4015 hours/year

Cfp = 322.5 / 4015 x100

Cfp = 8.03 (8.03% limitation).

Storm Correction Factor (Csf): Weather conditions where the wind speed is ≥17.2m/s according to meteorological data are defined as "stormy". Storm is considered a factor that hinders or significantly complicates recreation in open spaces.

Cfs = V_1 / V_t x 100

V_1 = 38 stormy days x 4 stormy hours = 152 hours/year

V_t = 11 visiting hours x 365 days = 4015 hours/year

Cfs = 152 / 4015 x 100

Cfs = 3.7 (limitation of 3.7%)

The factors restricting the excursion areas of the GOAM are formulated and given in Table 6 and the degree of limitation of these factors on recreation is calculated in %.

Table 6. Cf (Correction Factor) Values of Göreme Open-Air Museum.

C_f (Correction Factor)= V_v / V_t × 100	Göreme Open-Air Museum
Disturbing Temperature Factor (C_{ft}): V_v= (y_d – T) V_t = Vy_d	72,8 (%72,8 limitation)
Pprecipitation Correction Factor (C_{fp}): V_v = R × R_h V_t = d_h × y_d	8,03 (%8,03 limitation)
Storm Correction Factor (C_{sf}):	3,7 (%3,7 limitation)

$V_v = S \times S_d$	$V_t = d_h \times y_d$

Source: own elaboration.

The calculated correction factors were used to determine the actual carrying capacity of GOAM. The annual value of RCC refers to the physical capacity of the area in relation to the amount of recreational use during the year. When correction factors expressed as percentage values are substituted in the formula (Table 7).

Table 7. Göreme Open-Air Museum RCC Values (Scenario 1).

Museum Area RCC: (person/day)	1.715
Museum Area RCC: (person/month)	51.450
Museum Area RCC: (person/year)	625.975

Source: own elaboration.

Table 8. Göreme Open-Air Museum RCC Values (Scenario 2).

Museum Area RCC: (person/day)	858
Museum Area RCC: (person/month)	25.740
Museum Area RCC: (person/year)	313.170

Source: own elaboration.

Considering Scenario 1 and Summer Season in the calculation of the Physical Carrying Capacity of Göreme Open Air Museum;
PCC= 213840 : 30 = 7.128 visit/day. So,
RCC= 7.128 x (100 – 72,8 /100) x (100 – 8,03 /100) x (100 – 3,7 /100)
RCC= 7.128 x (0.272) x (0.919) x (0.963)
RCC= 1.715 visit/day can be calculated.

Considering the calculation results according to both scenario 1 and scenario 2 in Table 7, it can be said that the GOAM has an overcrowding problem in all months of the year.

Calculation of the Effective Carrying Capacity of the GOAM (ECC):

In calculating the effective carrying capacity, the number of active tourist guides, museum employees and security guards registered with the Nevşehir Chamber of Tourist Guides was included in the number of personnel. According to the information obtained, the total number of personnel is 782. In addition, the authorities (Nevşehir Chamber of Tourist Guides and Provincial Directorate of Culture and Tourism Personnel Affairs) stated that the number of personnel available was sufficient. Therefore, the number of personnel required was set at 785. According to this information;
MC= 782 / 785 x 100 = 99 (% 99)
ECC = RCC x MC
ECC = 1.715 visit/day x 0.99

Effective Carrying Capacity = 1,697 visits/day.

According to the results of the calculation of Effective Carrying Capacity, the number of personnel in the GOAM was found to be sufficient for the number of visitors hosted on a daily basis.

Calculation of the Physical Carrying Capacity (PCC) of the DUC: DUC covers an area of 4km^2 with its uncleaned area. However, the area that can be visited today was calculated to be 2500m^2 (Nevsehir Governorship). The properties required to determine the physical carrying capacity of the DUC are listed in Table 9.

Table 9. PCC Features of Derinkuyu Underground City.

V_h: Derinkuyu Underground City average visit time (hour)	1 hour
A: Derinkuyu Underground City Area (m^2)	2500m^2
d_t: Daily Period during which the Underground City is open to visitors (summer period)	11 hours
d_t: Daily Period during which the Underground City is open to visitors (winter period)	10 hours
D: Optimum sightseeing area per person (person/m^2)	1 or 0,5

Source: own elaboration.

In accordance with this information, the PCC for the DUC was calculated in two different ways by considering the scenarios of Hall & Page (2001) and the summer (April-September) – winter (October-March) periods. The PCC values calculated according to Scenario 1 and Scenario 2 are shown in Table 10 and Table 11.

Table 10. Derinkuyu Underground City Summer Period PCC Values.

* Derinkuyu Underground City PCC: (person/month)	27.500 people
** Derinkuyu Underground City PCC: (person/month)	13.750 people

*Scenario 1: D= 1 person, **Scenario 2: D= 0,5 person
Source: own elaboration.

Table 11. Derinkuyu Underground City Winter Period PCC Values.

* Derinkuyu Underground City PCC: (person/month)	22.500 people
** Derinkuyu Underground City PCC: (person/month)	11.250 people

*Scenario 1: D= 1 person, **Scenario 2: D= 0,5 person

Table 12 shows the distribution of the number of visitors to DUC by month, according to the statistics of the number of visitors to museums and ruins in 2019 by NPDCT.

Table 12. Number of Visitors to Derinkuyu Underground City in 2019.

Summer Period		**Winter Period**	
April	52.729	October	47.770
May	39.812	November	31.884
June	50.298	December	18.948
July	50.701	January	18.748
August	57.168	February	19.806
September	44.221	March	27.649
Total	**294.929**	**Total**	**164.805**

Source: own elaboration.

Looking at Table 12 and D = 1, it can be seen that there is a physical carrying capacity exceeding problem in all other months except December, January and February in DUC. With D = 0.5 people, the problem of exceeding the physical carrying capacity occurs throughout the year in both periods.

Calculation of the Social Carrying Capacity (SCC) of the DUC:

The information required for the calculation of the social carrying capacity of the DUC is shown below.

SCC= Gs x GEn x Rf

Gs (Group size -average-): 16 people
GEn (Average number of groups to be encountered): 4
Rf = the time the area is open daily / the average duration of a visit / rotation factor.

Duration of the underground city open to visitors: 11 hours
Visit duration (average): 1 hour
Rf = 11 hours / 1 hour = 11 visits/day
SCC= 16 x 4 x 11
SCC= 704 visitors/day.

According to the calculations, it can be seen that the social carrying capacity in DUC has been exceeded.

Calculation of KUC's Physical Carrying Capacity (PCC):

The navigable area of KUC which has a relatively smaller area than DUC, was determined to be 1450m^2 (Mutlu, 2008). The features required to determine the physical carrying capacity of KUC are shown in Table 13.

Table 13. PCC Features of Kaymaklı Underground City.

Vh: Kaymaklı Underground City average visit time (hour)	1 hour
A: Kaymaklı Underground City Area (m^2)	1450m^2
dt: Daily Period during which the Underground City is open to visitors (summer period)	11 hours
dt: Daily Period during which the Underground City is open to visitors (winter period)	10 hours
D: Optimum sightseeing area per person (person/m^2)	1 or 0,5

Source: own elaboration.

In accordance with this information, the physical carrying capacity for KUC was calculated in two different ways by considering the scenarios of Hall & Page (2001) and the summer (April-September) – winter (October-March) periods. The PCC values calculated according to Scenario 1 and Scenario 2 are shown in Table 14 and Table 15.

Table 14. Kaymaklı Underground City Summer Period PCC Values.

*Kaymaklı Underground City PCC: (person/month)	15.950 kişi
**Kaymaklı Underground City PCC: (person/month)	7.975 kişi

*Scenario 1: D= 1 person, **Scenario 2: D= 0,5 person
Source: own elaboration.

Tablo 15. Kaymaklı Underground City Winter Period PCC Values.

*Kaymaklı Underground City PCC: (person/month)	14.500 kişi
**Kaymaklı Underground City PCC: (person/month)	7.250 kişi

*Scenario 1: D= 1 person, **Scenario 2: D= 0,5 person
Source: own elaboration.

Table 16 shows the distribution of the number of visitors to KUC by months, according to the statistics on the number of visitors to museums and ruins in 2019 by NPDCT.

Tablo 16. Number of Visistors to Kaymaklı Underground City in 2019

Summer Period		**Winter Period**	
April	70.067	October	70.067
May	62.391	November	62.391
June	66.127	December	66.127
July	61.002	January	61.002

August	70.791	February	70.791
September	64.857	March	64.857
Total	**395.235**	Total	**395.235**

Source: own elaboration.

Analyzing Table 16 where D is calculated as both 1 and 0.5, it can be seen that KUC faced the problem of exceeding its physical carrying capacity throughout the year for both periods.

Calculation of KUC's Social Carrying Capacity (SCC):

The information required for the calculation of the social carrying capacity of KUC is shown below.

SCC= Gs x GEn x Rf

Gs (Group size -average-): 16 people
GEn (Average number of groups to be encountered): 3
Rf = the time the area is open daily / the average duration of a visit
Duration of the underground city open to visitors: 11 hours
Visit duration (average): 1 hour
Rf = 11 hours / 1 hour = 11 visits/day
SCC = 16 x 3 x 11
SCC= 528 visitors/day.

Considering the above information, it can be said that there is a problem of exceeding the social carrying capacity in KUC.

5 FINAL CONSIDERATIONS

The increase in the number of visitors and the excessive use of resources have begun to cause irreversible negative impacts on nature. The importance of sustainability in tourism, as in all sectors, has become evident in order to ensure the sustainability of existing resources and to allow future generations to benefit from them. It is well known that one of the most important factors affecting sustainability in tourism is demand management and that visitor management models and carrying capacity calculations are carried out in order to manage demand in a healthy way (Renjaan & Susanty, 2020).

The concept of carrying capacity emphasizes appropriate levels of use when considered in terms of tourist areas. However, determining these levels is quite difficult due to the content of the definition and the complexity of the concept. This difficulty is also reflected in the studies conducted in this field and the content of the concept and carrying capacities to be calculated have been discussed in the researches.

As a result of the literature review, studies were found in the field of tourism that mainly considered the social carrying capacity (Gonson et al., 2018). The studies based on the three recreational carrying capacity models used in this research were conducted in different disciplines other than tourism (De Sousa et al., 2017; Lorenz & Pusch, 2012; Morales et al., 2018), while there are a few in tourism (Soylu & Özkök, 2016; Tran et al., 2007).

In this respect, the research is expected to contribute to the tourism literature. In addition, literature review shows that the areas where calculations of three recreational carrying capacity are conducted are generally forests, parks/national parks/gardens and beaches (Cornejo-Ortega et al., 2011; Göktuğ & Yenilmez Arpa, 2016; Melo & Alcantara, 2014; Tran et al., 2007; Zacarias et al., 2011).

However, in this study, GOAM located in Göreme National Park and Cappadocia Rocky Sites, Derinkuyu and Kaymaklı Underground Cities, which are included in the UNESCO World Heritage List, were selected as application areas. Therefore, the study differs from other existing studies in this respect.

Since the GOAM is not an indoor space due to its structure, three levels of recreational carrying capacity have been applied here. In this context, first of all, the physical carrying capacity was calculated and it was found that the physical carrying capacity was not exceeded when the number of people per square meter in the GOAM was one.

However, if the number of people per two square meters is calculated as one, it is concluded that the physical carrying capacity is exceeded in all remaining months of the year, except for December, January, February and March. Furthermore, the actual carrying capacity was recalculated for the GOAM, taking into account the conditions that affect the conduct of outddor recreational activities and the results of this calculation show that the museum hosted more visitors than the optimum number of visitors in all months of the year.

According to the effective carrying capacity calculated for the GOAM, which is one of the three carrying capacity levels for recreation, the number of personnel working in this archaeological site was found to be sufficient. Since Derinkuyu and Kaymaklı Underground Cities are closed areas, the social carrying capacity that takes into account crowding and social distance was calculated instead of the actual carrying capacity in both areas.

In addition, the physical carrying capacity was calculated in order to avoid undesirable consequences in case of collapse due to the structural features of the underground cities. Based on the assumption that one person falls per square meter according to the physical carrying capacity results, it is concluded that the physical carrying capacity is exceeded in the remaining months of the year, except for December, January and February.

Based on the assumption that there is one person per two square meters, it is concluded that the physical carrying capacity in DUC is exceeded in all months of the year. Considering both "square meter/person" number assumptions in the calculations of physical carrying capacity in KUC, the results show that the problem of overcapacity occurs in all months of the year. In addition, the social carrying capacity results calculated for both underground cities refer to the number of visitors to be hosted on a daily basis.

These numbers are the most appropriate number of visitors / days determined in order for the guides to make healthy narrations, to prevent the sounds from mixing with each other in the narrations, to encounter fewer other groups when tourists ascend and descend the stairs and thus to reduce the waiting times.

5.1 Suggestions

Considering the findings obtained from the relevant literature and the results of the study, it is crucial to highlight the problems of the tourist areas in terms of carrying capacity, with various dimensions, in order to define the problem. It is well known that defining and understanding the problem is the most important step that can be taken to solve the problem. Carrying capacity is not a concept that should be addressed when problems arise in any tourist area. Rather, it is a situation that should be considered and calculated when touristic areas are still planned or before they are developed for tourism, and it is recommended that this situation be more in the interest of the area managers.

5.2 Theoretical Implications

Although it has been noted that physical, ecological and social degeneration caused by recreation has occurred in many national parks and natural protection areas in Türkiye, capacity determination studies have not yet been comprehensively addressed by decision-makers in the planning and management process. Among the main factors of this situation is the lack of sufficient scientific research in our country regarding the methods of carrying capacity analysis. For this reason, the study is intended to serve as a guide for calculating the carrying capacity of natural protection areas in our country.

The balance between protection and use of natural and cultural heritage areas, which has become an important planning and management problem, has required various studies aimed at producing alternative solutions. Studies have been conducted in many countries (America, China, Italy) to determine the capacities of natural and cultural heritage sites used for recreational purposes, especially national parks. However, it can be said that Türkiye remains weaker in this context compared to other countries. Such studies can guide decision-makers in ensuring the conservation-use balance of national parks and other natural protected areas, where recreational uses are intensive and of great interest to visitors.

5.3 Practical Implications

The absence of visitor management plans in most protected areas in Türkiye is an indication that the sustainable management approach in these areas has not yet reached the desired level (Manavoğlu & Yıldırım, 2020). In order to enable visitor management in the protected areas of our country, realistic budgets should be allocated by the relevant ministries, interdisciplinary planning staff should be formed and visitor management plans should be prepared based on carrying capacity.

However, it is recommended to consider that the success of these plans in the field depends on proper implementation and effective monitoring processes. Implementation and monitoring of the visitor management strategies and management tools defined in these plans by a management team to be composed of appropriately qualified and sufficient staff may also be taken into consideration.

5.4 Suggestions for Future Research

In addition, the literature review revealed that the calculations of the three carrying capacity levels for recreational purposes were mainly carried out in the fields of engineering/architecture. It is therefore recommended that future researchers conduct further studies including national parks, museums and beaches, with a view to including three recreational carrying capacity calculations.

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CRediT author statement

Term	Definition	Author 1	A2
Conceptualization	Ideas; formulation or evolution of overarching research goals and aims	x	X
Methodology	Development or design of methodology; creation of models	x	x
Software	Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components	x	
Validation	Verification, whether as a part of the activity or separate, of the overall replication/ reproducibility of results/experiments and other research outputs	x	
Formal analysis	Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data	x	
Investigation	Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection	x	
Resources	Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools	x	
Data Curation	Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later reuse	x	
Writing - Original Draft	Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation)	x	
Writing - Review & Editing	Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre-or post-publication stages		x
Visualization	Preparation, creation and/or presentation of the published work, specifically visualization/ data presentation	x	
Supervision	Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team	x	x
Project administration	Management and coordination responsibility for the research activity planning and execution		x
Funding acquisition	Acquisition of the financial support for the project leading to this publication	x	x

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