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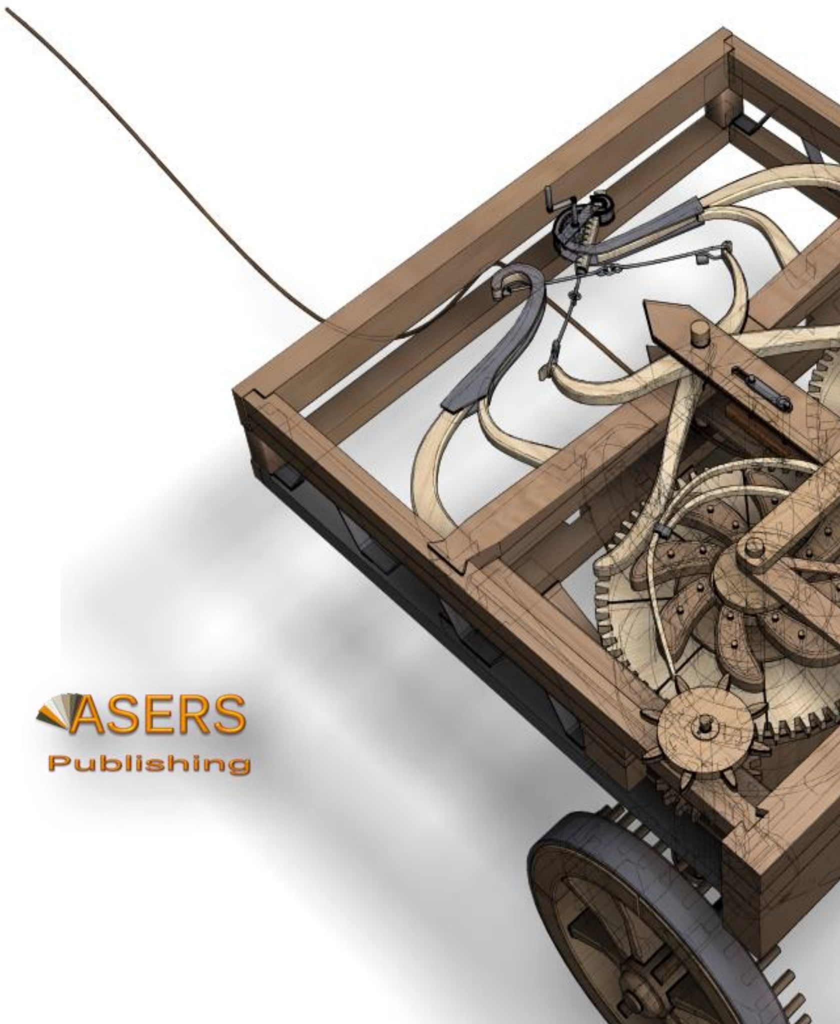

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Physical and Ecological Carrying Capacity for Cave Tourism Management

Onanong CHEABLAM
Tourism and Hospitality Industry Program, School of Management
Walailak University, Thailand
Corresponding author: conanong64@gmail.com

Jantira RATTANARAT
Marine Science Program, School of Science
Walailak University, Thailand
jantira.ra@wu.ac.th

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Abstract:

Cave tourism is a nature-based tourism which has recently gained its popularity in Thailand. Cave sare natural attractions which are extremely vulnerable, especially caves with limitations in both size and area. Thus, this study aims at studying and determining the maximum and suitable carrying capacity to support physical and ecological tourism in Ban Tham Sua tourism community area to avoid overtourism. The methodology used in this research was a survey on the tourist 's utilization, duration, number of tourists, and tourism impacts . Moreover, the impact assessment using 16 indicators presented by 5 geological experts for ecological carrying capacity of the cave areas were also conducted. This area-based study was conducted in 3 areas: Thep Nimit Cave, Nang Fa Cave, and Sua Noi Cave. The study found that the number of tourists in these three caves were below carrying capacitywhich had no or insignificant impact on natural resources. However, it was found that SuaNoi Cave was a huge destruction of the original resources. The study suggests that carrying capacity of cave tourism should be well planned and managed to prevent the environmental degradation.

Keywords: ecological carrying capacity; physical carrying capacity; impact assessment; cave tourism; tourism resources management.

JEL Classification: Q54; Q57; Z32.

Introduction

Cave tourism, a form of nature or ecotourism, recently gains its popularity in tourist industry as it can attract a large number of tourists (Demir 2019; Okonkwo, Afoma and Martha 2017; Antić *et al.* 2020). One of the most abundant natural attractions in Thailand is Ban ThamSua tourism community, Ao Luek Tai subdistrict, Ao Luek district, Krabi province (Thailand Convention and Exhibition Bureau 2020; Ministry of Tourism & Sports 2020a). This attraction consists of forest, mountain, and sea. Moreover, there are several attractive tourist destination caves including Thep Nimit Cave, Nang Fa Cave and Sua Noi Cave. However, these sites have some limitations (Hirunsalee 2020), including the size of the area, the fragility of the stalactites and stalagmites, as well as the amount of oxygen inside the caves According to Calaforra *et al.* (2003), cave lighting and tourist behavior lead to the increase of CO_2 and temperature which affects cave characteristics .As a result, ambient quality of speleothems, cave art, and biodiversity are degraded (Andrieux 1988; Baker and Genty 1998).

Therefore, the effective management system is essential in developing sustainable tourism to maintain the cultural, ecological, and biodiversity of the tourist attraction (Grilli *et al.* 2020). To create sustainable tourism, various issues, such as environment, local communities, and cultures, should be considered. Natural resources should be the least impacted and last long despite of tourism (Wongphatanasiri 2019; World Tourism

Organization 2020). The competition in the world tourism market nowadays results in the needs of tourism management to meet the tourist demands (Papatheodorou 2016). To maintain the existing tourists and attract the newcomers, the development of tourist attractions, standard of service, tourist experience, and satisfaction should be taken into account (Papatheodorou 2016), especially in the tourist destinations located in local communities which are currently in demand for tourism (Ministry of Tourism & Sports 2020b). Tourism must adhere in the sustainable community practices to preserve cultures and tradition and not to destroy natural resources which will devalue the tourist attractions (Amir *et al.* 2015) .Therefore, it is necessary to encourage local communities to participate in determining the carrying capacity of tourist destinations in their communities (Ministry of Tourism & Sports 2020b).

It is anticipated that using carrying capacity as a tourism planning tool will reduce the negative impacts arisen by overtourism (Noosut and Duangsaeng 2019; Lobo *et al.* 2013; Coccossis and Mexa 2017; Saveriades 2000; Tran *et al.* 2007). Overtourism can lead to conflicts overuse of space of tourist destination (Namberger *et al.* 2019). According to the National Tourism Policy Committee (2016), the criteria for sustainable community-based tourism development in Thailand are established. Two criteria of the development plan include the community's carrying capacity and community participation which impact the effectiveness of tourism management (The National Tourism Policy Committee 2016). The diversity of stalactites and stalagmitescan be preservedand protected from tourism impacts by implementing the sustainable management of cave attractions. The study of tourism management and determination of physical and ecological carrying capacity are necessary for protecting the tourist attractions from negative impacts in the long term (Cigna 2016; Hirunrattanaphong *et al.* 2017). This research aims at improving a management system of cave tourism by conducting a survey of the area condition and identifying current physical and ecological carrying capacity of Ban ThamSua tourism community, Krabi province. This study will fill a knowledge gap of management impacts on cave and natural resources in tourist destinations .

1. Literature Review

Tourism carrying capacity is significant for social elements related to tourism activities and the development of areas to support tourism (Wolters 1991). The World Tourism Organization defines the term 'carrying capacity'as the level of visitors that area or destination can accommodate with the lower negative impact on resources (WTO/UNEP 1992). In other words, it refers to the maximum number of people visiting a tourist destination simultaneously, without destroying the physical, economic, and sociocultural environment as well as without decreasing tourists' satisfaction (Kyrıakou, Hatırıs and Sourıanos 2017). In this study, the carrying capacity includes two dimensions: physical carrying capacity determination (PCC) and ecological carrying capacity determination (ECC).

Physical Carrying Capacity (PCC)

Physical carrying capacity is defined as the maximum number of tourists that an area can accommodate without causing any impact and can facilitate the demand on tourism activities which varies according to the nature of tourism activities and types of attractions. The physical data used in the assessment is the size of the area used by tourists per person to carry out activities, the size of the area for supporting activities, duration of the activity, the unit of physical carrying capacity which is the number of people used during the same period or people at one time (PAOT)(Wiyono, Muntasib and Yulianda 2018).

Ecological Carrying Capacity (ECC)

Ecological carrying capacity (ECC) is an important indicator in evaluating sustainable development in an ecosystem (Ma *et al.* 2017). ECC is a mirror reflecting the impact of human activities on an ecological environment as well as an index to identify whether human activities are in harmony with ecosystems and resource utilization (Ma *et al.* 2017). It is considered as a key link between the ecosystem and the human system (Xu and Pan 2020).

Environmental or ecological carrying capacity is the maximum value of human activity that can be accepted without environmental degradation. Determination of carrying capacity to accommodate ecological tourism, it is necessary to consider both the utilization quantity and the behavior of the area usage as well as ecological resilience that impacts arising from tourism activities (Liu *et al.* 2018). This ecological carrying capacity was studied by measuring the level of tourism utilization related to the impact on the composition of the ecosystem or environment, such as the impact on water quality, tourism waste on the environment, etc. (Peng *et al.* 2018).

Based on the above-mentioned principles, many researchers have developed a conceptual framework to be used as a model for studies and to define the carrying capacity, including:

(1) Limits of Acceptable Change (LAC): This is the most useful and flexible method to avoid or manage over-tourism. It is related to a plan for tourism without degrading the socio-cultural and physical environment (Goodwin 2019). The LAC also represents a reformulation of the recreational carrying capacity concept, with the primary emphasis now on the conditions desired in the area rather than on how much use an area can tolerate (Stankey *et al.* 1985);

(2) Visitor Impact Management (VIM): It refers to the management related to visitor behavior and interaction with a place or destination in order to mitigate or avoid negative impacts of visitation such as congestion, pollution, or damage to flora and fauna (Albrecht 2018);

(3) Visitor Experience and Resource Protection (VERP): This process consists of nine elements, which are the grouping of interdisciplinary project members, developing a public involvement strategy, developing objectives, theme and expected limitations, identifying existing resources, describing visitor experiences and resource conditions, allocating specific areas, selecting indicators and developing a monitoring plan, monitoring resources, and taking action (Hof and Lime 1997);

(4) Visitor Activity Management Process (VAMP): It is a management plan for matching visitor's interest and protection of the area. It is related to the understanding and integrating data about visitors, their characteristics and satisfactions with the natural environment in order to encourage them to reduce negative impact on natural environment (Graham, Nilsen and Payne 1988).

The study of ecological carrying capacity uses the assessment model based on the Limits of Acceptable Change (LAC) concept. It is the determination of variables that measure the impact of human activities in order to indicate whether such utilization exceeds the carrying capacity. This model can help area managers realize what impact has exceeded the standard of carrying capacity or what impact is at and approaching maximum acceptable carrying capacity or what impact is below the standard (Hof and Lime 1997).

Carrying Capacity for Cave Tourism Management

The carrying capacity concept is proposed to estimate the number of visitors or travelers that a destination can have with minimum impacts on ecosystems while enhancing visitors' experience (Guerrero *et al.* 2015). Determination of carrying capacity of the destination helps identifying the maximum number of people who can use an environment without an unacceptable decline in the quality of experience (Sarantakou and Terkenli 2019) as well as avoiding conflicts over the overuse of spaces, often referred to as overtourism (Namberger *et al.* 2019).

Caves are a part of nature tourism, or "ecotourism' which is attracting adventure tourists nowadays (Rindam 2014). The idea of tourist carrying capacity has been traditionally used as a tool to plan and manage in cave tourism (Putra, Haryono and Nurjani 2017; Lobo 2015; Lobo *et al.* 2013). It is the way to maintain environment by focusing on quantifying impacts as well as to create economic-administrative sustainability and community support. In order to maintain carry capacity for cave tourism management, the destination area should conduct a process of participative discussion among stakeholders aiming to verify the pros and cons about the implementation of each cave so that the caves and their sustainable usage will be also examined. The topics for discussion that should be covered are as follows (Lobo *et al.* 2013):

(1) The completive tourist route and pathway;

(2) The identification of specific areas of incompatibility or high fragility levels;

(3) The number of tourists and tour guides per group (These numbers may vary due to many factors, such as the day of the week);

(4) The quality of tourism services to be provided;

(5) The duration of the tour and the total time of visitation in a day;

(6) Climate seasons (Lobo 2015; Lobo *et al.* 2013).

Moreover, one more important aspect that should be considered is cave air or cave temperature. Natural influences should be studied, especially air ventilation which have greater long-term impact on cave air temperature, including heat, warm air, and cool air. This will help determine the appropriate number of visitors when planning the visitation in a specific time. For example, higher visitor numbers will be allowed during the winter while they are limited in number during summer months (Sebela and Turk 2014).

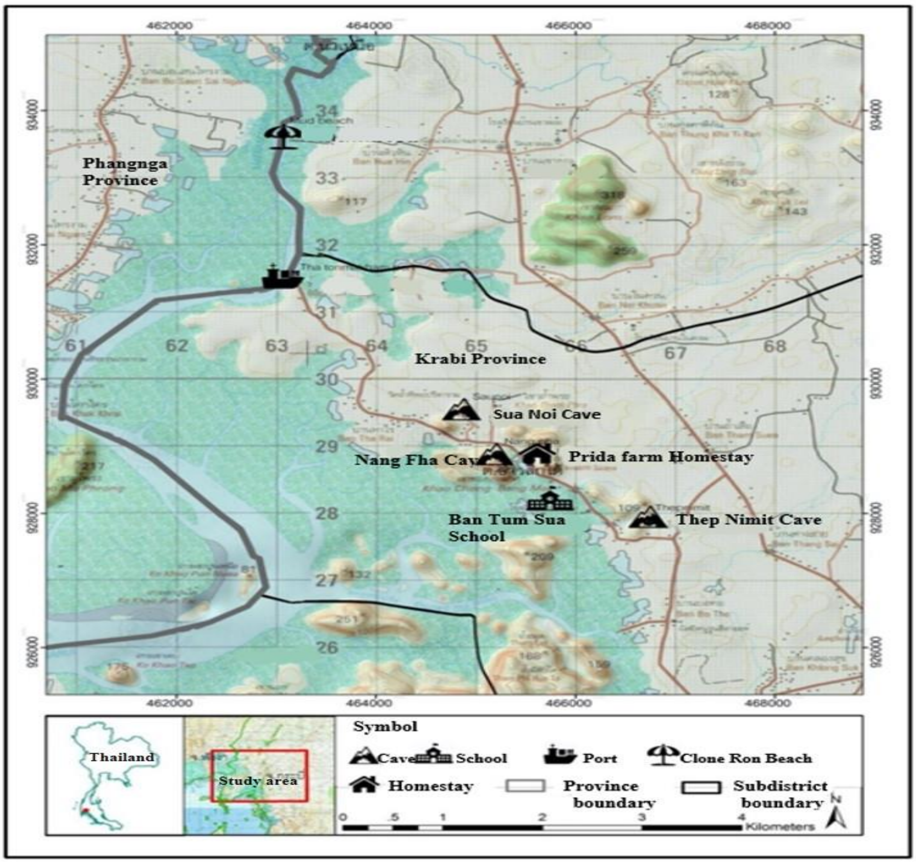
Due to the fact that different cave characteristics influence the difference in carrying capacity of each cave (Putra, Haryono, and Nurjani 2017), carry capacity for cave tourism management should be flexible based on the conditions of each area, such as environmental resources, travelling demand from tourists, different groups of visitors, patterns of consumption, local realities, unanticipated environmental impacts, climate seasons, etc.

Additionally, a continued monitoring should be conducted to look after environmental factors, visitor satisfaction, and the dynamics of the tourism inside the cave (Lobo 2015; Lobo *et al.* 2013) .

Study Areas

Ban Tham Sua tourism community, Ao Luek Tai subdistrict, Ao Luek district, Krabi province was a community located in the middle of the forest. It was a tropical evergreen forest close to mangrove forest and on the edge of the main saltwater canal. Moreover, there are various tourist resources, such ascaves which includeThep Nimit Cave, Nang Fa Cave and Sua Noi Cave (Thailand Convention and Exhibition Bureau 2020; Ministry of Tourism & Sports 2020a). They were all traditional tourism resources as shown in Figure 1.

Figure 1. Map of Ban Tham Sua Tourism Community



The popular activities in Ban Tham Sua tourism community were kayaking, visiting prehistoric human graveyard caves (Readme 2020), elephant trekking, ATV driving at a maze safari, cycling in villages, basketry activity, hot mud spa program, etc., (Community Tourism Network 2018). However, caves were the most popular sites among all attractions in Ban Tham Sua tourism community. Thep Nimit Cave (Sua Nok Cave) was a home of Thep Nimit Monastery, which was located on a cliff with many shells piled on each other created by water pressure from an under water tunnel inside the cave (Thai-tour 2020). Nang Fa Cave was a tourist attraction located along cycling routes in Ban Tham Sua tourism community. It is believed to be a cave hall. The cave's ceiling was collapsed for over 4,000 years ago by tectonic shifts (Ao Luek District 2020). Sua Noi Cave was full of stalactites which looks like a tiger. Inside the cave, there was a Buddha image for tourists to worship. The tourists can walk through a hollow and a tunnel. In the past, this cave was a home of a Buddhist monastery. Then, the villagers decided to build a new temple nearby for uniting people in the community (Office of Contemporary Art and Culture (OCAC) 2018).

2. Methodology

This study focused on three cave attractions: Thep Nimit cave, Nang Fa cave and Sua Noi cave by conducting a survey on the tourist's utilization, duration, number of tousists, and tourism impacts. These factors determined the physical and ecological indicators of tourism in the community and the results was utilized to design the effective management system for sustainable tourism. The study of carrying capacity of caves in Ban Tham Sua tourism community was based on two types of capacity as follows:

2.1. Physical Carrying Capacity

Research instruments employed in data collection include atape for measuring an area size, record form, utilization distribution form,and number of tourists who participated in activities in the area.

Data analysis

(1) Calculating the maximum number of tourists that each cave can accommodate per day.

The PCC calculation is as follows (Ríos-Jara *et al.* 2013; Wiyono, Muntasib and Yulianda 2018):

$$PCC = \left[\frac{A \times Rf}{a} \right] \quad 2.1$$

PCC = Physical carrying capacity(user/area/period)

A = Available area for public use (cave area; m^2)

a = Area occupied per a tourist (1 tourist per m^2)

Rf = Rotation factor (number of visits /day). Rf can be calculated from a duration of operating hours or availability for utilization (TT), operating hoursper an average amount of time required per a visit (Ta), and average time of visitsas follows:

$$Rf = \frac{TT}{Ta} \quad 2.2$$

(2) Assessing the current utilization level under the physical carrying capacity.

The relationship between current utilization and physical carrying capacity was examined by creating criteria for determining a number of tourists according to the physical carrying capacity of each area. The utilization level was classified into 3 levels: low level a number of tourists was less than 50 % according to the PCC value from the equation moderate level a number of tourists was between 50 and 80 % and high level a number of tourists was more than 80. Theses levels were calculated by the equation 2.1 in each toursism destination area.

2.2. Ecological Carrying Capacity

The ecological carrying capacity (ECC) was employed in environmental impact assessment (EIA) (Bhattacharya and Suchitra 2003; Sharma 2016).

Table 1. Ecological impact indicator for evaluating ecological carrying capacity

Ecological Impact Indicator	Sub indicators	weighting scorer (W)
1. The composition of the cave environment and ecosystem	1.1 types of stalactites and stalagmites	5
	1.2 collapsed holes within the cave	4
	1.3 the number of opened holes or windows in the cave roof	4
	1.4 the level of carbon dioxide in the cave	4
	1.5 average temperature inside the cave	4
	1.6 the type of fossils found in the cave	5
	1.7 the number of months of water droplets per year	4
	1.8 creatures living in the cave	4
	1.9 distance from the quarry or limestone industry	5
	1.10 the destruction of archaeological evidence	4
	1.11 the destruction from a disaster	3
2. Landscape and architecture	2.1 the number of cave zones for utilization	4
	2.2 expanding the administrative areas for aesthetics purpose	4
	2.3 aesthetics and beauty	4
	2.4 shapes, colors and materials	4
3. Cave management	maintenance of the facilities/construction in both inside and outside the cave	4

Source: Office of Natural Resources and Environmental Policy and Planning (2016)

The ECC evaluation indicators for impact assessment in this study were borrowed from the Office of Natural Resources and Environmental Policy and Planning (2016). (Table 1) 5 geological experts employed the ECC evaluation indicators to survey the composition and assess the cave condition. An assessment form of natural environment quality for natural caveswas used in data collection process.

Data analysis

I collected general information about caves, including name, location based on the Universal Transverse Mercator (UTM) by using a global positioning system (GPS), external and internal geology, cave mapping, thorough exploration of the cave elements, external and internal climate, utilization, types of land use surrounding caves, accessibility and tourism activities, and the size of the area where activities took place. After that, I determined factors and their significance level .Three indicators and 16 sub-indicators were taken into account in an assessment (Office of Natural Resources and Environmental Policy and Planning 2016). The evaluation scale ranged from 1 to 5 *i.e.* low to very important, which were adapted from the Office of Natural Resources and Environmental Policy and Planning (2016) .The most significant indicators of ecological carrying capacity for natural caves were marked 5 while the least significant indicators were rated 1 .The evaluation was completed by at least 5experts to achieve an average score calculation. Next, I collected data from indicators and converted them to the environmental quality efficiency scores of each indicator which ranged from 1 to 3 as follows:

1 means no impact or little impact (below standard/below carrying capacity);

2 means moderate impact level (at and approaching standard/maximum acceptable carrying capacity);

3 means high impact level (exceeding standard/exceeding carrying capacity).

Then, I used weighting score method to calculate the carrying capacity of each natural cave destination as follows:

$$CENQ = \frac{\sum_{i=1}^{n} Ri \times Wi}{\sum_{i=1}^{n} Wi} \quad 2.3$$

CENQ = Natural environment quality of natural caves

Wi = Weighting score of indicators for environmental quality assessment of natural caves .It determines the significance of each indicator using a 5-point scale (from 1 to 5 or from low to very important).

Ri = The natural environmental quality score of the given indicator

N = The number of indicators

After obtaining the scores for natural environment quality of natural caves, I compared them with the criteria below;

1.00-1.66 = Good level of carrying capacity

1.67-2.33 = Moderate level of carrying capacity

2.34-3.00 = Low level of carrying capacity

After the research team has assessed the potential and carrying capacity of the attractions, the results of the aforementioned assessment were reviewed with all stakeholders to determine indicators and criteria to make a decision which may affect caves' environment. This is to enable the community to manage tourist attractions effectively and sustainably in the future.

3. Result

The project to determine the level of tourism utilization according to the physical and ecological carrying capability at Ban Tham Sua tourism community, Krabi Province was divided into parts: physical aspect, and ecological aspect. The issues in the area were also identified in order to provide suggestions to effectively manage tourism resources and to preserve community ecosystems. The results of the study can be summarized according to the following research objectives.

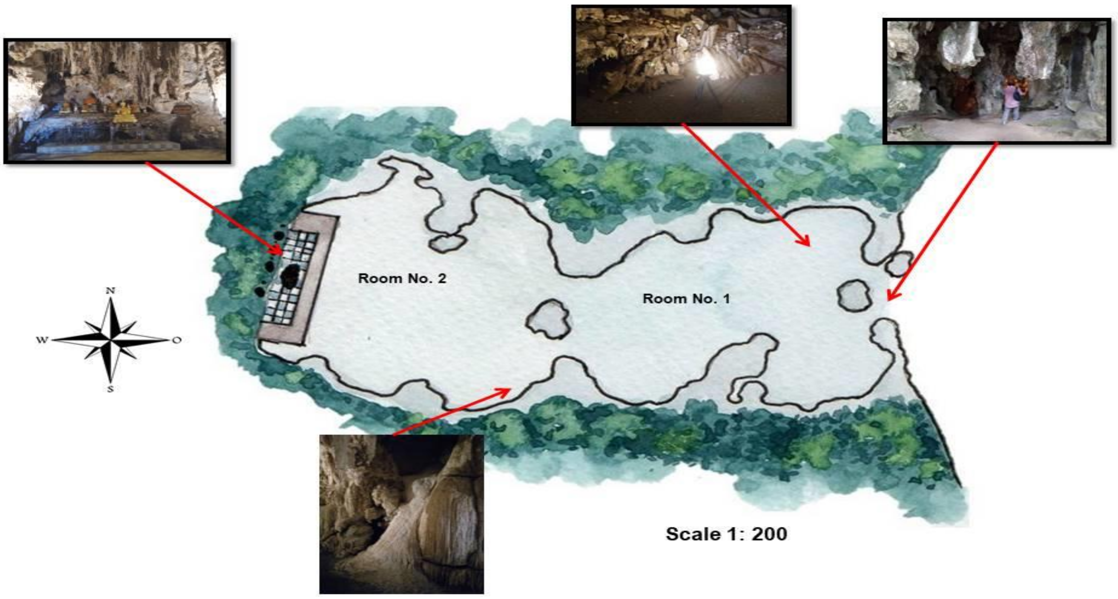
Characteristics of Caves

Thep Nimit Cave

Thep Nimit Cave was a small abundant cave including attractive stalagmite, stalactite, columns, chandelier, drapery, flowstone, soda straws, and limestone. They varied in size depending on their origin. There were also various sizes of music pipes formed by knocking the stalactite in the inner hollow which made different melodious sounds like music notes. The color of the outer coating was green from living moss, black color from the dead moss, or red color from the decomposition of iron ore, the chemical component of limestone. The cave's entrance was exposed to both air and sunlightcreating stalagmites and causing high temperature outside which was lower than the temperature inside. The environment mentioned was suitable for the formation of stalactites.

The survey results of the current condition found that the cave was a house of Thep Nimit Buddhist monastery. There were many cliff sheds .Upstairs was a large dark cave and there was an arhat cave full of stalactites and stalactites like a glass tube with a nature trail almost around the cave in the next 5 0 meters as shown in Figure 2. Human construction in the area caused partial limestone, stalactites, and stalagmites partially destruction.

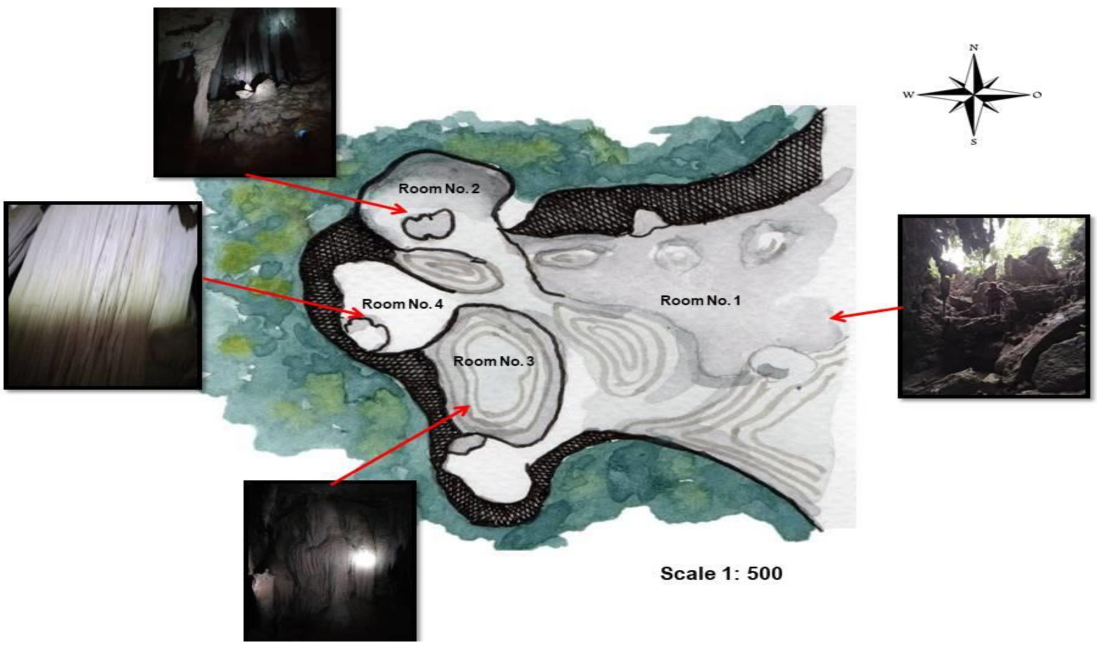
Figure 2. Scenario and tourist spots of Thep Nimit Cave



Nang Fa Cave

Nang Fa Cave was a deserted cave where its walls were collapsed resulting in a wider cave entrance and a breakdown of stalactites. However, water was still flowing through the cave walls which created stalactites and a sparkle of mineral. Nang Fa Cave was a large cave whose elements similar toThepNimit Cave and SuaNoi Cave.

Figure 3. Scenario and tourist spots of Nang Fa Cave



There were 4 accessible rooms. Additionally, the stalactite was grown in the state of anti-gravity where its axis was tilted away from the pelictites, which was rarely found. The cave pearl or Oolitic limestone-Egg stone was also found as well as a very large white column of at least 2 meters in diameter and more than 5 meters in height. Nang Fa Cave were divided into several levels and there were different numbers of rooms at each level. Some rooms were very deep while some were very high. Yet, each floor or each room has not been explored because it was difficult to access. Travelers must bow their heads while passing through corridors to access each room as well as had to be careful of trampling the stalagmite on the floor. Sometimes, they had to carefully climb a steep slope; otherwise, the cave may be damaged, or it may cause an accident.

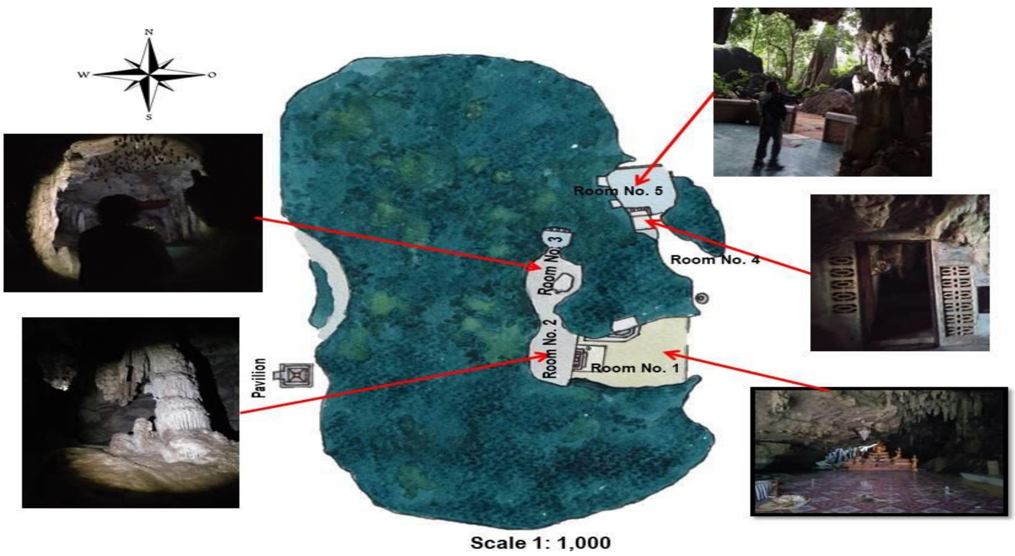
The survey results show that it was a tourist attraction on cycling routes for recreational purposes as well as educational purposes including learning the nature and ecosystems. The entrance to the cave looks like a pile of stalactites and stalagmites which are over 20 meters high, which is suitable for adventurous tourism. The cave features a wide variety of stalactites and stalagmites which are very unusual. There were also many traces of the shells. This cave made a great impression on those who visited as shown in figure 3.

Sua Noi Cave

Sua Noi Cave contained complete cave elements, including attractive stalagmite, stalactite, columns, drapery, flowstone, stalactite, and soda straws. They varied in size according to the birth duration, layer or goat condo, and color .The outer coating was in green from living moss, black color from the dead moss or red color from the decomposition of iron ore, a chemical component of limestone. The cave mouth was exposed to both air and sunlight causing high outside temperature and forming stalagmites and stalactites slower than inside the cave where the temperature was lower and there is no direct sunlight. Some parts of the stalactite which broke or partially fell from the ceiling from natural causes, such as its weight, natural decomposing, and several earthquakes in the past. Furthermore, many broken clay pots were found in the cave. This indicates that this cave may be inhabited by humans or be a temporary refuge before they settled down in other places.

Sua Noi Cave was close to the community and easily accessible. It was also a house of priest. In front of the cave, there was a wide cliff shed surrounded by peaceful nature. Inside the cave, there was limestone with stalactites and stalagmites. In addition to visiting the natural sources of the cave, tourists can worship Buddha images in the cave and admired the remains of ancient shells in the caveas shown in figure 4. These days, cave conditions have changed by constructions which partially destroyed the stalactites and stalagmites.

Figure 4. Scenario and tourist spots of Sua Noi Cave



Physical Carrying Capacity

According to the determination of the maximum and suitable physical and ecological carrying capacity to support tourism at Ban ThamSua tourism community in Krabi province, the study found that PCC in Sua Noi Cave can accommodate most tourists due to wider area of usable cave rooms and tourists can rotate more time, followed by Nang Fa Caveand Thep Nimit Cave, which can accommodate as 187,135and 76 tourist /day, respectively as shown in Table 2.

Table 2. Physical carrying capacity of cave in Ban Tham Sua tourism community

Tourist destinations	Utilized area (square meters)	Average time of visit (hours)	Open period (hours)	Area required per person (m^2) 1/	Rf	PCC (person/day)
1 .Thep Nimit Cave						
Room 1	21	0.75	8	6.76	10.67	33
Room 2	27					43
Total	48					76
2 .Nang Fa Cave						
Room 1	22	1	8	2.25	8.00	78
Room 2	2					7
Room 3	5					18
Room 4	9					32
Total	38					135
3 .Sua Noi Cave						
Room 1	42	0.63	8	6.76	12.63	78
Room 2	3					6
Room 3	5					9
Room 4	5					9
Room 5	45					84
Total	100					187

Remark 1/ data from onsite tourist interviews

The impact on physical congestion of tourist destinations was determined by the physical carrying capacity on the same period (PAOT) of Ban Tham Sua tourism community as shown in Table 3.

Table 3. Physical congestion of tourist destinations determined by PAOT

Tourist destinations	PCC (person/PAOT)	Current utilization level (person/PAOT) 1/	Proportional percentage and PCC (%)		
			<50% Below CC	50-80% Approaching & At CC	>80% Exceeding CC
1. ThepNimit Cave	7	3	<4	4-6	>6
2. Nang Fa Cave	17	none	<9	9-14	>14
3. SuaNoi Cave	16	5	<8	8-13	>13

Remark 1/ data from onsite surveys

The physical impact assessment of the area to find the relationship between the current utilization level and physical carrying capacity found that all sources had a current utilization level which did not exceed the carrying capacity. All three caves were found to have a current utilization level below their carrying capacity. The authors should take into accountthat carrying capacity is one of tools for tourist destination management (Lobo *et al.* 2013). Carrying capacity was considered based on the cave characteristics and natural environment.

Ecological Carrying Capacity

Temperature parameters and number of visitors were important for cave carrying capacity (Calaforra *et al.* 2003). It was found that the outside temperature of the three caves was not much different. The temperature was between 25.5 and 26.5 °C. The temperature inside the three caves was 25.7 -26.3 °C, 25.4 - 28.0 °C and 26.0 - 28.3 °C, respectively. The temperature inside the three caves was higher or equal to the outside temperature. However, during the study period between 16-17 June 2018, it was raining all the time. This may cause the fall of temperature outside the cave. There are various factors, such as humidity, relative, and a higher wind inside the cave. As Carbon dioxide (CO_2) played a key role in the cave, the control number of tourists who added CO_2 were recognized as an issue in the conservation of caves (Milanolo and Gabrovšek 2009). It is found that a carbon dioxide level in ThepNimit Cave, Nang Fa, and Sua Noi Cave was 483.4 ppm, 542.2 ppm and 417.9 ppm, respectively (Table 4).

The carbon dioxide content in all three caves was not very high compared to the environmental impact assessment criteria of the Office of Natural Resources and Environmental Policy and Planning (2016).

Table 4. Temperature and carbon dioxide concentration of outside and inside the cave

Cave	Temperature (°C)		Carbon dioxide concentration (ppm)
	Inside	outside	
1. Thep Nimit Cave			
Room1	25.7	25.5	496.6
Room2	26.3		470.2
Average	26.0		483.4
2. Nang Fa Cave			
Room1	25.7	26.5	599.4
Room 2	25.4		561.0
Room3	26.9		531.6
Room 4	28.0		476.6
Average	26.5		542.2
3. Sua Noi Cave			
Room1	26.4	27.1	402.9
Room2	27.3		515.1
Room3	28.3		441.9
Room4	27.7		457.5
Room5	26.0		272.3
Average	27.1		417.9

According to the evaluation of the ecological carrying capacity of Thep Nimit Cave, Nang Fa Cave, and Sua Noi Cave, it is found that Sua Noi Cave obtained higher environmental impact than other caves. Thep Nimit Cave and Nang Fa Cave had a good level of carrying capacity at the scores of 1.64 and 1.58, respectively as shown in Table 5. Thep Nimit Cave had a small number of tourists visited while the natural resources of Nang Fa Cave was still rich since it had not been opened for tourism purposes yet. The carrying capacity of Sua Noi Cave was at a moderate level with 1.94 scores as it was modified to different rooms and tiled over the stalactites and stalactites to prevent their growth. It can be concluded that it was a huge destruction of the original resources for housing and utilizing for religious activities.

Table 5. Ecological carrying capacity of cave destinations

Indicators	ThepNimit Cave			Nang Fa Cave			SuaNoi Cave		
	Score (R)	weighting scorer (W)	total (RxW)	score (R)	weighting scorer (W)	total (RxW)	score (R)	weighting scorer (W)	Total (RxW)
1 .The composition of the cave environment and ecosystem									
1.1 types of stalactites and stalagmites	1	5	5	1	5	5	1	5	5
1.2 collapsed holes within the cave	1	4	4	3	4	12	1	4	4
1.3 the number of opened holes or windows in the cave roof	1	4	4	1	4	4	1	4	4
1.4 the level of carbon dioxide in the cave	1	4	4	1	4	4	1	4	4
1.5 average temperature inside the cave	3	4	12	3	4	12	3	4	12
1.6 the type of fossils found in the cave	3	5	15	3	5	15	3	5	15
1.7 the number of months of water droplets per year	1	4	4	1	4	4	1	4	4
1.8 creatures living	2	4	8	2	4	8	2	4	8

in the cave									
1.9 distance from the quarry or limestone industry	2	5	10	1	5	5	1	5	5
1.10 the destruction of archaeological evidence	1	4	4	1	4	4	3	4	12
1.11 the destruction from a disaster	1	3	3	1	3	3	1	3	3
2 .Landscape and architecture									
2.1 the number of cave zones for utilization	2	4	8	1	4	4	2	4	8
2.2 expanding the administrative areas for aesthetics purpose	2	4	8	1	4	4	3	4	12
2.3 aesthetics and beauty	1	4	4	1	4	4	3	4	12
2.4 shapes, colors and materials	3	4	7	1	4	4	3	4	12
3 .Cave management									
maintenance of the facilities/construction in both inside and outside the cave	2	4	8	3	4	12	2	4	8
Summary of total score	-	66	108	-	66	104	-	66	128
Level of ECC	1.64 = Good			1.58 = Good			1.94 = Moderate		

Regarding the ecological carrying capacity of Sua Noi Cave, ECC was estimated to be in a moderate level as the caves may be affected by tourism developments which impact the cave ecosystem including stalagmites, stalactites, and cave walls. The installation of lights has a direct impact on the formation and development of stalactites and stalactites in caves (Ikner *et al.* 2007) as they were extreme environments (Schabereiter-Gurtner *et al.* 2004). This is consistent with the study of (Ratanaphan *et al.* 2019) which found that in order to develop tourism routes of fragile caves with stalactite and stalagmite, the management of cave should considered the impact arisen from tourism activities. Cave carrying capacity should be flexible and environmental monitoring. Moreover, the level of tourist demand is one of the conditions which should be considered in tourism management (Lobo *et al.* 2013). The fragility of cave is the limitation of tourist potential assessment (Lobo 2007). Moreover, the use of technology could be applied to monitor and measure an overtourism mitigation in a certain area (Camatti *et al.* 2020). The plausible number of tourists is not the purpose of determining carrying capacity, but the acceptable level of ecosystem changes are the main indicators of area management (McCool and Lime 2001).

This study found that the number of tourists in all caves was lower than the carrying capacity. However, cave tourism capacity should be monitoring regarding the demand and pattern of tourists' consumption (Lobo *et al.* 2013). However, the community was concerned that the number of tourists will increase in the future and cause the natural deterioration. According to Wiyono, Muntasib, and Yulianda (2018), carrying capacity management should be planned out to prepare for peak season, although the current number of tourists is still not exceed the carrying capacity. Moreover, carrying capacity also need for landscape planning, policy formulation (Sarantakou and Terkenli 2019) and decision-making in tourism planning (González-Guerrero *et al.* 2015).

Conclusion

The physical carrying capacity of each cave was determined by a maximum number of tourists that the area can accommodate. Sua Noi Cave had the highest physical carrying capacity because of the wider area of usable cave rooms and more facility to support tourism. It can carry 187 tourists per day, followed by Nang Fa Cave and Thep Nimit Cave that can accommodate 135 and 7 6 tourists per day, respectively. Regarding the ecological carrying capacity of ThepNimit Cave, Nang Fa Cave, and Sua Noi Cave, it is found that Thep Nimit Cave and

Nang Fa Cave had a good level of carrying capacity with 1.64 and 1.58 scores, respectively. SuaNoi Cave had carrying capacity at a moderate level with 1.94 scores .

Although the carrying capacity of the caves was not exceeded, the cave attraction should be managed to conserve natural tourist destinations. The effective management will enable the tourist attractions to accommodate more tourists and become a source of income of the communities. To prevent any damages to the attractions, the guidelines for tourism management of Ban ThamSua tourism community are provided as follows:

(1) Provide staff to take care and guide tourists to control the specified number of tourists, to prevent dangers which will occur, and to conserve the natural resources in the caves, especially ThepNimit Cave and Nang Fa Cave;
(2) Educate tourists in terms of the conservation and maintenance of natural resources so that they have positive behaviorstowards natural resource conservation;
(3) Clearly set the operating time for the caves so that the community can control the access of tourists;
(4) To determinethe carrying capacity of tourist destinations,tourism communities in Thailand should be educated on tourism management;
(5) Utilize the data of carrying capacity of tourist destinations by cooperating with communities, government agencies, and other related parties. Moreover, the ongoing evaluation and monitoring should be carried out.

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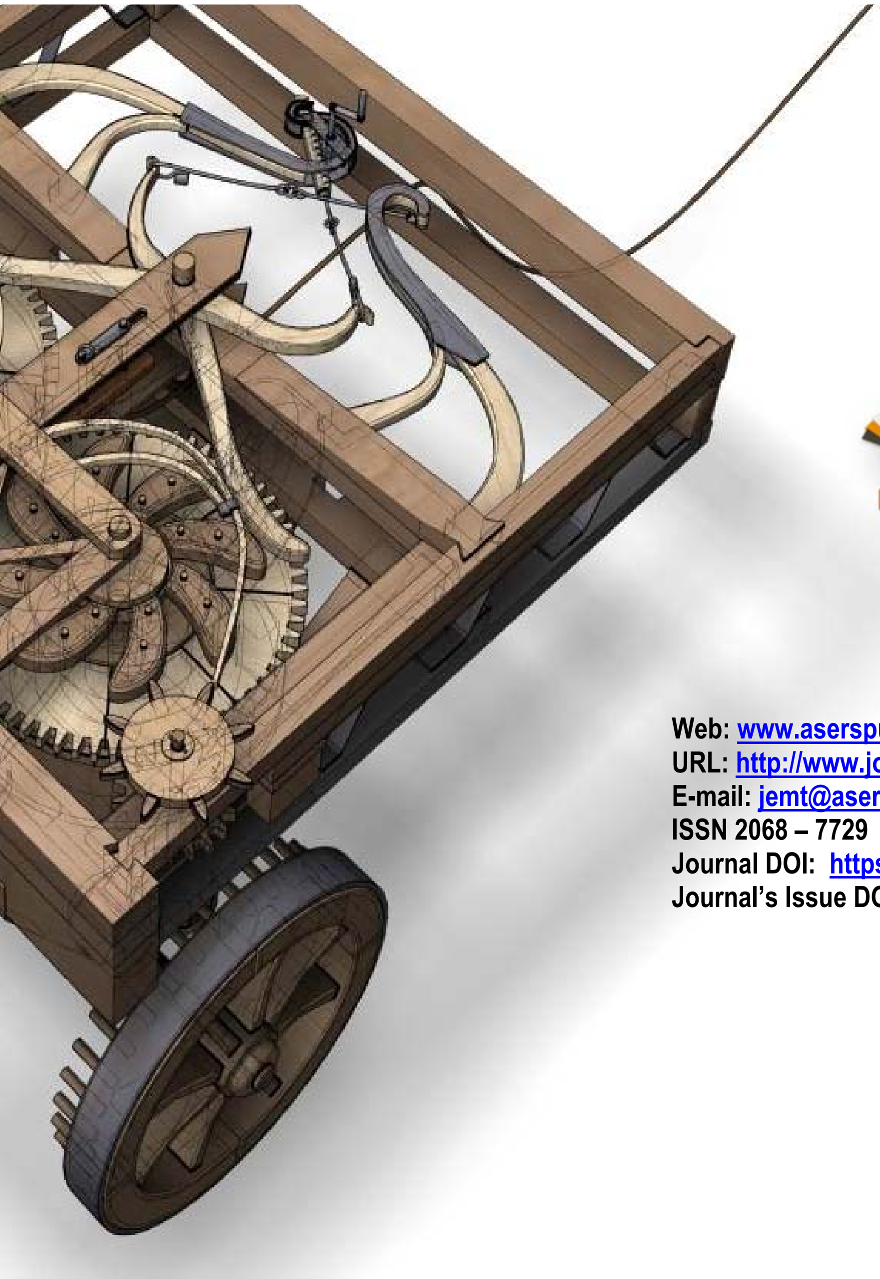

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