Sustainable tourism management in protected areas using a systemic approach

A case study from Þingvellir National Park, Iceland

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SUSTAINABLE TOURISM MANAGEMENT IN PROTECTED AREAS USING A SYSTEMIC APPROACH

A CASE STUDY FROM ÞINGVELLIR NATIONAL PARK, ICELAND

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30 ECTS thesis submitted in partial fulfillment of a
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Abstract

Rapid expansion of nature-based tourism in protected areas is likely to have adverse impacts to the natural environment. In order to safeguard the possibility of equivalent use of nature for future generations, adequate management for environmental sustainability in nature-based tourism in protected areas is critical. The challenge is to find a compromise between the use and protection of natural resources for tourism, to sustain current as well as future use. To be able to implement an effective environmental management that can reduce undesirable tourism impacts on the natural environment, it is crucial to understand the underlying mechanisms leading to these environmental impacts. This study attempt to provide a holistic understanding of the causal relationships between the influencing variables in a tourism environmental subsystem, based on a system analysis approach. The general aim of this research is to investigate the potential of system analysis for sustainable tourism management in naturally fragile environments by firstly evaluating environmental impacts of tourism activities and tourism infrastructure, and how these impacts influence visitor experience. Secondly, by analysing the causes and effects of different management tools in reducing negative environmental impacts of tourism and maximizing positive impacts. A case study was carried out for Thingvellir National Park, Iceland, were key variables in the tourism environmental subsystem were identified and their causal relations analysed. The results emphasize the importance of proper environmental management in order to prevent negative environmental impacts of nature-based tourism. It is concluded that system analysis a critical tool in sustainable tourism management providing the transparency needed to increase the understanding of causal relation of influencing variables within the system.

Útdráttur

Ör vöxtur náttúruferðamennsku á friðlýstum svæðum getur haft skaðleg áhrif á viðkvæm vistkerfi. Til aðtryggja aðkomandi kynslóðir eigi sömu möguleika á aðnjóta náttúru friðlýstra svæða er mikilvægt aðstýra ferðamennsku í átt aðsjálfbærni. Áskorunin liggur í því aðfinna jafnvægi í nýtingu og verndun náttúruauðlindarinnar til aðviðhalda núverandi og framtíðar nýtingu auðlindarinnar. Grundvallaratriði í árangursríkri umhverfisstjórnun sem dregur úr óæskilegum umhverfisáhrifum ferðamennsku, er aðskilja þá undirliggjandi þætti sem geta leitt til neikvæðra umhverfisá hrifa. Í þessari rannsókn er stuðst viðkerfisnálgun til aðná fram heildrænum skilningi á orsakasamhengi milli hinna ýmsu breyta í náttúruferðamennsku á friðlýstum svæðum. Meginmarkmiðrannsóknarinnar er tvíþætt. Í fyrsta lagi aðrannsaka möguleika á aðnota kerfisgreiningu viðstjó rnun sjálfbærrar ferðamennsku á friðlýstum svæðum sem einkennast af viðkvæmum vistkerfum, meðþví aðmeta umhverfisáhrif af afþreyingu og innviðum ferðamennsku, og hvernig þau hafa áhrif á upplifun ferðamanna. Í öðru lagi, meðþví aðgreina orsakir og afleiðingar mismunandi stjórnunartækja viðaðdraga úr neikvæðum umhverfisáhrifum ferðamennsku og hámarka jákvæðáhrif. Tilviksrannsókn var gerðfyrir Þingvallaþjóðgarð, þar sem lykilbreytur voru dregnar fram og orsakatengsl á milli þeirra greind. Niðurstöður undirstrika mikilvægi viðeigandi umhverfisstjórnunar til aðdraga úr neikvæðum umhverfisáhrifum náttúruferðamennsku. Niðurstöður leiða jafnframt í ljós aðkerfisgreining er grundvallartæki í sjálfbærri stjórnun ferðamennsku sem veitir nauðsynlegt gagnsæi til aðauka skilning á orsakatengslum lykilbreyta í kerfinu.

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Acronyms

CLD	Causal loop diagram
EAI	Environment Agency Iceland
ITB	Icelandic Tourist Board
IUCN	International Union for Conservation of Nature
LAC	Limits of Acceptable Change
NBT	Nature Based Tourism
NLSI	National Land Survey of Iceland
PA	Protected Area
UNEP	United Nations Environment Programme
UNWTO	World Tourism Organization Network
WCED	World Commission on Evironment and Development

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Mieke Van Houtte, May 2015

1 Introduction

1.1 General information

The tourism sector is one of the fastest growing industries worldwide. In 2014, the number of international tourists was over 1.1 billion, an increase of 4.7 % compared to the previous year according to the World Tourism Organization Network (UNWTO, 2015a). Moreover, it is one of the world's most important sources of economic outcomes and employment (UNEP, 2015a; UNWTO, 2015a). However, tourism inevitably impacts upon the natural and socio-cultural environment (e.g. UNEP, 2015a; Butler, 1996; Briassoulis, 2002; Ferraro & Hanauer, 2014). Hence, associated with increasing tourism, increasing pressure is being placed on the world's sensitive natural environment (e.g. UNEP, 2015a; Leung & Marion, 2000). Coincide with increasing visitor numbers, more accommodation, transport, services and infrastructure are needed, and more tourist activities are also intensifying adverse environmental impacts such as e.g. soil erosion, damage to vegetation and biodiversity, sewage pollution, littering, air and noise pollution, change of landscape, disturbance of wildlife, habitat loss, loss of fauna and flora and alteration of ecosystems (UNEP, 2015a; Leung & Marion, 2000). If not managed well, tourism and the related damaging environmental effects has thus the potential of degrading and destroying the natural resources on which tourism relies (UNEP, 2015a).

In order to assure the long-term sustainability of tourism in the world's protected areas it is of major importance to avoid the degradation of ecosystem services, such as water and air quality, scenic value and biodiversity (e.g. UNEP and UNWTO, 2005). These ecosystem services are not only vital for own survival as they act as mechanisms for supporting continued human existence, they also provide provide the natural resources on which nature-based tourism depends, and hence to ensure the possibility of equivalent use of the natural resources for tourism for future generations, degradation of ecosystem services needs to be avoided. The challenge is thus to balance the use and protection of natural resources for tourism, to sustain current as well as future use. In order to minimize potential adverse environmental impacts of tourism and to avoid gradual deterioration of natural assets significant to tourism on the one hand, and to provide visitors with a high-quality experience

on the other hand, provident environmental management in tourism is critical. A tourism system is however a complex system, and the system needs to be understood before it can be managed. A holistic understanding of the relationship between tourism and the environment is therefore fundamental in order to develop tourism activity based on sustainable principles.

System analysis offers the tools needed to clarify the complexity and therefore, in this research, system analysis will be used to overcome the lack of a holistic view and a systemic approach. When causal factors to undesirable environmental changes can be identified, suitable management actions can be more easily selected and implemented.

In Iceland, tourism has become one of the most important sectors of the country's economy (ITB, 2014). The number of international visitors to Iceland has experienced extreme growth, and reached 997 556 visitors in 2014, which is three times the country's population (ITB, 2015; Statistics Iceland, 2015). Since 2000, the mean annual increase in international visitors to Iceland has been 9.3% (ITB, 2015), compared to a mean annual increase of 3.5% worldwide over the same period (World Bank, 2015). In Iceland, nature and the scenic landscape are the most important assets for tourism (ITB, 2015), while at the same time the country's ecosystems are very fragile and sensitive to tourism pressure (Ólafsdóttir & Runnström, 2009). The extreme growth of tourism in Iceland is increasing the pressure on the sensitive environment, requiring adequate management. This study will focus on a case study carried out in Þingvellir National Park, southwestern Iceland. Þingvellir National Park was selected as i) it has for a long time been one of the most visited tourist sites in Iceland, ii) the Park is characterized by unique historical, geological and biological features, and iii) it was nominated for inclusion on the World Heritage List in 2004, being the first World Heritage site in Iceland.

1.2 Aims and research questions

General aim

A tourism system is a complex system. To be able to implement effective environmental management that can reduce undesirable tourism impacts on the environment, it is of vital importance to understand the underlying mechanisms leading to these environmental impacts. In this study, system analysis will be used to increase the understanding of the causes and effects of environmental impacts

of tourism and recreational activities. The general aim of this research is to investigate the potential of system analysis for sustainable tourism management in naturally fragile environments by firstly evaluating environmental impacts of tourism activities and tourism infrastructure, and how these impacts influence visitor experience. Secondly, by analyzing the causes and effects of different management tools in reducing negative environmental impacts of tourism and maximizing positive impacts.

Specific aims

- To identify key variables in a naturally fragile tourism system, making up the environmental subsystem within the tourism system.
- To explore tourism environmental impact within the environmental subsystem, including both the terrestrial and lake ecosystem
- To analyze the causal relation between the ecosystems and the tourism system.
- To provide potential policy actions and management measures to achieve success goals towards sustainable tourism

Research questions

In order to achieve these aims, the following research questions are put forth:

- What are the key variables of the tourism environmental subsystem?
- How are these variables linked to each other through causes and effects of tourism?
- Which effects do the different management and policy implementations on environmental quality?
- What measures can be taken to reduce environmental impacts of tourism and to optimize the environmental quality as well as the visitors experience?
- What are the success indicators and success goals in the environmental tourism system?
- What are the most beneficial policy outputs in the system?

1.3 Scope

Following this introduction chapter, a theoretical background about sustainable tourism, environmental impacts and management of tourism and system analysis of tourism systems makes up chapter two. A description of the case study area, Þingvellir National Park in Iceland, will be given in the third chapter. Chapter four explains the applied methodology and presents the data used in the case study. In chapter five, the results are presented, first the key variables in the environmental subsystem and the causal relations between the key variables, followed by the results of the implementation of possible management measures. In the sixth and last chapter, results are critically discussed and the thesis conclusions are presented.

2 Background

2.1 Tourism and sustainability

Over the years, tourism has experienced continued growth. In 2014, the number of international tourists was over 1.1 billion, an increase of 4.7 % compared to the previous year (UNWTO, 2015b). For 2015, the UNWTO (2015b) forecasts international tourist arrivals to grow between 3% and 4%. The tourism industry is a fundamental contributor to the global economy by generating substianal exports and employement. In 2014, international tourism generated 9% of world's GDP, 6% of world's export, corresponding with US$ 1.5 trillion in export earnings or 30% of services exports worldwide, and supported 1 in 11 jobs, underscoring he global importance of the tourism industry (Figure 2.1).

Figure 2.1: Infographic: the global importance of the tourism industry (UNWTO, 2015a).

However, the growth of the tourism industry is consequently also associated with an increase in pressure to and impacts on the natural and socio-cultural environments

of the host areas (e.g. UNEP, 2015a; Buckley, 2004; Pierce, 1996; Briassoulis, 2002; Neto, 2003; Ferraro & Hanauer, 2014). Tourism not only impacts the natural environment in many ways, but also affects social outcomes and human welfare. Under the influence of growing tourism, local communities worldwide are affected both positively and negatively. In this study, the main focus will be on the environmental impacts of tourism. Numerous studies (e.g. UNEP, 2015a; Cessford & Dingwall, 1999; Leung & Marion, 2000; Buckley, 2004) show that unsustainable tourism can easily result in severe degradation of natural resources, ecosystems and landscapes, while at the same time undisturbed environments and unique ecosystems act as tourist attractions. Due to the importance of environmental quality and biodiversity for tourism, the tourism industry should have a long-term interest in environmental protection and conservation.

To ensure long-term benefits from tourism, it is of utmost importance that tourism is sustainable. According to the World Commission on Environment and Development (WCED, 1987, p. 43), sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition represents an ideology of developing and maintaining the long term prosperity and well-being. This long term prosperity and well-being is formulated in the traditional three dimensions of sustainability, i.e.: ecological, economic and social factors. In tourism, the interaction between the social, economic and ecological side is evident: tourism is a social activity, which creates economic revenue, and is based on natural and cultural resources, while at the same time it is affecting those resources upon which it relies (e.g. UNEP, 2015a; Pierce, 1996; Buckley, 2004). Thus, to develop sustainable tourism, it is critical to consider the impacts on and benefits for social, economic and ecological system at the same time, and not just trying to maximize the benefits for one of the three dimensions as this will, on the long term, be impossible to sustain.

The concept, and consequently the definition, of sustainable development have been highly debated, and therefore various definitions have emerged over the years (Drexhage & Murphy, 2010). The focus in the definition by the WCED (1987) is on the integration of the three pillars of economic development, social development, and environmental improvements, meaning that the perspectives of society and nature are equal to that of economy. A more holistic understanding of sustainability limits economic growth and other human activities to the capacity of nature for self-regeneration (e.g. Nieto, 1996; Adams, 2008), putting emphasis on respecting the physical limits of the global ecosystem in any economic, political or cultural strategy. The ability of the environment to maintain functional vital and essential processes is core to sustainability. Economy and society are a part of a closed system that is the global ecosystem, and because resources are limited, growth cannot extend beyond the definite limits of nature (e.g. Sverdrup & Svensson, 2005).

UNEP and UNWTO (2005, p. 11) define sustainable tourism as "tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities". The well-being of future generations can only be ensured if this generations leaves the environment in a functional state to sustain itself. Therefore, sustainable tourism should deal with maintaining essential ecological processes and help to conserve natural heritage and biodiversity. According to UNEP and UNWTO (2005, p. 11), sustainable tourism should also "maintain a high level of tourist satisfaction and ensure a meaningful experience to the tourists, raising their awareness about sustainability issues and promoting sustainable tourism practices amongst them". Thus, while respecting environmental quality is an important element of the sustainability of tourism, the ability of society to benefit from tourism in a sustainable way and to meet the tourists' needs and expectations is also important.

2.2 Environmental impacts of nature-based tourism

2.2.1 Negative impacts of nature-based tourism to the natural environment

In any relatively pristine protected area, all human use produces some impact (e.g. Buckley, 2000; Eagles, McCool, & Haynes, 2002). The impacts of nature-based tourism and recreational activities on the environment are thus inevitable, and they are produced in many different ways. The negative environmental impacts of nature-based tourism in protected areas are also produced at a wide variety of scales, ranging from for example the minimal impact from one single hiker to large-scale infrastructure within protected areas (Buckley, 2004). Direct and indirect effects to almost all components of the natural environment, i.e. soil, vegetation, wildlife and water, can be expected. Impacts can be easy-to-observe and have relatively coarse effects on the natural environment, for example vegetation clearance or even trampling, but often the more fine, subtle effects that are less directly noticeable, for example changes in composition of microorganism communities, may often be more significant (Buckley, 2000). Moreover, effects of different types of tourists activities on different components of the natural environment may be cumulative, especially when impacts are repeated or continued over an extended period of time (Buckley, 2000). This makes the assessment of environmental impacts from tourism difficult.

The United Nations Environment Programme, UNEP (UNEP, 2015a), describes three main impact areas of tourism on the environment: depletion of natural resources, pollution and physical impacts. Depletion of natural resources includes water resources, local resources, such as energy, food and other raw materials, and land degradation. Pollution includes air emissions, noise, solid waste and littering, releases of sewage, oil and chemicals and aesthetic pollution, e.g. degradation of the scenic landscape by roads and other infrastructure. Physical impacts are caused both by tourism development, e.g. through land clearing and construction, and by tourism activities, e.g. through trampling and alteration of ecosystems. A comprehensive overview of the most common forms of recreation impacts is given in a review by Leung and Marion (2000), summarized in Table 2.1.

Table 2.1: Common forms of environmental impacts of tourism and recreation activities in different components of the ecosystem according to Leung and Marion (2000).

	Soil	**Vegetation**	**Wildlife**	**Water**
Direct effect	Soil compaction	Reduced height and vigour	Loss and alteration of habitats	Introduction of exotic species
	Loss of organic litter	Loss of ground vegetation cover and fragile species	Introduction of exotic species	Increased turbidity
	Loss of mineral soil	Loss of trees and shrubs	Wildlife harassment	Increased nutrient inputs
		Tree trunk damage	Modification of wildlife behavior	Increased levels of pathogenic bacteria
		Introduction of exotic species	Displacement from food, water and shelter	Altered water quality
Indirect effects	Reduced soil moisture	Composition change	Reduced health and fitness	Reduced health of aquatic ecosystems
	Reduced soil pore space	Altered microclimate	Reduced reproduction rates	Composition change
	Accelerated soil erosion	Accelerated soil erosion	Increased mortality	Excessive algal growth
	Altered soil microbial activities		Composition change	

Examples given by Buckley (2000, 2004) are in line with Leung and Marion (2000), such as soil erosion and compaction, direct vegetation damage (through trampling, breakage, clearance, etc), indirect vegetation modification (introduction

of weeds, introduction of plant diseases, disruption of plant reproduction, etc), direct and indirect impacts on wildlife (fishing, noise disturbance, habitat modifications, migration barriers, disruption of reproduction, diseases and pathogens, etc) and changes to water quality and hydrology (streamflow patterns, turbidity, pH, nutrients, dissolved oxygen, microorganisms, etc). Littering is also a problem in many tourist sites, especially when decomposition of waste is slow, for example leaving waste visible atop the permafrost (OECD, 2014). There are many other factors causing environmental impact from tourism, such as biking, driving, off road driving, etc. The examples given, just to mention few, are the most important in the context of this research.

Some of the described impacts are likely to be more specifically applicable to arctic ecosystems like in Iceland. Trampling by hikers may have a major impact on the steep and sparsely-vegetated scree slopes in northern hemisphere arctic-alpine environments, as indicated by Buckley (2000). Vegetation and forest deterioration and subsequent soil erosion have been one of the most important environmental issues in Iceland for centuries (e.g. Jónasson, 1992; Arnalds et al., 2001). Tourists using the same trails over and over again trample soil and vegetation, causing damage that eventually can lead to loss of biodiversity and other impacts (UNEP, 2015a). The damage caused by trampling can be even more extensive when visitors are leaving the established trails, as the impact of trampling on soil and vegetation will affect larger areas. Table 2.2 gives an overview of the impact of trampling on vegetation and soil, according to UNEP (2015a).

Table 2.2: Impacts of trampling on vegetation and soil according to UNEP (2015a).

Trampling impacts on vegetation	**Trampling impacts on soil**
Breakage and bruising of stems	Loss of organic matter
Reduced plant vigor	Reduction in soil macro porosity
Reduced regeneration	Decrease in air and water permeability
Loss of ground cover	Increase in run off
Change in species composition	Accelerated erosion

A conceptual model of the effects of trampling caused by hiking and camping is presented by Cole (2004) (Figure 2.2). The main effects of trampling are abrasion of vegetation, abrasion of organic matter and compaction of soil. Many plants are killed by trampling, and generally, where trampling is intense, plant cover and biomass are low, species richness is reduced and species composition shifts (Cole, 2004). Hiking does not only impact the native soil and vegetation, but also the trail itself, as hiking can increase soil erosion from the constructed trails, which are barren and compacted by design. Trail use by hikers loosens soil particles, making them easier to detach, and therefore, available to be transported by wind and water (Cole, 2004). Soil erosion, trail widening and deepening, rutting, bad drainage, multiple thread and trail braiding (user-created trails along hiking routes forming a braided,

eroding web) are impacts that arise from trail use (Cole, 2004).

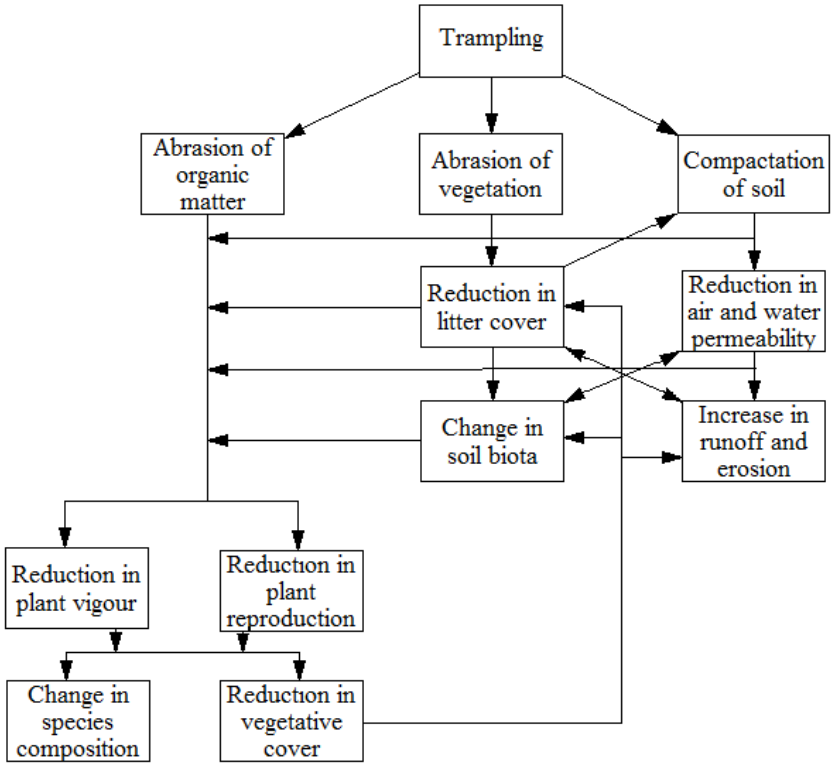

Figure 2.2: A conceptual model of the effects of trampling caused by hiking and camping, according to Cole (2004).

The impacts of camping include all effects of trampling, as well as some unique impacts (Cole, 2004), such as elimination of vegetation, lower organic horizon thickness and exposure of mineral soil. Moreover, camping can also cause off-site impacts, of which informal trailing is the most common.

Moreover, as pointed out by Buckley (2004), the production of goods and services for tourism also involves most other sectors of the human economy, with consequential increases in consumption of energy, water and other resources, for example food, and production and disposal of wastes. A greater extraction and the transport of these resources creates physical impacts associated with their exploitation. For managing nature-based tourism in parks however, local-scale in-park impacts are ecologically more significant than broad-scale but proportionally smaller impacts such as for example on global air quality, according to Buckley (2003). The impacts that tourist can have on air and water quality are ecologically more significant because of the local-scale effects on the aquatic ecosystem and vegetation, than because of their contribution to global pollution.

2.2.2 Positive impacts of tourism to the natural environment

Beside negative environmental effects, tourism also has the potential to create beneficial effects to the natural environment, mainly through nature conservation. According to Buckley (2000), the most promising mechanism for tourism to contribute to conservation is through influencing land use allocation. He also points out that tourism can displace other, more damaging land uses, for example primary extractive activities such as logging or grazing, while at the same time tourism has the potential to also provide a higher economic return.

Tourism can help appreciate and deem natural areas valuable because of their attractiveness, which can lead to conservation measures and management implementation in order to keep the attraction alive (UNEP, 2015a; Buckley, 2000). Tourism for example can provide infrastructure to mitigate tourism impacts and construction related to nature conservation at tourist destinations. Tourism can also help support nature conservation through funding of conservation and management, via government funding or subsidies, taxes, entrance fees, services and permit fees (UNEP, 2015a). Ideally, tourism could be used as a conservation tool, as a mean to fund management and conservation. However, many tourists use natural areas for recreation and their enjoyment, but relatively few contribute to the conservation of the natural area they visit (Buckley, 2000). In Iceland, an accommodation tax on lodging was introduced in 2011 (OECD, 2014). Part of the revenue from the accommodation tax is used to finance the Tourist Site Protection Fund. The Tourist Site Protection Fund promotes the development, maintenance and protection of tourist attractions anywhere in Iceland which are under public ownership or in protected areas (Tourist Site Protection Fund, 2015). The fund is used to help finance infrastructure, to ensure tourist safety and to protect Icelandic nature. In addition to that, the fund is intended to increase the number of tourist sites so as to reduce pressure on the most frequently visited tourist destinations (Tourist Site Protection Fund, 2015).

Educating tourists to raise more environmental awareness and knowledge about nature and environmental values should also be one of the important parts of sustainable tourism. Nature tourism brings people into closer contact with nature and the environment, and this can lead to increased appreciation the value of nature and to environmentally conscious behavior and activities to preserve the environment (UNEP, 2015b).

2.2.3 Environmental quality: ecosystem goods and services

In general, natural ecosystems provide us with drinkable water, breathable air and usable biodiversity, services that are vital for our own survival, and act as a mechanism for supporting and ensuring continued human existence. Next to these vital life supporting services, ecosystems also provide us with plenty of other goods and services, direct and indirect: production of natural resources (timber, minerals, etc), farmaceutica, locations for recreational activities and the opportunity to experience solitude and self-realization or to find inspiration, and many more (Nelson, 1998). Even potential goods and services, i.e. unknown and indirect benefits, are probably provided by Earth's natural ecosystems (Nelson, 1998).

To safeguard the provision of these ecosystem goods and services to present as well as to future generations, intact and functional ecosystems exerting essential ecological processes need to be maintained (e.g. Pisano, 2012). The quality of ecosystems will determine the goods and services it can provide. Therefore, the quality of an ecosystem can be assessed by the quality of goods and services it provides us with, such as clean water, biodiversity and other natural resources. A link with sustainable tourism can be found in this safeguarding of ecosystem goods and services: a system is sustainable if tourism is not affecting the quality of the environment irreversible, as an irreversible change could mean that future generations cannot use and enjoy the same services and goods provided by the environment as we do at present. A more diverse ecosystem is a healthier ecosystem, as it has a higher resilience and its ecological processes are more likely to absorb disturbances. Therefore, protecting biodiversity and overall ecosystem quality is important to maintain essential ecological processes and life support systems.

An economic valuation of ecosystem services, as for example done by Jóhannesdóttir (2010) for the ecosystem services provided by two lakes in the capital area of Iceland, could serve as an indicator of a potential value of the ecosystem service provision, and could be a contributor to environmental management.

2.2.4 Ecological sensitivity in fragile northern ecosystems

Multiple definitions exist for the concept of 'fragile environment'. Natural environments can be inherently fragile: ecosystems with a low resilience, a low capacity to recover from disturbances, or a slow rate of recovery. They can also be fragile in relation to human activities, when they are subject to significant deterioration due to human uses and human impacts (Pierce, 1996). Buckley (2000) defines fragility as small impacts causing serious damage. Different ecosystems are

fragile or sensitive to tourist impacts, and even different parts of an ecosystem can differ greatly in sensitivity or fragility. For example, a densely vegetated ecosystem with rich organic soils and a rapidly turned-over litter layer will be more resilient to trampling by hikers, while this will have a major impact a sparsely vegetated steep slope, as this is the case in Iceland. Similarly, the fragility of an ecosystem to different types of tourist activities can differ widely, as described by Buckley (2000).

In a study by Ólafsdóttir and Runnström (2009) on ecological sensitivity to tourism pressure, following factors were used to estimate the sensitivity of the landscape to tourism pressure: vegetation cover type, soil type and slope angle. For example, mossy vegetation on a steep hill falls within the high sensitivity category. The vegetation cover moss heath was classified as having a high ecological sensitivity to tourism trampling.
The character of the natural environment in northern regions makes the ecosystems there extremely vulnerable to the negative effects of tourism. In Iceland, the uneven distribution of tourism impact even increases the need to be aware of this (Ólafsdóttir & Runnström, 2009). In Iceland, erosion is one of the most active geomorphic processes shaping the surface. Severe land degradation has damaged Icelandic ecosystems to a large extent, resulting in loss of woodlands and creating vast deserts (Arnalds et al., 2001). Ecosystems in Iceland have been subject to severe degradation since the beginning of settlement ca. 871 AD. The main reasons for this are overgrazing and cold spells during the little Ice Age. Research by Arnalds et al. (2001) shows that soil erosion and the depletion of vegetation are Iceland's most severe environmental problems.

If not managed well, high tourism impact may damage ecosystems, especially in the case of fragile ecosystems, and destroy the main resource upon which tourism in these areas depends. The quality, variety and aesthetic aspect of the environment are basic resources upon which tourist activities rely. If impacts tourism and recreational activities are changing the natural environment to a too high degree, the tourist destination may lose its attraction. Moreover, tourist activities can break down the natural environment, when the carrying capacity of the area is exceeded.

2.3 Environmental management in tourism

2.3.1 Tourism management concepts

In order to manage nature-based tourism towards sustainability, numerous managerial concepts and methods exists (e.g. McCool, Clark, & Stankey, 2007;

Font, Flynn, Tribe, & Yale, 2001; Hughey et al., 2004). Carrying capacity is hitherto one of the widest used central concepts for in the management of nature-based tourism (e.g. Butler, 1996; Zelenka & Jaroslav, 2014; Eagles et al., 2002). In the context of management of tourism and recreation, the carrying capacity of a tourist site could be defined as the number of visitors that the site is capable of absorbing (Butler, 1996). How many tourists can visit an area without threatening the natural resources, or, how many visitors can be put together without spoiling the scenery for other visitors (European Charter for Sustainable Tourism in Protected Areas, 2002)? Carrying capacity can be described in many different ways. According to Butler (1996), it is the maximum number of visitors that can be sustained by an area ecologically, without irreversibly damaging the area, but it can also refer to alternative capacity levels, based on human preferences, i.e. levels of use acceptable by most users. Different types of carrying capacity include (Eagles et al., 2002): ecological capacity, based on biological and physical factors such as ability of certain species to withstand disturbance; socio-cultural capacity, based on unacceptable impacts on the local community; psychological capacity, i.e. the amount of crowding that tourists perceive as acceptable without affecting the quality of their experience; and infrastructural capacity, such as number of bedrooms or the capacity of transport systems.

The research on carrying capacity has evolved from a search for specific numbers, to management approaches based on social expectations. In the context of sustainable development, it has been recognized that there are limits to consumption and to actions that impact the environment. Various definitions of carrying capacity in tourism contain the concept of limits of use to which an area can be exposed before there is significant decline not only in the quality of the resource, but also in the quality of the user's experience (Butler, 1996). Thus, from a sustainability point of view, the concept of carrying includes both social/perceptual norms by users, as well as environmental aspects.

Stankey, Cole, Lucas, Petersen, and Frissell (1985) introduced in their research the argument that it is more appropriate to concentrate on levels of acceptable change (LAC) in destination areas, rather than trying to identify specific numbers of users that could be sustained by these areas. This approach relies on what users regard as acceptable change, and bases usage levels on user norms and expectations. Users concerned about increasing numbers of visitors will go elsewhere, and will be replaced by those who are more tolerant to higher use levels (Butler, 1996). This can result in environments that are not sustainable, in the sense that the environment will not have the ability to sustain existing levels of quality. Management frameworks based on social and perceptual norms of users or on the principle of visitors expectations are often used. However, when the attention shifts to allowing levels of use that are viewed as acceptable by most users, this can be detrimental to the environmental

quality. Butler (1996) argues that in the long run destination areas, especially those that rely on natural features for their attractiveness, are poorly served by such approaches, because they could potentially lead to overuse of natural areas, as these approaches result in a gradual increase of tourism development and a change of the type of visitors towards those that are accepting higher levels of use. Therefore, in order to be able to control or mitigate environmental impacts from tourism and recreation, and to preserve the natural characteristics that makes a tourist attraction appealing, it is necessary to identify appropriate numbers of maximum use and, if needed, restrict the amount of use to those levels.

There is a direct relationship between the level of use and the level of impacts, depending on the sensitivity of the soil and nature. Based on this, carrying capacity can be determined. Limits to tourism use can be defined on the basis of physical characteristics of the destination area (Butler, 1996). Even though absolute numbers of visitors are often less important than the type of tourists and the activities they engage in, limiting total numbers, even if total numbers may be only a part of the problem of capacity, will at least reduce the numbers of undesirable tourists and activities, even if it also reduces the numbers of other types of tourists and activities (Butler, 1996). Leung and Marion (2000), however, point out that studies addressing the application of carrying capacity to recreation and tourism management often conclude that the relationship between the level of use and the level of impacts is complex, depending on several environmental and social factors. An systemic approach offering a holistic view could help overcome this problem.

Zelenka and Jaroslav (2014) emphasize that tourism carrying capacity is multidimensional and that it cannot be seen as a one-dimensional instrument. It is not exclusively a function of the number of visitors, but other variables, e.g. the distribution of visitors in the area, their activities, behaviour, the state of tourism infrastructure, etc. also have to be considered (Zelenka & Jaroslav, 2014). However, the resource dimension, the experiential dimension and the managerial dimension of the carrying capacity are often handled separately due to scientific and managerial specialization (European Charter for Sustainable Tourism in Protected Areas, 2002). Saveriades (2000) moreover emphasizes that carrying capacity is not fixed but dynamic, and that it develops with time and with the growth of tourism and that it can be influenced by managerial techniques and controls. Again, a systemic holistic approach could most likely be useful in respect to these issues, to obtain a better integration of the different dimensions of carrying capacity and to cope with its dynamic character.

Zelenka and Jaroslav (2014) moreover argue that, eventhough from a theoretical point being a useful approach in sustainable tourism management, the practical

application of carrying capacity to the protection of nature and landscape is full of possible pitfalls. Tourism carrying capacity as well as LAC approach suffer from a lack of ways how to determine whether or not a change is reversible and the state of a socio-cultural or natural system is still acceptable (e.g. Zelenka & Jaroslav, 2014; Manning, 2002). McCool and Lime (2001) state that tourism carrying capacity is unrealistic during implementation and that it is impossible to measure carrying capacity.

Carrying capacity as a management instrument is thus likely to benefit from being included in a more holistic view, as combination of two interpretations: ecosystem carrying capacity and social carrying capacity, because degradation of the environmental quality affects the visitor experience, and the visitor experience will influence, through visitor behaviour, the quality of the natural environment and the level of impact. System analysis is likely to overcome many of the shortcomings of the approaches presently used in tourism environmental management by providing the holistic overview needed to understand the system.

2.3.2 Indicators in managing environmental impacts from tourism

In the context of sustainable tourism development, indicators are information sets that measure changes in assets and issues that are key for the tourism development and management of a certain tourist site (UNWTO, 2015c). In the context of tourism in national parks, environmental indicators are used, for example by park agencies, to determine what impacts visitors have on the park's natural environment, and consequently undertake and evaluate management responses to these impacts (Buckley, 2003). In order to detect or monitor impacts of tourism, baseline conditions, either measured or assumed, need to be known, as impacts can only be detected as a change relative to a prior baseline (Buckley, 2003). These baseline conditions are often not a fixed value, but are likely to be subject to considerable natural variation.

Several studies (e.g. Buckley, 2003; Hughey et al., 2004; Choi & Sirakaya, 2006; Azar, Holmberg, & Lindgren, 1996) researched ecological indicators of tourist impacts in national parks. Buckley (2003) argues that indicators need to reflect the priority conservation values for the protected areas concerned, and the types of use. Buckley (2003) also indicates that to be useful in the management of tourism and recreation to minimize environmental impacts, indicators in an particular protected area need to focus on impacts which are ecologically significant for its particular ecosystem, and which reflect the particular characteristics and activities of its users.

An indicator hence is ecologically significant when it reflects ecological processes and when a change indicates an effect that is important for the park's conservation values.

The most valuable types of environmental indicators in managing environmental impacts from tourism are those that measure visitor impacts on the environment directly, according to Buckley (2003). Common examples include track erosion, human noise, litter along trails and at campsites and measures of stress, individual mortality, behavioural changes or population impacts on wildlife and analogous measures for particular plant species.

Environmental indicators that reflect conservation priorities/values and ecological processes) include:

- indicators for trampling: The most common indicators include trail widening and deepening, multiple tread formations, root exposure and damage, and soil erosion (OECD, 2014).
- biodiversity
- areas of remaining undisturbed vegetation
- physicochemical indicators of streamwater quality
- the number of individuals in a local population
- atmospheric concentrations of nitrogen oxides
- soil compaction

In protected areas and in national parks, i.e. areas with high levels of visitation, park managers also need information on visitor characteristics and visitor experience/satisfaction, to assess the effectiveness of visitor management tools. Eagles et al. (2002) note that tourists visiting protected areas are increasingly demanding high quality recreational opportunities and the services that support them. According to Leung and Marion (2000), littering was among the most highly rated indicators affecting the quality of wilderness experiences. Similarly, wilderness visitors rated ground vegetation loss and bare ground on campsites as two important determinants of their satisfaction.

Indicators for the quality of visitor's experience are:

- crowdedness perceived by the tourist

- visitor's safety
- presence of services and facilities
- overall environmental quality
- naturalness of the landscape
- presence of unique natural features
- littering

2.4 System analysis of tourism systems

2.4.1 System thinking and system analysis

The behaviour of social-ecological systems is dynamic and complex (e.g. Holling, 2001; *Resilience thinking: sustaining ecosystems and people in a changing world*, 2006; Pisano, 2012). Humanity is embedded in Earth's ecosystems and societies and nature are interdependent systems, both on local and global scales (Pisano, 2012). Understanding the underlying variables that drive a social-ecological system is important to be able to sustain and ensure the integrity and vitality of the system (e.g. Pisano, 2012). System thinking enables a better understanding of these complex dynamics (e.g. Ckeckland, 1981; Sterman, 2000). System thinking also involves holistic thinking: thinking about the whole system and the identification of causalities that induce events (Ckeckland, 1981). System analysis deals with sorting out the relevant information and organization of logic for understanding patterns and relations of complex problems (e.g. Ckeckland, 1981; Sterman, 2000). Understanding causal relationships and feedbacks is key in system analysis. System analysis works through taking apart a complex system to understand the causal relationships, detect and discover their structural arrangement and understand the effects emerging from the flows and accumulations from the causalities acting in the system (Ckeckland, 1981).

Causal loop diagrams (CLDs) are used to describe cause-effect relationships between variables and how feedbacks are present in the system. Through the use of CLDs it can be examined how a behaviour has been manifesting itself in a system, so strategies to counteract undesirable behaviour can be developed, and tested (e.g. Sterman, 2000).

2.4.2 System analysis of a complex tourism system

A tourism system is a complex system. UNEP and UNWTO (2005) point out that tourism is an activity which involves a special relationship between visitors, the industry, the environment and local communities. Plenty definitions of tourism exist, but a definition of tourism assuming a holistic approach is given by Jafari (1977, p. 6): "Tourism is the study of man away from his usual habitat, the industry which responds to his needs, and the impact that both he and the industry have on the socio-cultural, economic, and physical environments."
Another holistic approach was given by Gunn (n.d.), who presented a model, including five main constituents of tourism: people, attractions, services and facilities, transportation and information and direction. The approach was critised based on its failure to explicitly recognize the environmental interactions (Batta, 2000). In the context of environmental impacts from nature-based tourism, there are two elements that interact within the tourism system. First, there is the tourist or visitor, in search of experiences and who needs services and facilities. Secondly, there are the resources for tourism, which provide the experience, services and facilities (Batta, 2000). According to UNEP and UNWTO (2005) and (Eagles et al., 2002) tourists seek a high quality experience in safe and attractive environments, and visitor experience also affect visitor attitudes and behaviour.

Casagrandi, Rinaldi, and Mattei (1997) introduced the a minimal descriptive model in the context of tourism, to replace the traditionally used black-box econometric model,in which the environment is rarely taken into account. The model was used to predict the economic and environmental impact of any given policy on tourism sustainability. They presented a minimal model with tourists, quality of ecosystem goods and services, and capital as the three main compartments of the model, and the interactions between these compartments. In the model introduced by Casagrandi et al. (1997), the number of tourists is a function of the attractiveness, and attractiveness in its turn is function of the environmental quality, number of tourists, to indicate congestion, and capital as an indicator for the availability of facilities. Quality of the environment in absence of tourism was described as a logistic equation, depending on the carrying capacity of the ecosystem. This environmental quality was decreased by damages induced by tourism, depending on the number of tourists and on capital, i.e. facilities. Lacitignola, Petrosillo, Cataldi, and Zurlini (2007) developed a descriptive model of a tourism system as a socio-ecological system, based on the work of Casagrandi et al. (1997), focusing on the interplay between tourists, the quality of ecosystem goods and services, and capital. This approach is comparable with an system dynamics modelling approach, in that they look at the system in a holistic way and account for interactions and interplay between different components of the system.

The limitations of these approaches are that the model is abstract and crude, as

it was not representing any specific system. This model hence is not intended an operational tool for managers. The strength of this approach is however that it includes the core features of many systems, so it can be used to predict the economic and environmental impact of any given policy. Walker, Greiner, McDonald, and Lyne (1998) created a framework to evaluate the benefits and impacts of nature-based tourism and the policy options for managing tourism activity and development. Within the framework, wide range of economic, environmental, social and external factors affecting tourism activity can be evaluated simultaneously. Rather than focusing on the interactions between these compartments, this study focusses on the relevant interactions within the ecological compartments, and how the presence of tourists and their activities affects the quality of the ecosystem.

Liao, Jin, Ren, and Luo (2014) investigated the sustainable development of scenic spots based on a system dynamics model. The scenic spot system was analyzed in this study, highlighting the relationship between the economic subsystem and the environmental subsystem. Wamwara-Mbugua and Kamau (n.d.) used a system dynamics view to examine the development of tourism in Kenya. In their study, it was argued that negative impacts from tourism results from a reductionist view on tourism development, and it was suggested that system dynamics, through an examination of the total system may present better solutions for tourism development in a sustainable way. Van Mai and Bosch (2010) describes tourism as an open, dynamic and complex system, consisting of many interacting components and involving many different stakeholders. Their study showed that systems thinking has proved to be an effective and powerful tool to explain the complexities of the tourism system, and that it helps to simplify, clarify and integrate isolated problems associated with the industry.

Lastly, Ólafsdóttir and Haraldsson (2015) used a systemic approach to assess environmental impacts of tourism and the attractiveness of tourism destinations. A systemic approach was used in this study to examine the impact of destination exploitation on the attractiveness of a tourist site perceived by different types of visitors.

2.5 Summary

From this background, the importance of managing the natural resources for tourism in protected areas to avoid degradation of the natural environment has to be noted. It is crucial to manage natural resources and visitors today, so that future generations can also have high quality tourism experiences. A holistic view in management for environmental sustainable tourism, including the relationship between visitors and

the natural environment is important, so that complex relations and mechanisms underlying environmental impacts can be understood.

3 Study area

3.1 Tourism in Iceland

Tourism is one of the fastest growing sectors in Iceland. Since 2000, the mean annual increase in international visitors to Iceland has been 9.3% and reached 997 556 visitors in 2014 (ITB, 2015)(Figure 3.1). Estimates suggest that over one million international tourists might visit Iceland each year by 2020 (ITB, 2015). This is significantly more than the country's population of 329 100 (Statistics Iceland, 2015).

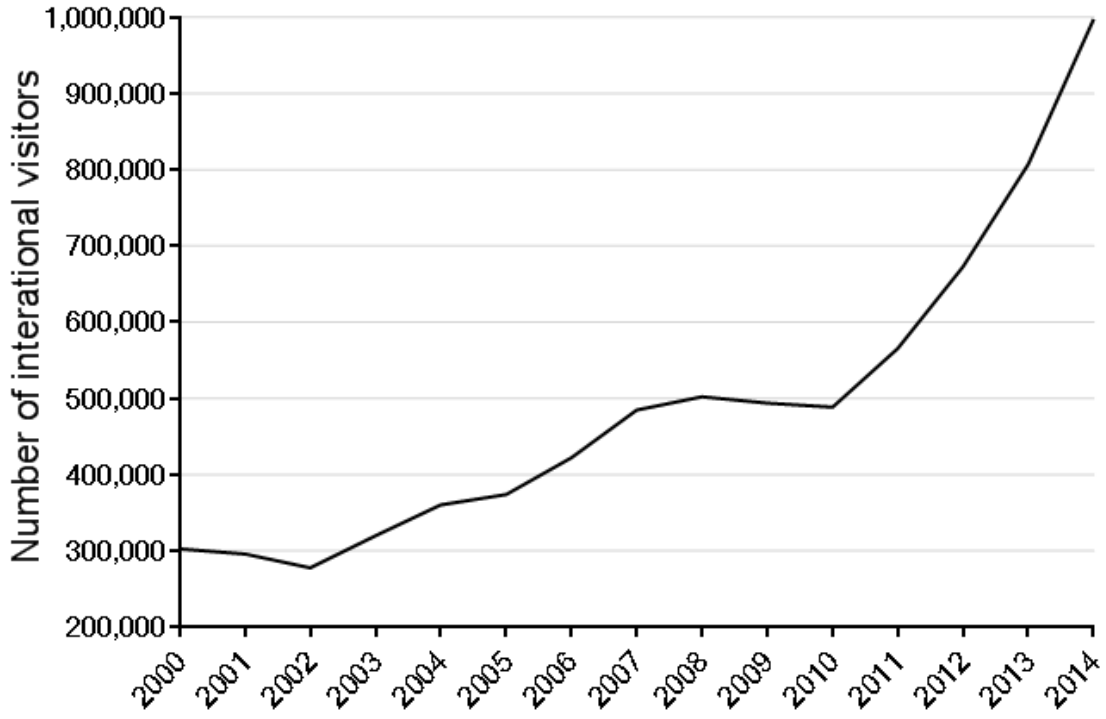

Figure 3.1: Number of international visitors to Iceland over the period 2000-2014. Data Source: ITB (2015).

Tourism has subsequently become an important sector of Iceland's economy. At present, the foreign exchange earnings of tourism even surpasses that of the fisheries industry and aluminum production (Figure 3.2) (ITB, 2014).

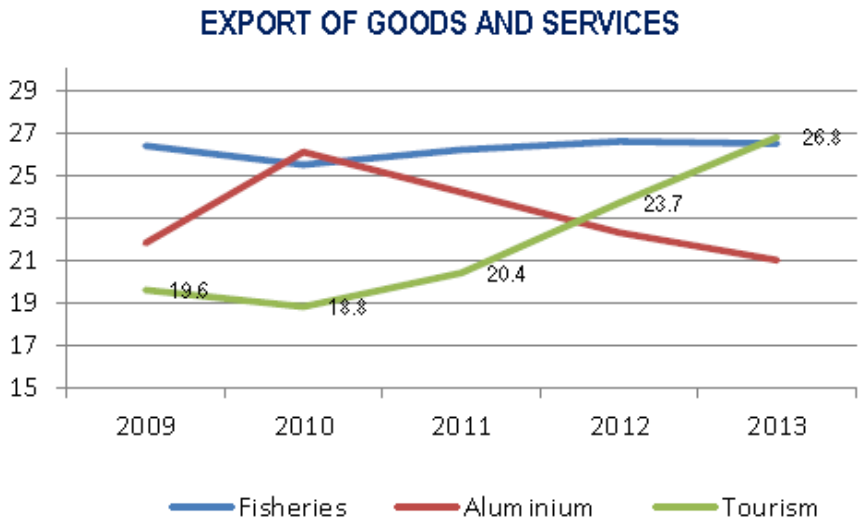

Figure 3.2: The share of foreign exchange earnings in Iceland for tourism, fisheries and aluminum production (2009-2013) (ITB, 2014).

Nature is the most important factor attracting tourists to Iceland, with about 80% of tourists in the summer of 2014 indicating that Icelandic nature had a major impact on their decision to visit Iceland (ITB, 2015). According to the OECD (2014) tourism in Iceland is largely based on a unique combination of environmental assets, e.g. areas of pristine wilderness, picturesque lava fields and glaciers, and the opportunity for adventurous outdoor activities such as hiking, mountain biking, whale, seal and bird watching, and fishing.

Tourism in Iceland is further characterized by a high degree of seasonality (see Figure 3.3), with most of the international tourists visiting from mid-May to mid-September (ITB, 2014). This leads to an uneven distribution of tourism impact in time, with a high pressure on the natural environment in the summer months.

Jóhannesson, Huijbens, and Sharpley (2010) emphasize that although prominent issues of sustainability for tourism in Iceland been noted, they have not translated into policy or planning practice in an efficient way. Jóhannesson et al. (2010) hence mention environmental issues and sustainability as fundamental challenges to the future development of Icelandic tourism.

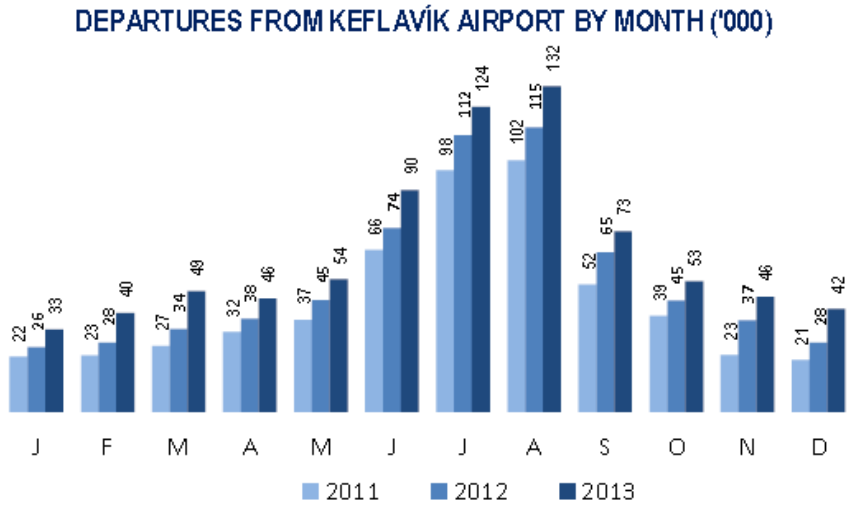

Figure 3.3: Number of international visitors to Iceland by months (2011-2013). In 2013, around 44% of visitors came during the three summer months (Jun-Aug). ITB (2014).

3.2 Protected areas

Protected areas are of significant importance because of their intrinsic value, global ecosystem services, local ecosystem services, such as drinking water supply, recreational opportunities and commercial opportunities, such as tourism (e.g. Buckley, 2004; European Charter for Sustainable Tourism in Protected Areas, 2002; Espiner & Becken, 2014). Protected areas are attractive settings for the growing demand for recreational activities in natural environments, setting the challenge of ensuring that while visitors have the opportunitiy to exercise desired activities, they are aware of and maintain the natural value of the protected area (Eagles et al., 2002). Protected areas all over the world, thus also in Iceland, are subject to increasing human pressures, from increasing visitor numbers and expectations, but also from around outside their borders (e.g. Buckley, 2004; Briassoulis, 2002; Espiner & Becken, 2014; European Charter for Sustainable Tourism in Protected Areas, 2002). The protection and environmental conservation of natural sites is a critical component for tourism in Iceland, as it ensures the sustainability of the tourism industry. Not only because the appeal of tourism to Iceland relies on its natural beauty and scenery, but also because preservation of the country's natural resources is an important goal on its own. Therefore, protected areas require management actions to reduce impacts and ensure their conservation.

In Iceland, about 20% of the total area is under some form of nature protection (OECD, 2014). The Environment Agency of Iceland (EAI, 2015) mandates the

protected areas. Currently there are 31 areas protected according to the Nature Conservation Act no. 44 (1999), including country parks, monuments, national parks, nature reserves and other areas. National parks are established in areas considered outstanding in landscape, flora or fauna, or having special historic significance, and make up over half the total protected areas. There are three national parks distributed around the country, of which Þingvellir National Park is the oldest one, established in 1930 (Icelandic Act no. 59, 1928). Þingvellir is located in a rift valley between the American and Eurasian geological plates, which makes the natural environment very dynamic and at the same time sensitive. Lake Þingvallavatn, located in the southern part of the park, is furthermore of special ecological interest as it contains species of fish found nowhere else. Moreover, based on its unique cultural landscape, Þingvellir is a World Heritage site (UNESCO, 2015).

3.3 Þingvellir National Park

Þingvellir National Park (Figures 3.4 and 3.5) is located in the southwest of Iceland, about 50 km from the capital, Reykjavik. The park has an area of 237 km^2, Figure 3.6 shows the park boundaries as they are today. The interplay between history and the unique natural features and geological phenomena make Þingvellir a remarkable place, and one of the most frequently visited tourist sites of Iceland (Þingvellir National Park, 2015).

Historically, Þingvellir, which literally means "Parliament Plains", is of special importance to the Icelandic nation, as it is the place where in the year 930 the Icelandic Parliament, called Alþingi in Icelandic, was established and where it was located until 1798. People from all parts of the country used to gather together in Þingvellir for about two weeks each summer to attend a general assembly (Þingvellir National Park, 2015). During these two weeks, Þingvellir became the the centre of the nation's social life, so it seems to be generally accepted that the foundation of the Icelandic national culture, language, and literature was laid at Þingvellir (Þingvellir National Park, 2015). With its unique cultural history and all the great historic events that have taken place here, Þingvellir has become an embodiment of the national identity of Iceland (Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003).

A good overview of the environmental characteristics of Þingvellir National Park is given by Þingvellir National Park Management Plan 2004-2024 (2004), Nomination of the Þingvellir National Park for Inclusion in the World Heritage List (2003),

Þingvellir National Park (2015) and Jónasson (1992), and will be summarized here.

The distinctive landscape in Þingvellir National Park is mainly characterized by the rift valley (Figure 3.4) formed at the junction of the two tectonic plates of the Mid-Atlantic Ridge. Over the past 100 000 years, these two tectonic plates have been subject to subsidence and divergence, which, in combination with little volcanic activity to fill the fissure with lava, has led to a rift valley that is particularly clearly visible on the surface (Sonnette, Angelier, Villemin, & Bergerat, 2010). In few or no other places in the world, a fissure zone on tectonic plate boundaries is so clearly discernible on dry land, which makes the Þingvellir area of outstanding geological value (Þingvellir National Park, 2015; Þingvellir National Park Management Plan 2004-2024, 2004).

A Holocene lava field covers the majority of the park area. The major part of this lava flowed from a shield volcano east of the rift valley about 10,000 years ago (Sonnette et al., 2010). Low growing vegetation and dwarf birch covers the lava. Coniferous woods have been planted at several locations, but they are not part of the natural vegetation (Þingvellir National Park Management Plan 2004-2024, 2004).

Figure 3.4: The clearly discernible rift valley at Þingvellir National Park, which is a unique geological feature. Photograph: Mieke Van Houtte

Figure 3.5: View over the Parliament Site at Þingvellir National Park and part of the extensive lava fields characterizing the national park, on the eastern bank of Öxará river. Photograph: Frans Van Houtte

Figure 3.6: The boundaries of Þingvellir National Park, as defined in the act on Þingvellir national park (Act 2004 No. 47, 1 June) (Þingvellir National Park, 2015).

Lake Þingvallavatn, which is with an area of 83 $km^2$the largest natural lake of Iceland, falls partly within the park. The ecosystem of the lake is diverse and unique, in the sense that the evolution and formation of new species has taken place here. A large variety of habitats is present in the lake, due to subsidence and lava fields, for example offering hiding places for fish and holes along the shore of the lake. Another contributor to the large biodiversity of the lake is the fact that the majority (about nine-tenths) of the water that flows into the lake passes underground through the lava that is of recent age, absorbing plenty of minerals. The lake is eutrophic and very fertile, with abundant quantities of algae and one-third of the lake bottom covered in vegetation. According to Þingvellir National Park Management Plan 2004-2024 (2004), about 150 species of algae and vascular plants and 50 species of microorganisms have been identified in the lake. Fish is abundant in the lake, and the species found in the lake are four separate morphs of Arctic char, a characteristic stock of brown trout, a unique breed of small char, called "fissure char" and the three-spine stickleback. (Þingvellir National Park, 2015)

It is this unique interplay between history, nature and the distinctive scenery that makes Þingvellir one of the most frequently visited tourist sites in Iceland (Þingvellir

National Park Management Plan 2004-2024, 2004). The large amount of visitors to the park places pressure on the ecosystem and the natural beauty of the area. Keeping a balance between utilization of the park to attract tourists and protection of its unique natural and historical features is a difficult but necessary task. In 2004, the most recent management plan for the park was created by the Þingvellir Commission, and it presents a vision for the park for 2024. The management plan expressed the view that "the nature and appearance of Þingvellir should be safeguarded, while visitors should also be offered the opportunity to enjoy what the place has to offer, and to learn" (Þingvellir National Park Management Plan 2004-2024, 2004, p. 4). Based on its unique cultural landscape, Þingvellir National Park has been nominated for inclusion on the World Heritage List (Þingvellir National Park, 2015). Sites included on this list are internationally recognized conservation areas.

3.3.1 Conservation priorities

Echoing the conservation vision from the middle of the 19th century in the US, the combination of its historical value, nature and the beauty of the landscape triggered the idea of the Þingvellir area as something that must be cared for and preserved for generations to come. In 1928, the Alþingi passed the legislation for the protection of Þingvellir as a "national shrine" (Þingvellir National Park, 2015), which lead to the establishment of Þingvellir National Park in 1930 (Þingvellir National Park Management Plan 2004-2024, 2004). Þingvellir is a category II conservation area, i.e. national park, according to the guidelines of the IUCN, which means that the primary management objectives are mainly ecosystem protection, preservation of species and biodiversity and maintenance of environmental services as well as recreation and tourism purposes (IUCN, 1994). Secondary management objectives of category II conservation areas are scientific research, wilderness protection and education (IUCN, 1994).

The main goal of the in 2004 published management plan is to safeguard the integrity, authenticity and special historical, geological and natural value of the park based on sustainable principles, so that the potential for equivalent use for future generations is ensured (Þingvellir National Park Management Plan 2004-2024, 2004). At the same time, the objective of the park is that as many visitors as possible can have the opportunity to enjoy the unique character of the park and learn about it, without having a negative impact to this unique character. This means that the limits of acceptable change are not to be exceeded, so the unique character is preserved. For each zone in the National Park, limits of acceptable change are defined in Þingvellir National Park Management Plan 2004-2024 (2004). To be able to assess whether these limits and thus the carrying capacity are not or

will not be exceeded, environmental indicators in response to impacts to measure changes need to be determined. The management also plan stresses the importance of further planning and monitoring.

Conservation priorities for the park are based on the special value and nature of the park and on the types of impact that the park is subject to. According to the (Þingvellir National Park Management Plan 2004-2024, 2004) the special value of the park lies in the presence of several unique natural factors:

- The park is unique from a geological perspective: the clearly visible tectonic plate boundaries are found in no other place
- The ecosystem of Lake Þingvallavatn is unique in the world:
  - four separate morphs of Arctic char that have evolved there
  - distinctive stock of brown trout
  - about 150 species of algae and vascular plants
  - about 50 species of microorganisms

Tourism impacts in the park are several. Along the lake shore there is considerable wear and tear, and visible impact on vegetation (Þingvellir National Park Management Plan 2004-2024, 2004).In the interior reaches of the National Park, the condition of vegetation and paths is good, since the paths are wide, rough trails indicated by stakes, and all routes marked. Because it is a very small fraction of the total number of tourists coming to the park who go on long hikes, there is much less pressure on the interior portion of the park.(Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003) In some areas of the park, the vegetation is very sensitive and easily damaged, and considerable soil erosion has taken place. There are areas where visitor traffic can have impact on fauna, e.g. bird nesting sites. Fish habitats in the lake can be lost when water flow and water level of the lake are changed. Activities within the catchment area of the lake could cause pollution of the lake.

Based on the most important impacts in the park, the conservation priorities for the protection of the authenticity and special value of the park, are given in Table 3.1.

Table 3.1: Most important tourism impacts and related conservation priorities in Þingvellir National Park. Sources: Þingvellir National Park Management Plan 2004-2024 (2004); Nomination of the Þingvellir National Park for Inclusion in the World Heritage List (2003)

Important impacts	**Conservation priorities**
Abrasion of lava formations	Protect lava formations from abrasion
Sensitive vegetation is easily damaged	Condition of vegetation - protection of natural vegetation
Considerable soil erosion	Visual appearance of the landscape
Wear of paths	Condition of paths - protect paths from wear and tear
Impact on fauna by visitor traffic (e.g. bird nesting sites): disruption to birdlife	Protection of fauna
Pollution to the lake and Disruption of fauna and flora of the lake	Conservation of the lake's ecosystem
Loss of fish habitats and breeding sites	Protection of fish breeding sites and fish habitats in the lake
	Water flow and level of the lake (reduce fluctuation in surface level): take account of the need of the lake's ecosystem

3.3.2 Management, law and regulations at Þingvellir National Park

A specific act covering Þingvellir National Park (Act on the Þingvellir National Park no. 47, 2004) and a regulation on the Þingvellir National Park, its protection and management (AlÞing, 2005)), together with general legislation (Nature Conservation Act no. 44, 1999) provide the protection framework of the national park. The national park has furthermore been included in the World Heritage List and has thus obtained international recognition as a conservation area based on its unique cultural landscape. Rules in the regulations on Þingvellir National Park that are relevant in the context of this study include:

- No construction of buildings, roads, electric power lines or other structures or disturbance to the soil is allowed without permission of the Þingvellir Commission
- All traffic of snowmobiles and motorcycles in the national park is prohibited
- The public is not permitted to plant any vegetation in the national park
- Removing or damaging vegetation or other natural sites in the national park

is prohibited

- Care shall also be taken not to disrupt wildlife in the national park
- Any action which may contaminate or pollute water in the area, both surface water and groundwater, or which may disrupt the habitat or breeding grounds of varieties of arctic char and trout living in the lake are prohibited
- No one is allowed to alter, damage or destroy landscape types that fall under the Nature Conservation Act without prior notification to the Environment Agency of Iceland

The Þingvellir Commission is the agency that has management authority at Þingvellir, and is responsible for maintenance and any conservation measures which are necessary to protect the park (Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003).

4 Methodology and Data

4.1 Methodology

To evaluate the environmental impacts of tourism activities and tourism infrastructure and how these impacts influence visitor experience, a systemic approach is used, because it provides a holistic understanding on the relationship between tourism and the environment, and offers the tools needed to clarify the complexity of a tourism environmental subsystem. In system analysis, causal loop diagrams (CLDs) are used because they give a good overview of the problem in question (e.g. Randers, 1980; Sterman, 2000; G. P. Richardson & Pugh, 1981; Ckeckland, 1981; Wolstenholme & Coyle, 1983; R. Richardson, 1991). CLDs are a tool used for detailed system description and to depict cause-effect relationships between variables and how feedbacks are present in the system (Sterman, 2000). Through the use of CLDs it can be examined how a behaviour has been manifesting itself in a system, so strategies to counteract undesirable behaviour can be developed, and tested. From CLDs it can be moreover identified what we need to do today to reach a certain desirable state or condition in the future (backcasting). CLDs consist of variables connected by arrows in a way that shows how variables affect other variables: an arrow with a positive sign means two variables are changing in the same direction, an arrow with a negative sign means variables are changing in the opposite direction (Sterman, 2000). Feedbacks can be present in the system, and a positive feedback loop, i.e. a reinforcing loop means that the feedback is intensifying the process. A negative or balancing feedback loop signifies that the feedback gives a change in the oposite direction, balancing out a process.

The study's methodological procedure is made up of the following six components, illustrated in Figure 4.1:

1. Identify and select key variables

2. Determine causal relationships between key variables in the form causal loop diagrams

3. Define success goals

4. Determine system success indicators

5. Backcasting: formulate possible policy actions or management measures to achieve success goals

6. Implement policies in CLDs: policy entry points: apply management practices to ensure that standards for the success indicators are maintained

The key variables in this study are selected based on the aim of this study: this study analyzes environmental impacts from tourism, focusing on the relation between the ecosystem and the tourism system. Because this study is limited to the environmental subsystem of the complex tourism system, variables relating to the host community, to economical benefits or to the administrative system are not considered, as they are out of the scope of this research. Relevant variables for this study are moreover based on the conservation values and priorities and the overall objective of the park, as according to Cessford and Dingwall (1999) the most important information required to identify and assess impact problems is better definition and prioritisation of the key conservation values.

Success goals represent the desired behaviour of the system, or more specifically, they represent the desired state of a system success indicator (e.g. Holmberg, 1998; Dreborg, 1996). Based on the conservation priorities for the park, the success goals are defined. System success indicators are variables that indicate whether the system is working as desired, and they determined by looking at which variables in the system are indicators for the goal we want to achieve.

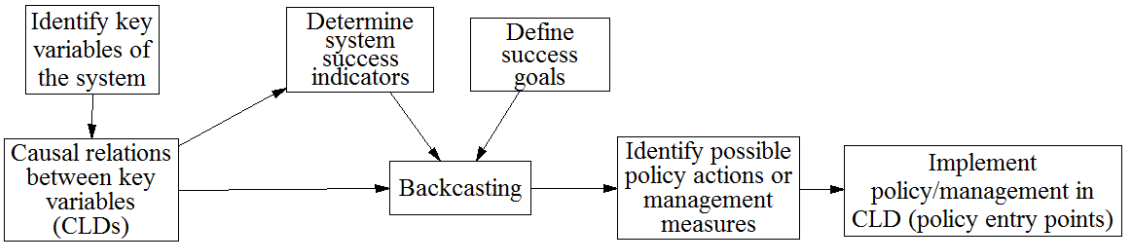

Figure 4.1: A schematic outline of the study's methodological procedure

In reality, there will often be a discrepancy between the success goal and the system success indicator. When desirable conditions, i.e. the success goals are defined, suitable policy and management actions to achieve these goals or conditions can be identified by working backwards in the causal loop diagrams (e.g. Holmberg, 1998; Dreborg, 1996; Höjer & Mattsson, 2000; Holmberg & Robèrt, 2000). This

is called backcasting (e.g. Holmberg, 1998; Holmberg & Robèrt, 2000)(see Figure 4.2). Possible policy or management actions can then be implemented in the CLDs to see their effect and side effects. The policy entry point is the variable on which the implementation of a policy will have a direct effect, to eventually, through a series of causal relations, have an effect on the system success indicator.

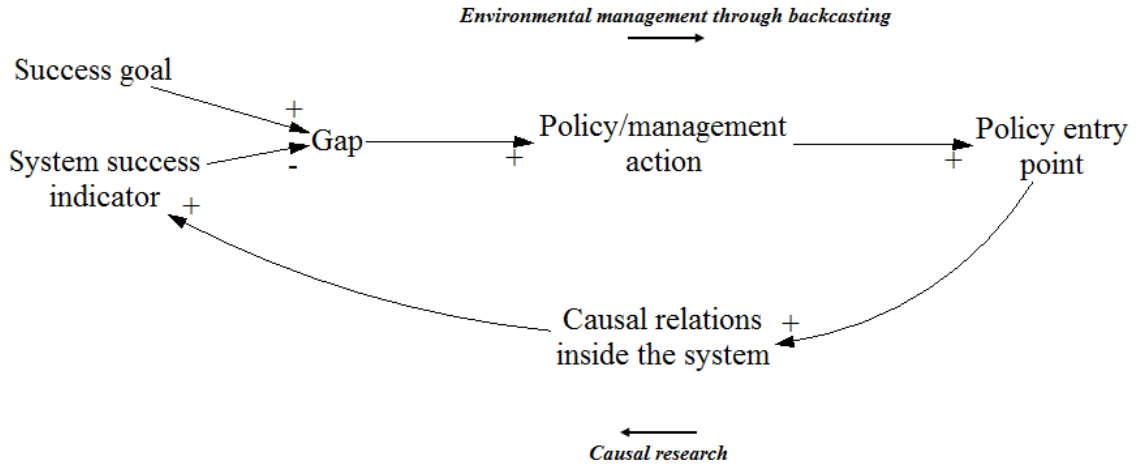

Figure 4.2: Causal loop diagram illustrating the approach of backcasting. A balancing loop runs until the gap between success goal and success indicator is filled, meaning that the success goal is reached.

Factors included in the system analysis are selected based on the major concerns/issues and conservation priorities for Þingvellir National Park, as pointed out in the Þingvellir National Park Management Plan 2004-2024 (2004):

- Infrastructure and services (visitor centers (environmental education and instruction), toilets, parking, paths, safety)
- Transport (access, emissions (air pollution))
- Biodiversity (trampling, vegetation damage)
- Landscape conservation (soil erosion)
- Water (wastewater treatment, water environment pollution, aquatic ecosystem)

The data for each of these factors will be described below (sections 4.2.1-4.2.5).

4.2 Data

4.2.1 Infrastructure

Facilities and services

According to the Þingvellir National Park Management Plan 2004-2024 (2004), no residents currently live within the National Park boundaries, as the three farms that were in the area when the park was established have gradually been bought out and are now abandoned. Close to the old parliament assembly site, there are a farmhouse and church (see Figure3.5) on the eastern bank of Öxará river. In two areas of the park there are also some summer cabins (Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003).

An interpretive visitor centre, where multimedia presentations about the cultural history and nature of Þingvellir are presented and were environmental education is provided, is located at Hakið, which is the top of the western edge of the Almannagjá gorge, from where visitors can walk down into Almannagjá and towards the old parliament site (Þingvellir National Park Management Plan 2004-2024, 2004; Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003). A viewing platform is also located at Hakið. Further to the north, by the main road into the park, is the national park's service centre, which includes an information centre, café and bookshop (Þingvellir National Park Management Plan 2004-2024, 2004). Within the park there are two campsites, of which one has showers and laundry facilities. Lavatory facilities are available at the visitor centre, the service centre and at the campsites (Þingvellir National Park Management Plan 2004-2024, 2004; Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003).

Construction of buildings, roads, electric power lines or other structures in the park is not allowed without the permission of the Þingvellir Commission (Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003).

In its services to visitors, the park places emphasis on outdoor activity and instruction on nature, history and the heritage sites (Þingvellir National Park Management Plan 2004-2024, 2004; Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003). Instruction on the heritage sites, ecosystems and on utilization of the lake is provided at the parliament site and along the lake shore. The national park and its principal service structures are to open to visitors all year round, and admission to the park is free of charge. Visitors pay for specific services they use, e.g. participation in organized activities, angling permits,

camping and use of lavatory facilities (Þingvellir National Park Management Plan 2004-2024, 2004).

Paths

A system of footpaths leads the visitors between the main points of interest within the national park. Þingvellir national park has a quite extensive network of paths, which are often ancient routes. Some of the paths are simple dirt tracks, others have been improved with gravel. Horse-riders have access to some of the paths, marked as bridle paths. Various popular walking routes connect to the national park (Þingvellir National Park Management Plan 2004-2024, 2004). A majority of visitors to the park come to the parliament site, emphasizing the pressure on the area. To keep the traffic of visitors at this site confined to the paths and to minimize encroachment by visitors, the paths are widest and best signposted here (Þingvellir National Park Management Plan 2004-2024, 2004). Footpaths in the National Park have been marked and improved to make it convenient for people to acquaint themselves with the history and nature of Þingvellir. Within the Parliament Site and the immediate vicinity, paths are paved with gravel, and wooden platforms are also used on the way to the waterfall in the Öxará river. Outside the Parliament Site, some paths are paved with gravel, other paths are mere trodden trails that have been used for centuries. Stakes now mark these trails so that people will stay on them and preserve them. (Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003) Figure 4.3 shows the location of infrastructures and facilities inside the National Park.

In a recent study conducted by Huber (2014), visitor's satisfaction of footpath and bridle path conditions in the national park was examined. The study concluded that the overall satisfaction level amongst hikers and horse-riders within the park is very high.

4.2.2 Transportation and accessibility

Þingvellir is one of the most visited locations by tourists. In 2013, 72% of tourists travelling to Iceland in summer, and 61% in winter visited Þingvellir National Park (ITB, 2014). Its proximity to other tourist attractions also makes the national park a popular tourist site. Many tourists visit Þingvellir in combination with two other major tourist attractions, the Gullfoss waterfall and Geysir geothermal area, the so-called 'Golden Circle'. The Golden Circle is one of the most travelled tourism routes and the most popular guided tour in Iceland, offered by many travel agencies from Reykjavik daily all year round. During the winter, access to the national

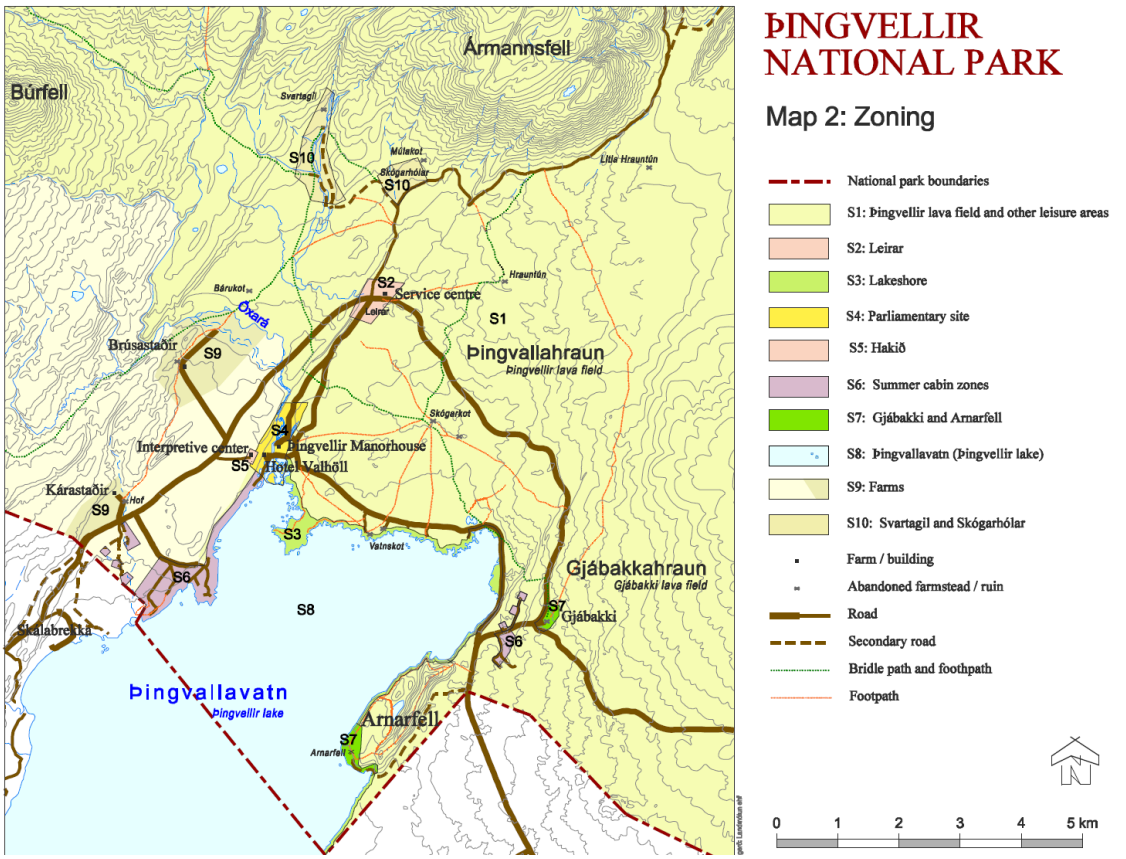

Figure 4.3: Zoning of Þingvellir National Park and location of infrastructure and service facilities according to the Þingvellir National Park Management Plan 2004-2024 (2004).

park is contingent upon weather and road conditions. (Þingvellir National Park Management Plan 2004-2024, 2004; Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003)

Most visitors at Þingvellir only stop for short visits. Visitors can roughly be divided into four groups, including those who come as follows (Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003):

- on their own on day trips, mainly by rental car from Reykjavik
- on group trips organized by travel agencies
- for the weekend
- due to special interests.

Þingvellir National Park is located at only 45 km northeast of Iceland's capital, Reykjavik, and is easily accessible for tourists. Route 36 is the main link between the national park and the capital and adjacent areas, and almost all visitors arrive by this route. The national park is also on route 52, a mountain road with little traffic, and closed in winter. These routes intersect at the service centre at Leirar. In addition, route 365 connects the national park to the Laugarvatn area. (Þingvellir National Park, 2015) Figure 4.4 shows the roads in the neighbourhood of the park.

Figure 4.4: Þingvellir National Park, located approximately 45 km northeast of Reykjavik, is easily accessible by road number 36. (Google Maps)

Tourism services (visitor centre, lavatory facilities, etc) and recreation (hiking, horse-riding, camping, snorkeling and diving) are provided in the park. Four car parks are located around the Parliament site, another six along the shore of Þingvallavatn Lake, and in many places by the roads space for one or two cars is provided. Visitor leave their car in the car parks and enter the site on foot. Motorized traffic within the park is not allowed on paths and tracks, but a road for motor vehicles leads from the service centre to the Parliament site, where traffic is confined to the special needs of those with limited mobility, the tasks of park wardens, and operational needs, except where special events and functions require otherwise. (Þingvellir National Park Management Plan 2004-2024, 2004)

Accessibility may be a determining factor for the number of tourists visiting the site. Visitor numbers may be expected to rise steadily (Þingvellir National Park Management Plan 2004-2024, 2004), increasing the pressure to the area, not only on the natural environment, but also on the infrastructure and roads. For example, in 2012, a tarmac road leading to Þingvellir National Park buckled and almost collapsed because of the steadily growing stream of visitors (OECD, 2014).

4.2.3 Biodiversity

Despite high precipitation, the lava is in general very porous resulting in unfavourable conditions for vegetation development (Jägerbrand, 2004; Jónasson, 1992). Birch woodland is characteristic of the Þingvellir area. In the National Park, 172 species of higher plants have been found, or about 40% of the Icelandic flora (Þingvellir National Park Management Plan 2004-2024, 2004). Birch, along with willow, moss heath, dwarf shrub heath and graminoid heath make up the majority of the plant community (Jónasson, 1992).

At several locations in the park, for example along the lake shore, vegetation is very sensitive and easily damaged. Moss heath is very susceptible to the effects of trampling. Tourists can trample vegetation, causing damage that can lead to the loss of biodiversity. Huber (2014) found that around 20 % of visitors (hikers and horse-riders) to Þingvellir National Park left the established paths whilst visiting the park, increasing the impacts on the sensitive vegetation.

Lake Þingvallavatn is particularly deep and thus does not attract as many waterfowl as do shallower lakes. Generally, 52 bird species live by the lake, while 30 others come and go. The most famous bird is the great northern diver, which nests in a few places by the lake. Mink live by the lake, preying on small birds, and foxes occasionally appear. (Þingvellir National Park, 2015).

4.2.4 Landscape conservation

Soil erosion is a serious problem in the area. Andosols, i.e. soils that form in volcanic deposits, are often sensitive to disturbance, because the lack a layer of silicate clay minerals (Arnalds et al., 2001) and are very susceptible to water and wind erosion (Jónasson, 1992). Considerable soil erosion has taken place in several areas within the national park Þingvellir National Park Management Plan 2004-2024 (2004).

The deepening and widening of tourist paths, multiple tread formations, root exposure and damage and erosion have a negative impact on the landscape. Also, tourist facilities lead to shrinking of pristine natural areas, affecting the scenic value of the landscape.

4.2.5 Water

The Þingvallavatn lake ecosystem

Lake Þingvallavatn is of volcanic origin, orginally formed by tectonic subsidence and glacial erosion (Adalsteinsson, Jónasson, & Sigurjón, 1992). This causes its high variety of habitats and ecological niches (Jónasson, 1992), created by land subsidence, rifting and lava. The soils around the lake have a low clay content and a mineral fraction consisting mainly of volcanic ash, and are therefore well drained. Hence, the precipitation in the catchment area of the lake is mostly percolated, and therefore the lake is mainly spring-fed, as 90 % of the inflow to the lake comes from groundwater inflow (Adalsteinsson et al., 1992).

The young age of the lava in the area means that there is a high uptake of minerals in the groundwater, and this is one of the reasons for the great diversity of life in Þingvallavatn. The lake is particularly fertile and rich in vegetation. A third of the bottom area is covered by vegetation, and there is a large amount of algae (Þingvellir National Park, 2015).

The constant, regular influx of groundwater into Lake Þingvallavatn, together with a very varied habitat, has created good conditions for fish and other life forms in the lake (Þingvellir National Park, 2015). The fish community of the lake consists of four separate morphs of Arctic charr, brown trout and threespine stickleback (Jónasson, 1992). The trophic interactions that will be represented in the causal loop diagram are based on the research on food webs and energy flows in Þingvallavatn by Jónasson (1992).

Nitrogen pollution in the form of nitrogen dioxide and nitrates (Veal, 2008) from traffic on nearby roads could lead to eutrophication of the lake, disturbing the existing ecosystem. More traffic at higher speed, or more roads inside the catchment area of the lake would only increase the pressure on the aquatic ecosystem.

Wastewater

Strict regulations concerning sewage apply due to the special status of Lake Þingvallavatn. According to regulation reg. no. 650/2006, sewage that is created in and around Lake Þingvallavatn, shall go through primary and secondary treatment. However, Guð mundsson (2014) notes that none of the summer cabins around the lake fulfills the requirements of reg. no. 650/2006, when it comes to sewage treatment. This poses serious threat to the biodiversity of Lake Þingvallavatn.

Toilet sewage from toilet facilities in the park at the visitor centre, service centre and campsites is collected in sumps and driven outside National Park boundaries, in accordance with specific permits on this matter (Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003). However, Guð mundsson (2014) studied the anthropogenic impact on the microbial diversity of the Þingvallavatn lake and found that fecal pollution from anthropogenic sources is present in the lake, and one location where fecal pollution was found was associated with Þingvellir national park. There was no decisive answer to where the pollution was coming from, but the question was raised whether sewage from tourism is polluting the lake.

Angling

Lake Þingvallavatn is the largest angling lake in Iceland (NLSI (2015)(NLSI)). An angling permit is needed to be allowed to fish there, and the information and service Centre sells angling permits and park personnel supervise fishing (Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003). The abundance of fish, inexpensive angling permits and easy accessibility from urban areas make the lake a popular place angling.

Diving and snorkeling

Diving and snorkeling is permitted in two fissures within the National Park, Silfra and Davíðsgjá, and has become increasingly popular in recent years. Silfra is one of Iceland's best diving locations and is known for its excellent visibility through the crystal clear water and the spectacular geologic formations. From March of 2013 to March of 2014, 15 126 divers and/or snorkelers visited Silfra, which correspond to more than 40 visits every day. (Nomination of the Þingvellir National Park for Inclusion in the World Heritage List, 2003; Guð mundsson, 2014)

Guð mundsson (2014) found in his study no evidence of anthropogenic pressure influencing the microbial community in Silfra or having a negative result on the ecosystem. However, since no legislations exist about importing diving equipment from abroad, equipment can be used without first being decontaminated. This poses the risk of introducing new microbial species to the vulnerable ecosystem.

4.2.6 Data analysis

The data described in the previous sections is converted into causal loop diagrams by selection of variables that describe the state, the special value and the conservation priorities of the park. The most important variables that characterise the national park were taken into the CLDs. For infrastructure, the amount of different facilities is not considered in the CLDs as CLDs do not provide a quantitative description.

4.3 Management techniques

The management techniques that will be evaluated in this study can be divided into two categories, according to Buckley (2000): measures applied to visitors, and measures applied to the environment.

Measures applied to visitors

Measures applied to visitors are aimed at changing the visitor's behaviour. Managing visitor flows can mitigate against environmental damage and crowdedness. This can be done through regulations or through economic incentives. Measures relating to visitors that will be implemented in the causal loop diagrams are:

- Restriction on visitor numbers: maximum permissible number of visitors
- Restrictions on activities on equipment: permits (in this case: diving and angling permits) and regulation (on diving equipment)
- Education of visitors: interpretive centres and signage
- Entrance and service fee
- Multi-access card (combined entrance to multiple sites)

Measures applied to environment

Measures applied to the environment both include measures to harden the environment against impact, and restoration measures, to restore the environment after past damage (Buckley, 2000). Included in this study are:

- Provision of infrastructure: boardwalks, trail construction, toilets, etc.
- Restoration of natural vegetation
- Soil conservation works

5 Results

5.1 Key variables in the tourism environmental subsystem

The key variable selection is based on the potential relation between nature-based tourism and the natural environment. In summary, the key variables selected are

- visitors
- visitor experience
- visitor attitude and behaviour
- services and infrastructure
- tourist activities
- pollution
- natural attractiveness
- natural resources for tourism
- overall environmental quality
- landscape

Key variables and their decisive influencing variables are selected based on what UNEP and UNWTO (2005) and Eagles et al. (2002) have pointed out as major variables in environmental sustainable tourism. Nature-based tourism can have both negative and positive impacts on the natural environment, while nature-based tourism at the same time relies on the natural environment (Figure 5.1). Key variables in the tourism environmental subsystem are thus both related to tourism and to the natural environment. Variables related to tourism

in the tourism environmental subsystem are *visitors*, *visitor experience*, *visitor attitude and behaviour*, *services and infrastructure*, *visitor activities* and *pollution*. These variables were selected because in nature-based tourism, *visitors* cause environmental impact through the *tourist activities* they exercise as well as through *pollution*. Moreover, *services and infrastructure* have several impacts on the *overall environmental quality* and *landscape*, as well as on the *visitor experience*. *Visitor experience* was selected as a key variable in the tourism environmental subsystem because the *visitor experience* will influence the *visitor attitude and behaviour*, and *visitor experience* is furthermore of importance in influencing the number of visitors as well as in the objective of the national park.

Key variable for the natural environment is the *overall environmental quality*, as this will determine the functioning of ecological processes and the provision of ecosystem services, which is what needs to be safeguarded for tourism to be sustainable. *Overall environmental quality* together with *landscape* are the *natural resources for tourism*, the products on which nature-based tourism depends. The *natural resources for tourism* determine the *natural attractiveness* of the park, as nature and the scenic natural landscape will attract *visitors* to the park.

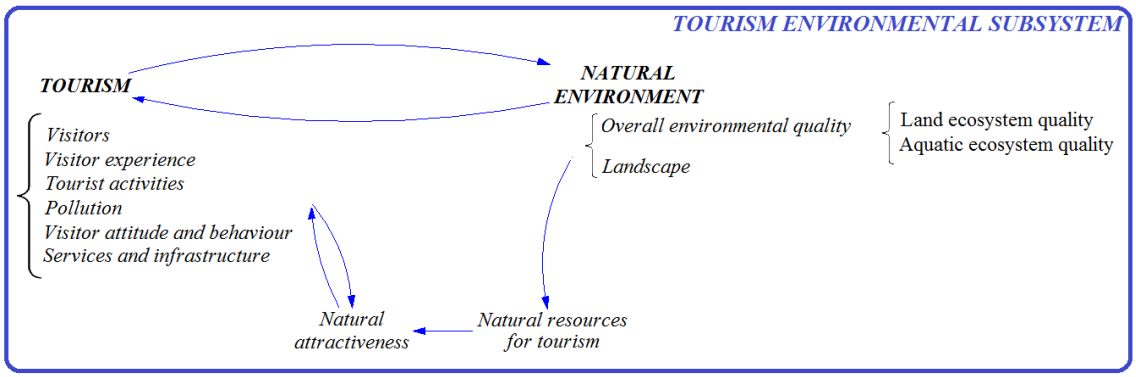

Figure 5.1: Interactions between tourism, the natural environment and the natural attractiveness in the tourism environmental subsystem, showing the selected key variables

Natural attractiveness depends on the natural resources for tourism and the presence of man-made structures. The *natural resources for tourism* are a combination of the overall environmental quality, the visual appearance of the landscape and the presence of unique natural features. The *overall environmental quality* is in this study defined as an aggregate of the aquatic ecosystem quality and the land ecosystem quality. Decisive variables for the number of *visitors* are accessibility, popularity of the tourist site and popularity of other tourist sites. There are many variables that can influence the visitor experience. Decisive variables influencing *visitor experience* that were selected in this study are crowdedness, presence of services and facilities, safety and natural resources for tourism.

Table 5.1 summarizes the selected key variables and the decisive variables influencing these key variables in the tourism environmental subsystem in Þingvellir National Park. The causal relationships between all the variables are present in the next section.

Table 5.1: Key variables with their respective decisive influencing variables of the environmental tourism subsystem in Þingvellir National Park

Key variables	**Decisive influencing variables**
Visitors	Popularity of the chosen tourist site Popularity of other tourist sites Accessibility
Visitor experience	Crowdedness Presence of services and facilities Safety Natural resources for tourism
Visitor attitude and behaviour	Visitor experience Educational activities, instruction and information
Services and infrastructure	Need/demand for services and infrastructure
Tourist activities	Visitors
Pollution	Visitors
Natural attractiveness	Natural resources for tourism Man-made structures
Natural resources for tourism	Overall environmental quality Landscape Unique natural features
Overall environmental quality Landscape	Aquatic ecosystem quality Land ecosystem quality

5.2 Causal relations between key variables

The causal relations between the key variables are analyzed in the causal loops diagram in this section. A positive sign means two variables are changing in the same direction, a negative sign means variables are changing in the opposite direction.

5.2.1 Visitors, visitor experience and natural attractiveness

Visitors

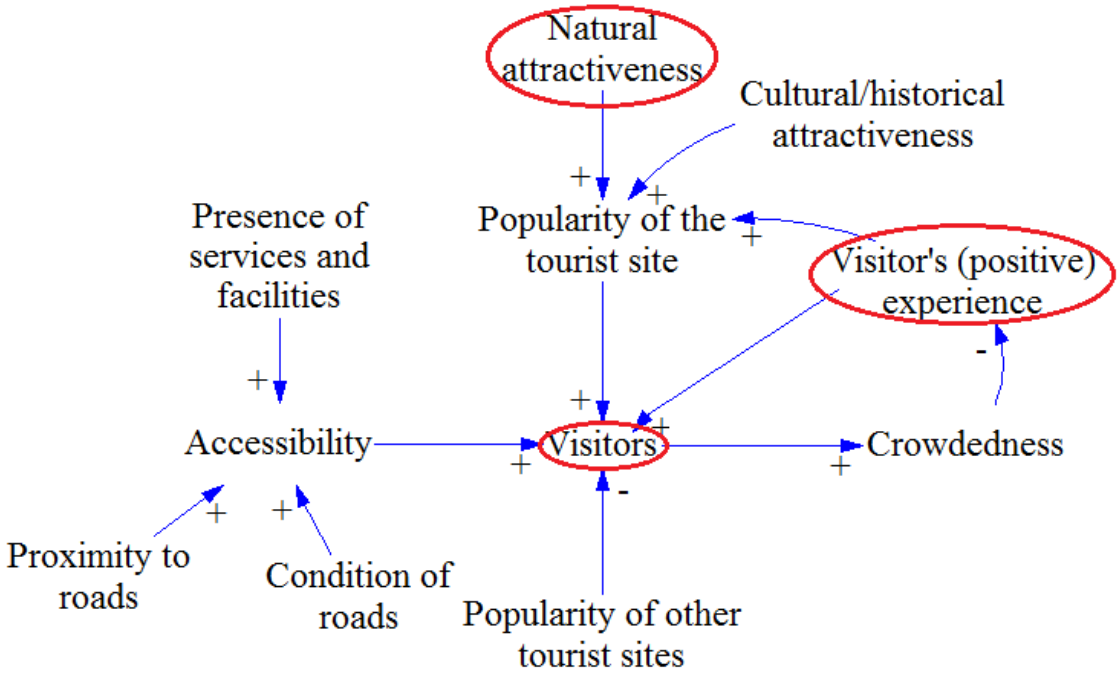

Figure 5.2: Variables influencing the number of visitors in Þingvellir National Park. Key variables are circled in red.

Visitors choose to visit a certain tourist destination based on its accessibility and popularity (see Figure 5.2). Popularity is here defined as depending on attractiveness and visitor's experience. Assuming that nature is the main attraction for which people visit national parks or protected areas in general, natural attractiveness causes visitor number to rise. Next to natural attractiveness, also cultural and historical interests can trigger people to visit a tourist destination, which is the case for Þingvellir National Park. This factor will however not be further examined in this project, but is just mentioned as one of the factors influencing visitor numbers. Visitors also base their decision to visit the park on the popularity of other tourist sites: when they find that other tourist sites are more attractive to them, and thus based on considering the popularities of other tourist sites, visitors might decide to go elsewhere.
Accessibility depends on the proximity of the site to roads, the condition of the access roads, but also on the presence of services and facilities in the park. The higher accessibility a tourist site has, the more tourists site will visit it, increasing the pressure and impacts on the natural environment.

Visitor experience influences the number of visitors indirectly, as a more positive experience will cause higher number of recurring visitors, together with a higher number of new visitors, as the positive visitor experience will help to increase the popularity of the site through word of mouth and online (social media) marketing by satisfied visitors.
A factor that is limiting the number of visitors is crowdedness. A higher number of visitors means more crowdedness, which will reduce the visitor's experience. This is thus a balancing loop, because visitors may avoid visiting the site thus the site becomes less popular because of too much crowdedness.

Visitor experience

Figure 5.3: Influencing variables in the CLD for the visitor experience in Þingvellir National Park. Key variables are circled in red.

The visitor experience (Figure 5.3) will be positively influenced by the condition of the natural resources for tourism (environmental quality, landscape and unique natural features), the presence of services and infrastructure and visitor safety, which is also dependent on services and infrastructure. Crowdedness will reduce the visitor's positive experience and visitor safety.

Natural attractiveness

A decisive variable for the natural attractiveness (Figure 5.4) is natural resources for tourism. People visit Þingvellir to enjoy nature and scenic beauty, so overall environmental quality and landscape are in this case the natural resources on which

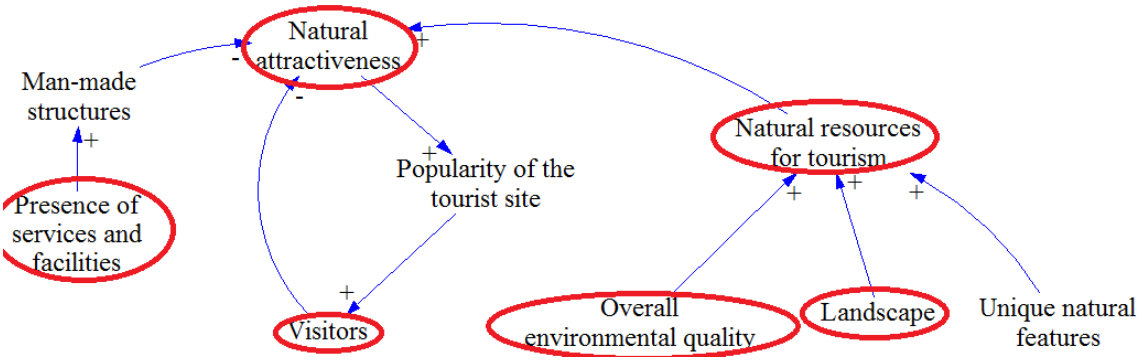

Figure 5.4: Influencing variables in the CLD for natural attractiveness in Þingvellir National Park. Key variables are circled in red.

tourism relies. Another reason for visitation, next to nature and scenery in general, is to see unique natural features. The presence of unique natural features in Þingvellir natural park thus also contributes to the natural resources for tourism. Negatively influencing the natural attractiveness are man-made structures (infrastructure) and the number of visitors: more infrastructure and more visitors lower the attractiveness of the natural site by degrading the pristineness of the environment

Interactions between visitors, visitor experience and natural attractiveness

The CLD in figure 5.5 shows how visitors, visitor experience and natural attractiveness are related, as a combination of Figure 5.2, 5.3 and 5.4.

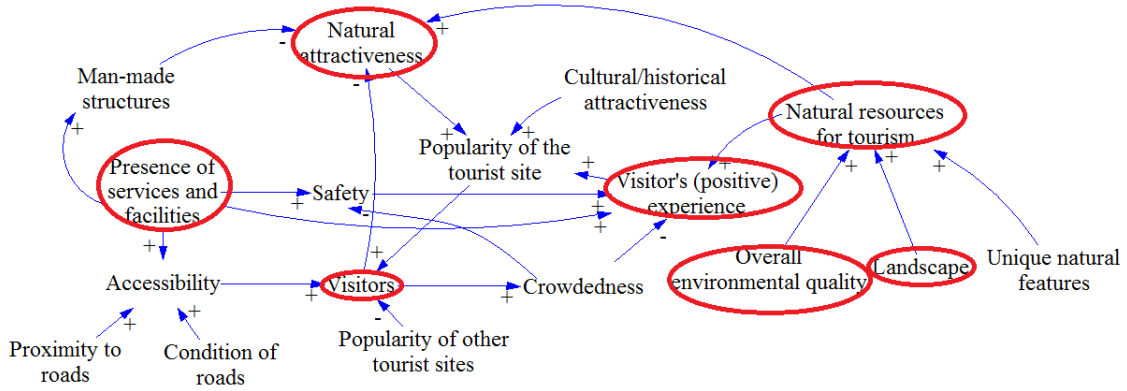

Figure 5.5: Causal relations between visitors, visitor experience and natural attractiveness in Þingvellir National Park. Key variables are circled in red.

5.2.2 Environmental impacts from tourism activities and pollution

Impacts associated with tourist activities

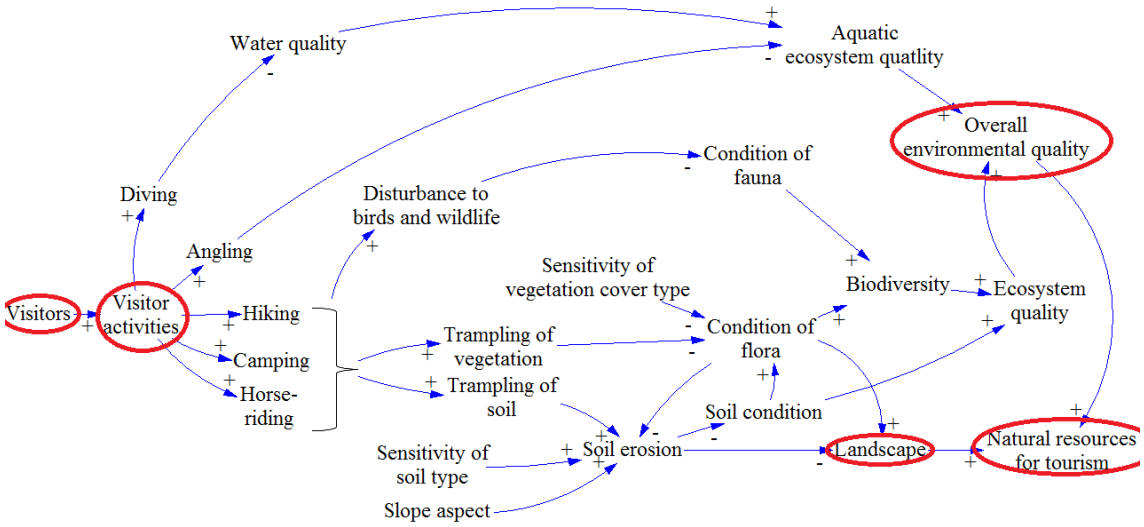

Figure 5.6: CLD of effects of tourism activities on the system in Þingvellir National Park. Key variables are circled in red.

Activities generally exercised in nature or as outdoor recreation, and that will be included in this study, are hiking, camping, horse-riding, diving (and snorkeling) and angling (Figure 5.6). Impacts to the ecosystem depend on the ecosystem sensitivity which is a combination of vegetation sensitivity, soil sensitivity and slope aspect, as discussed in Section 2.2.4. Hiking, camping and horse-riding have similar impacts: they damage vegetation, soil and landscape, and cause disturbance to wildlife, and thus overall affect the ecosystem quality negatively. Diving and angling have the potential of decreasing the aquatic ecosystem quality. The ecosystem quality is here dependent on the biodiversity and the soil condition. Together with the quality of the aquatic ecosystem, the ecosystem quality determines the overall environmental quality.

The effects of trampling on vegetation (breakage and bruising of stems, reduced plant vigor, reduced regeneration, loss of ground cover, change in species composition) cause a degradation of the condition of flora in general, leading to a decrease in biodiversity. Moreover, the effects of trampling on soil reduce the soil condition and cause accelerated erosion. Also, the condition of the vegetation will influence soil erosion, as loss of ground cover will accelerate erosion, and the condition of the soil

will affect the vegetation (reinforcing loop).

Impacts associated with pollution

Additional to the environmental impacts originating from recreational activities, visitors to the park also cause environmental impacts through pollution: production of sewage, littering and air pollution from transport to the park, as shown in figure 5.7.

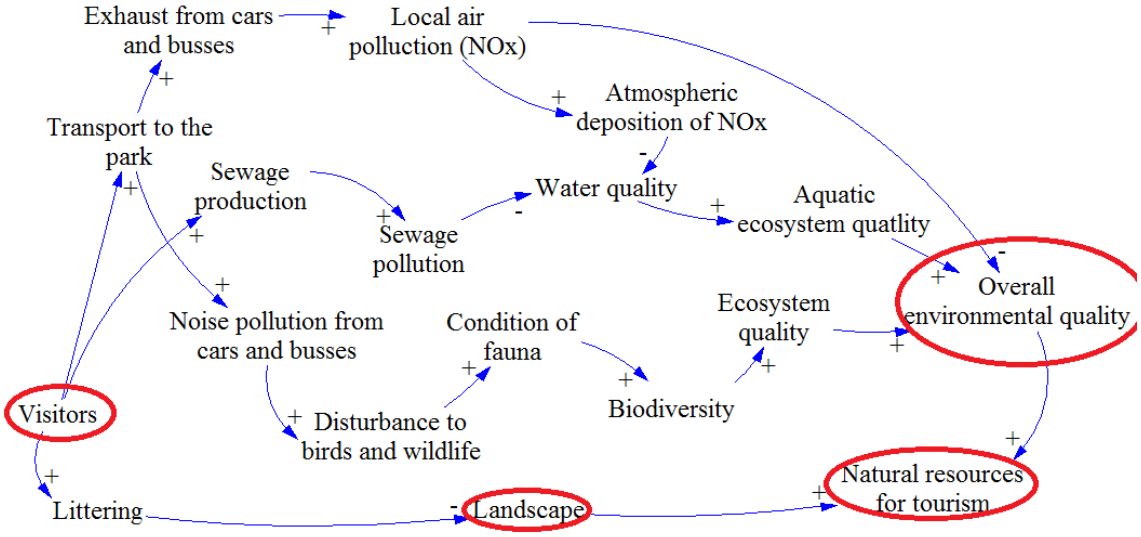

Figure 5.7: Effects of pollution on the system in Þingvellir National Park. Key variables are circled in red.

Littering affects the visual appearance of the landscape negatively, as it will cause the landscape to look less natural or pristine. Sewage production can lead to pollution to the lake when sewage is not completely treated. Sewage pollution to the lake will decrease the water quality of the lake, causing a decline in the aquatic ecosystem quality. Transport of visitors to the park causes pollution to the environment in two ways: noise pollution and local air pollution from the exhaust from cars and busses. Noise pollution disturbs birds and wildlife, leading to a diminished condition of fauna in the park, eventually decreasing the biodiversity and thus the ecosystem quality. Nitrogen oxides from the exhaust from cars and busses causes local air pollution. The nitrogen oxides in the air will be transferred to the lake by atmospheric deposition, negatively affecting the water quality and the aquatic ecosystem quality.

Figure 5.8 shows the overall CLD for impacts from pollution and activities, and the effect they have on the visitor's experience and natural attractiveness.

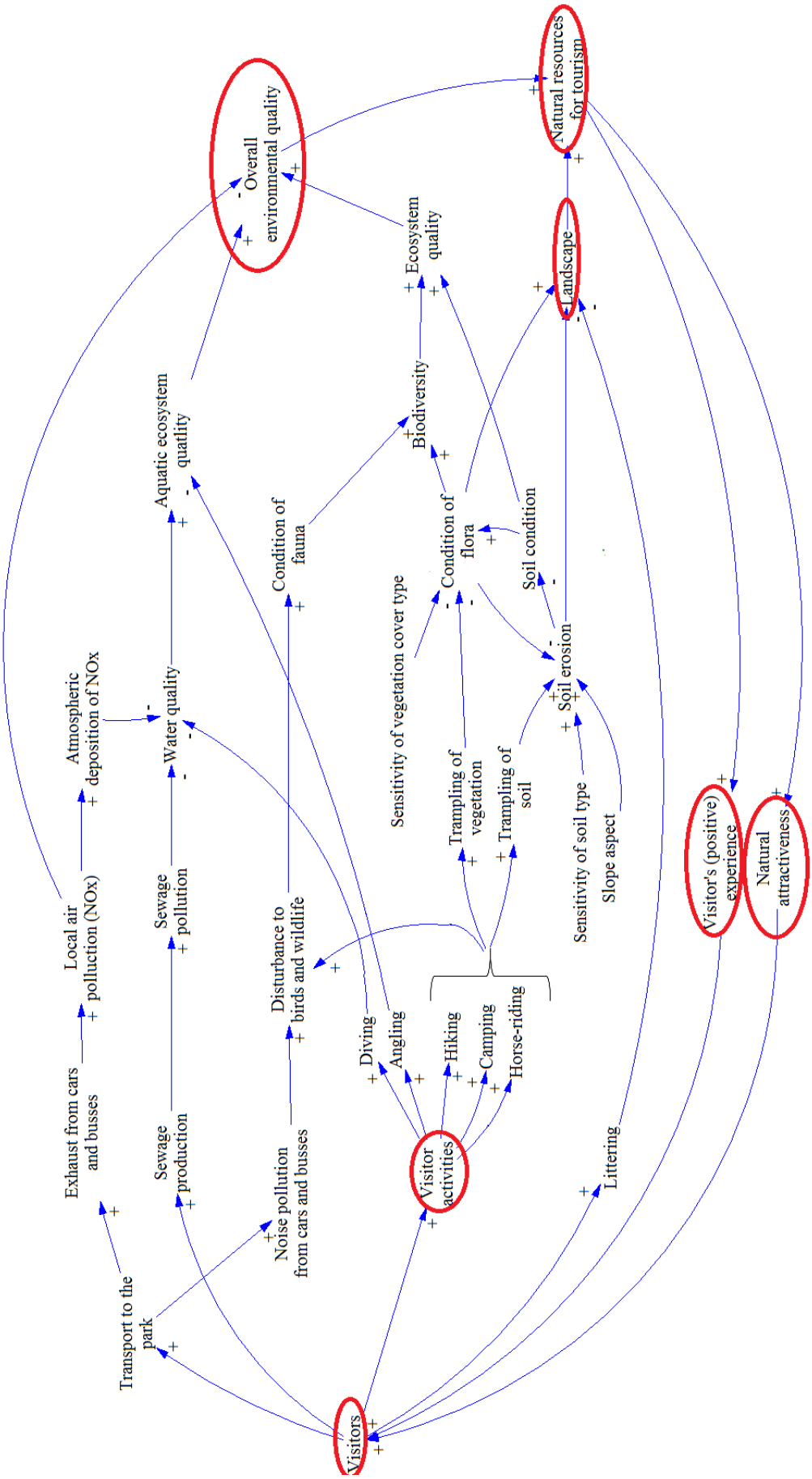

Figure 5.8: CLD of effects of tourism activities and pollution on the system in Þingvellir National Park. Key variables are circled in red.

5.2.3 Impacts from tourism services and infrastructure

Impacts from tourism infrastructure on natural environment

Figure 5.9 shows the cause-effect relations between tourism services and infrastructure and the natural environment.

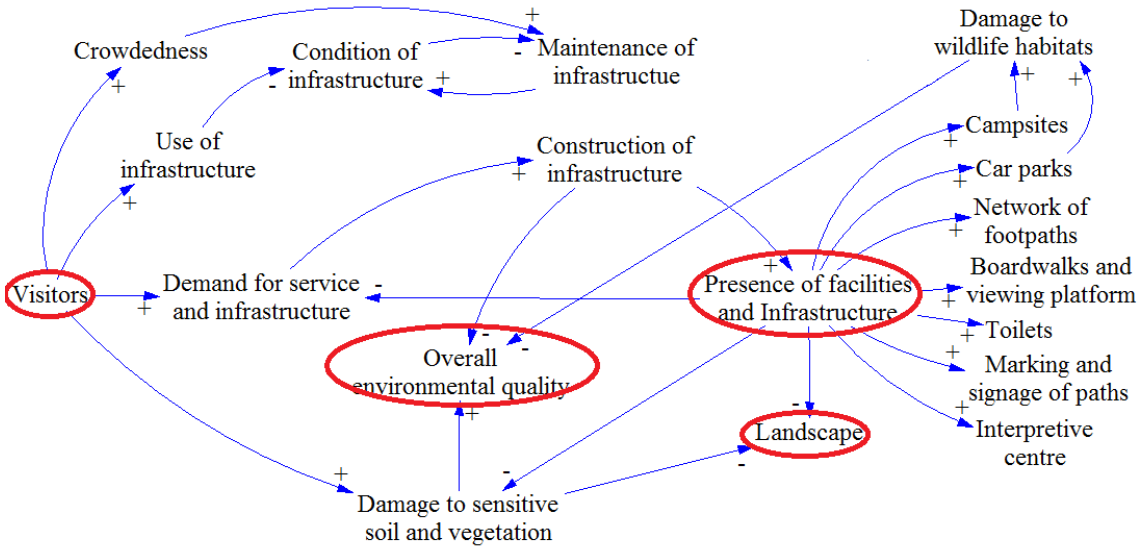

Figure 5.9: CLD showing the effects of infrastructure and facilities on the natural environment in Þingvellir National Park. Key variables are circled in red.

Next to impact from activities, visitors moreover pose the need for service and infrastructure. An increase in the number of visitors will drive the demand for services and infrastructure. When decided to act upon this need and to construct the needed services and infrastructure, more infrastructure will be present, satisfying the need for it (balancing loop). Services and infrastructure have several effects on the environment. Firstly, adequate services and infrastructure will mitigate the impact of recreational activities to the environment, by protecting the natural environment, for example by building bridges, boardwalks, paths, meaning less damage to sensitive nature, but also by providing visitors with information and education, changing visitor's attitudes and behaviour. A reduced environmental impact will, as described earlier, positively affect the natural attractiveness and visitor experience, inducing a higher popularity and thus a higher number of visitors. This thus also is a reinforcing loop. Secondly, infrastructure can however also have a negative impact on the environmental quality, by increasing the impacts to the natural environment

through the construction of infrastructure to meet the (increased) demand for services and infrastructure as the visitor number increases. Thirdly, when more services and infrastructure is provided, more man-made structures are present in the park. This reduces the natural attractiveness and thus the popularity, leading the fewer visitor (balancing loop). Infrastructure will also increase the visitor's safety, again increasing the visitor's positive experience and the number of visitors (reinforcing loop).

The more visitors that make use of infrastructure and facilities, the higher the impact on the infrastructure itself will be: hiking causes impact on constructed and maintained trail surfaces through erosion from trails and the use of toilets, boardwalks, the viewing platform, carparks, interpretive centre and campsites reduces the condition of them. So overall, the use of infrastructure reduces the condition of the infrastructure. This causes the need of maintenance, which will in turn again improve the condition of the infrastructure. More crowdedness will moreover also drive the need for better maintenance of infrastructure. The presence as well as the condition of infrastructure and facilities increases the visitor positive experience in general. Moreover, the construction of infrastructure will affect the environmental quality, as land clearing for construction will lower the environmental quality. On the other hand, most infrastructure has not only the purpose of increasing the visitor's experience, but is aimed at the protect protection of the sensitive soil and vegetation, e.g. boardwalks and to prevent trampling, toilets to prevent undesirable human waste in the ecosystem. In this way, infrastructure contributes to the ecosystem quality. However, the presence of infrastructure also can have a negative impact on the overall environmental quality, through the disturbance of habitats.

Impacts from tourism infrastructure on visitor experience and visitor attitude behaviour

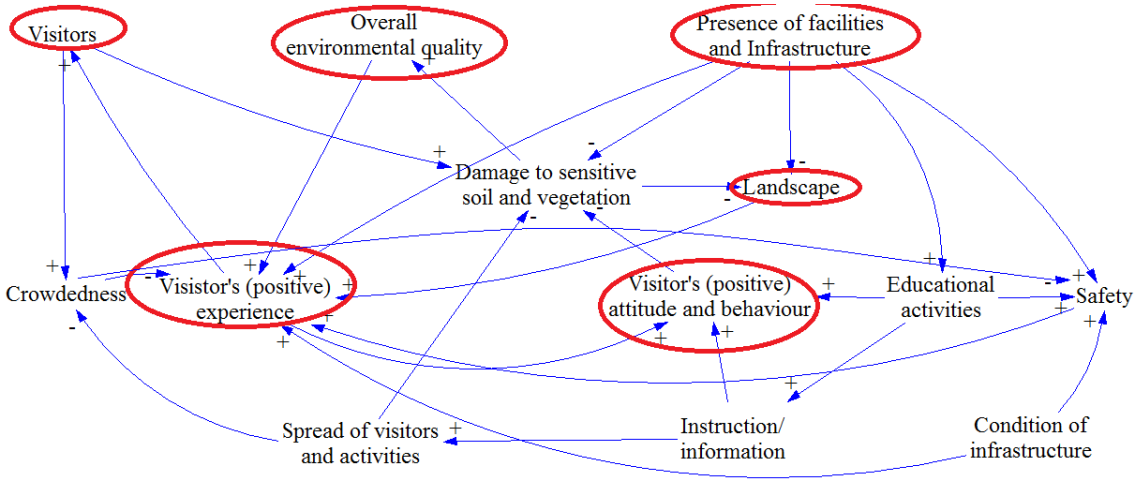

Figure 5.10: CLD showing the effects of infrastructure and facilities on the visitor experience and behaviour in Þingvellir National Park. Key variables are circled in red.

The presence of facilities and infrastructure effects the visitor experience in two ways: on the one hand, more infrastructure, i.e. more man-made structures, causes a lower natural attractiveness through degradation of the natural landscape, which lowers the visitor experience. On the other hand, visitors expect a certain level of infrastructure to be in place, hence the presence of infrastructure and facilities impacts the visitor experience positively in this way. More services and infrastructure will also increase the accessibility of the site, giving rise to an increased number of visitors (reinforcing loop).

The interpretive centre contributes to a better environmental quality through providing information and education to visitors, who will hence have a better attitude and behaviour and will therefore cause less damage to soil and vegetation. Signage and markings will increase both the visitor's experience and the visitor's attitude (e.g. not leaving the paths, no littering, etc). Informing and educating visitors also increases the visitor's safety, together with the provision of infrastructure such as paths, the viewing platform and signage and markings. A better visitor's safety improves the visitor experience.

Educational activities and instruction and information through sings and markings also help to achieve a better spread of visitors and hence a more even distribution of activities. This will lower the crowdedness, as well as cause less damage to

sensitive soil and vegetation, both having an increasing effect of the number of visitors, through a better visitor experience and a better environmental quality respectively (thus presenting reinforcing loops).

Interactions between infrastructure, visitors and environment

Figure 5.11 shows the cause-effect relations between tourism infrastructure and facilities, the ecosystem and the visitor.

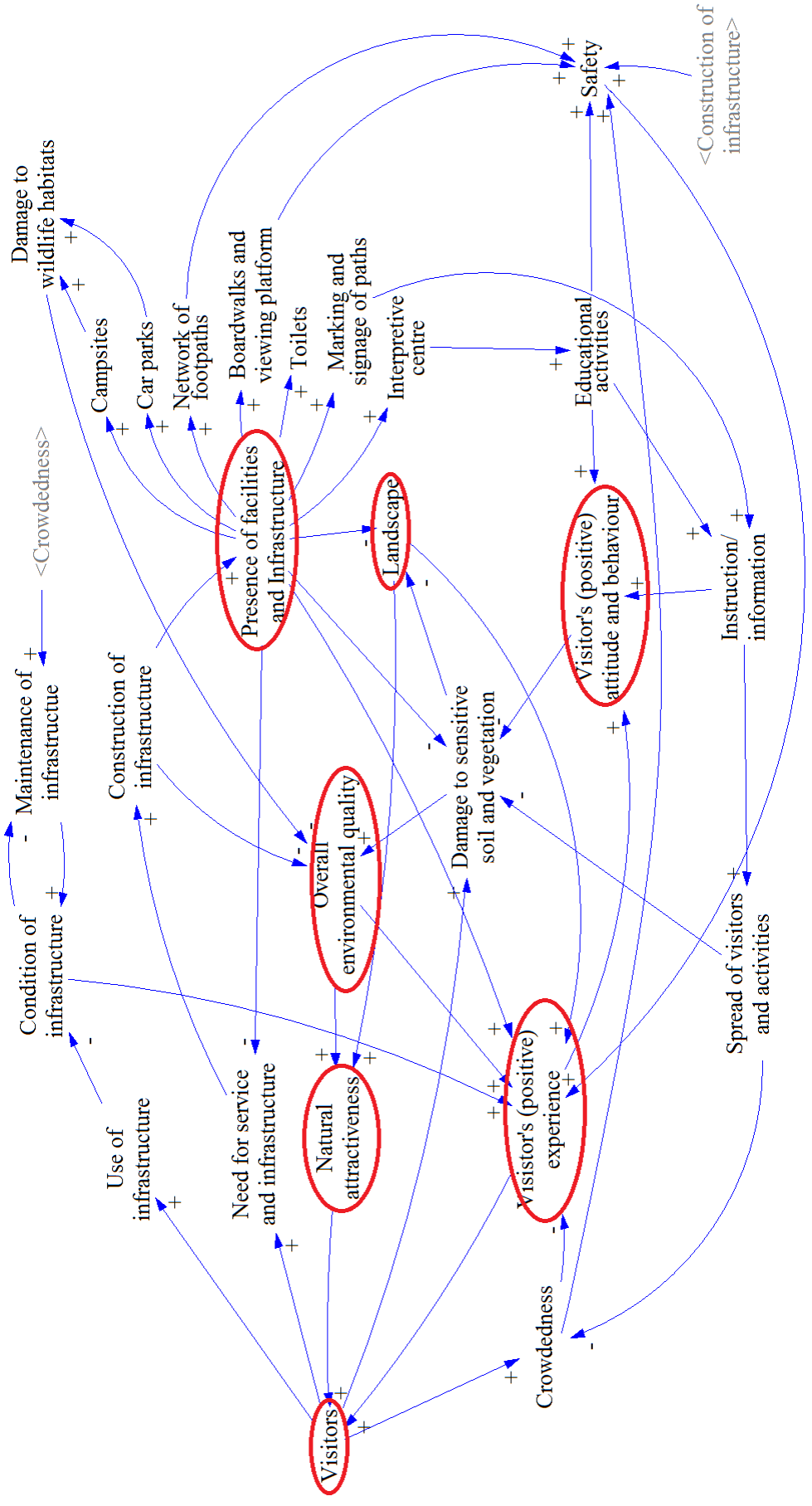

Figure 5.11: CLD showing the effects of infrastructure and facilities on the natural environment and on the visitors in environment and on the visitors in Pingvellir National Park. Key variables are circled in red.

5.2.4 Environmental impacts from tourism on the aquatic ecosystem

Impacts from tourism on the lake hydrology and lake water quality

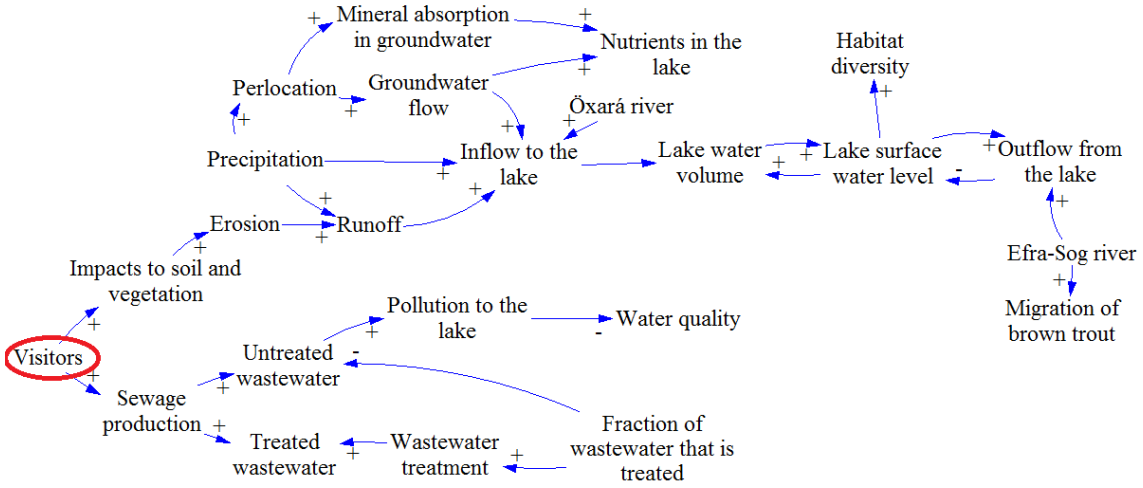

Figure 5.12: CLD showing the effects from tourism and recreation on the lake hydrology and water quality in Þingvellir National Park. Key variables are circled in red.

Water inflow to the lake is caused by precipitation, runoff, inflow from the Öxará river and mainly by groundwater flow. Precipitation percolates into the soil, replenishing the groundwater flow. Percolating water moreover absorbs minerals from the lava, causing an increase of the nutrients in the groundwater, and thus eventually of nutrients in the lake. Visitor impacts to the soil and vegetation leads to increase erosion, causing more runoff. The water inflow to the lake increases the water volume of the lake, and consequently the lake water surface level, which is also controlled by the outflow from the lake. The outflow from the lake in turn depends on the water volume of the lake. The outflow from the lake goes to the Efra-Sog river, which is an important migration route for the brown trout in the lake, as it goes to the river for spawning. The lake water surface level affects the habitat biodiversity in the lake, as a water level that is too low will lead to a loss of habitats. The lake water quality can be decreased by pollution to the lake, coming from untreated sewage produced by visitors.

Impacts from tourism on the lake biology

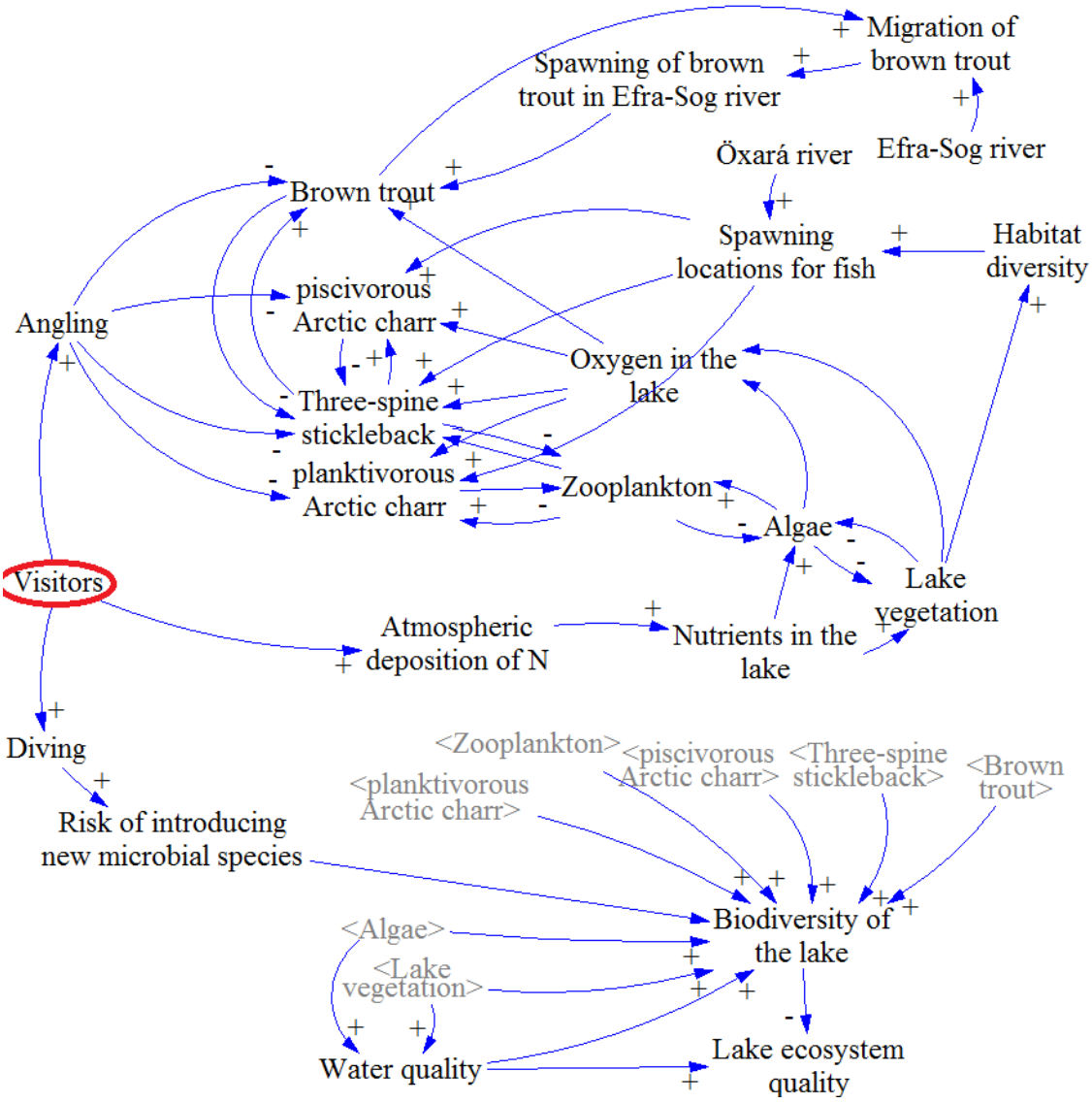

Figure 5.13: CLD showing the effects from tourism and recreation on the lake biology in Þingvellir National Park. Key variables are circled in red.

The quality of the lake ecosystem contributes to the overall environmental quality, influencing the number of visitors via natural attractiveness and visitor's experience, as described earlier. The quality of the lake ecosystem depends water quality of the lake and the biodiversity in the lake. The different fish species in the lake together with the population of zooplankton, algae and the lake's vegetation determine the lake's biodiversity. Habitat diversity depends on the lake vegetation and on the water level in the lake.

Angling has a direct effect on the biodiversity, as angling decreases the populations of the fish species. Angling also affects the soil and vegetation along the shoreline of the lake, causing erosion which can lead to increased runoff. Diving increases the risk of introducing new species to ecosystems. Depending on which species are introduced this will have an effect on the biodiversity in the lake. New microbial species could increase the biodiversity, but when the newly introduced species are invasive, this could lead to a decreased biodiversity.

An increase in nitrogen in the lake, coming from atmospheric wet or dry deposition of nitrogen oxides from exhaust from cars and busses, implies the risk of eutrophication. This means that because of an increased level of nutrients, algae will increase, which can cause oxygen depletion and possibly mortality of fish. Also, because of increased turbidity due to increased algal biomass, predators will have more difficulties finding their prey, also leading to a decrease in fish. Competition for light and nutrients exists between algae and lake vegetation, so a vast increase in algal population could lead to less lake vegetation, compromising the habitat diversity, leading to changes in fish populations. Overall, eutrophication thus leads to a decrease in biodiversity.

Relation between visitor impacts, lake hydrology and lake biology

A system analysis of the aquatic system inside Þingvellir National Park is shown in Figure 5.14.

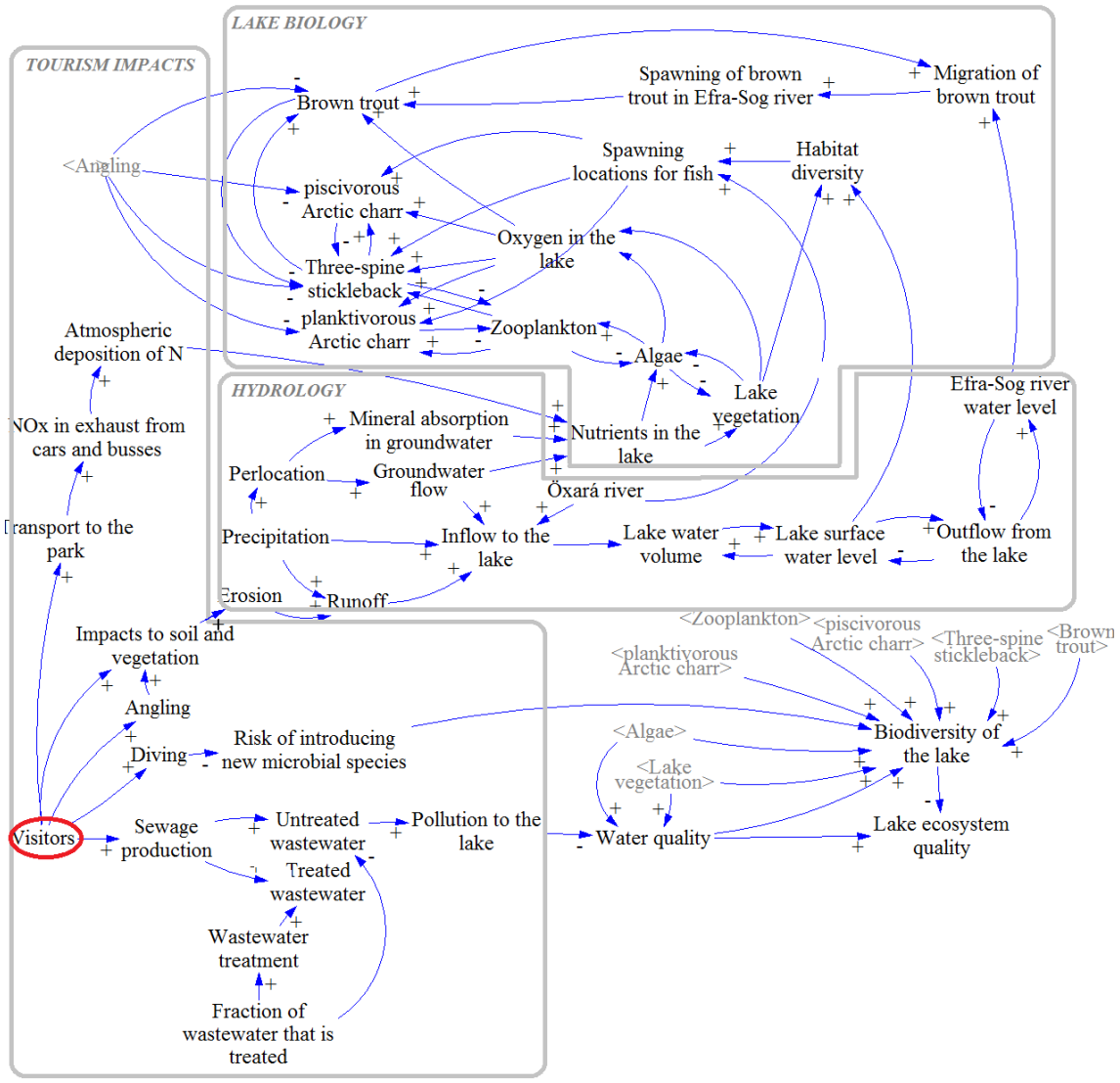

Figure 5.14: CLD showing the effects from tourism and recreation on the aquatic system in Þingvellir National Park. Key variables are circled in red.

Figure 5.15 show the simplified version of the CLD in 5.14.

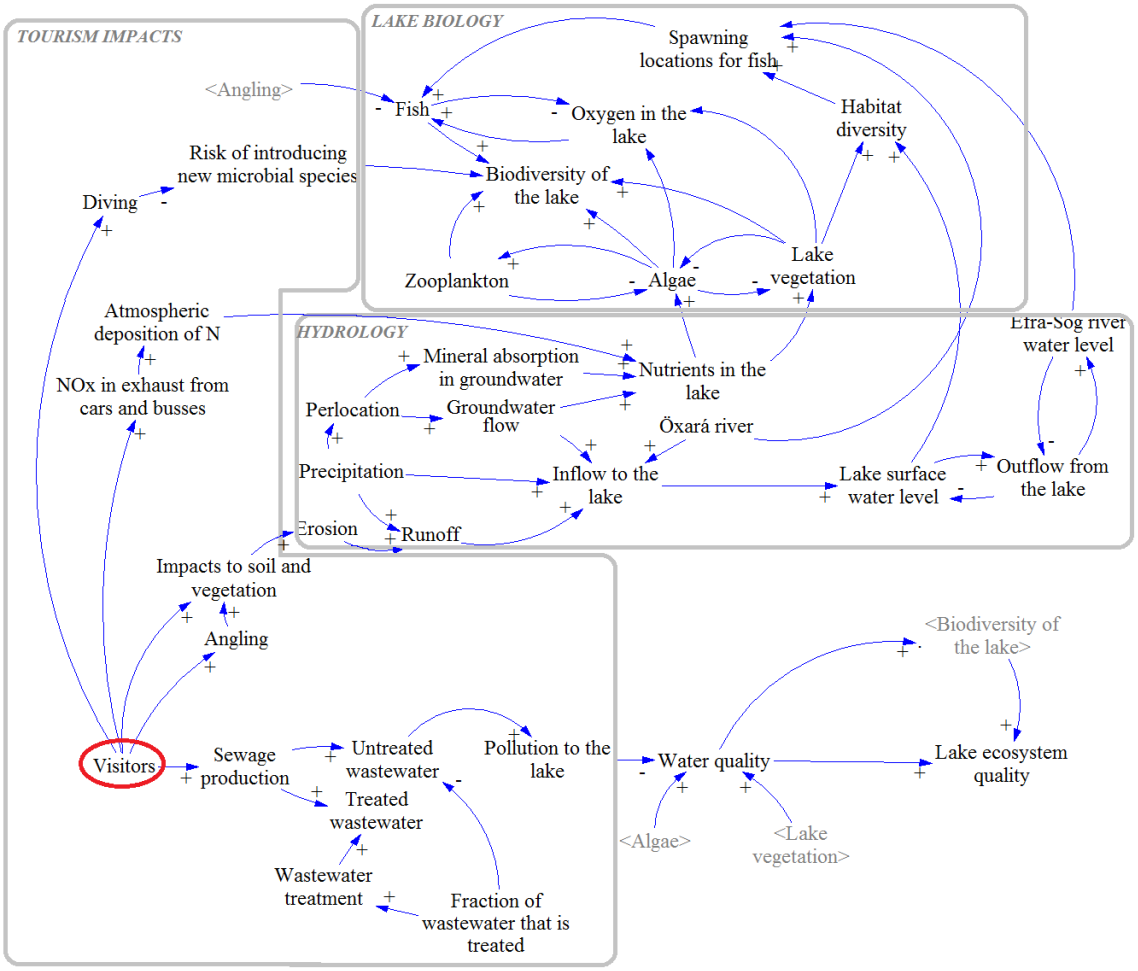

Figure 5.15: Simplified CLD showing the effects from tourism and recreation on the aquatic system in Pingvellir National Park. Key variables are circled in red.

5.2.5 Overview CLD

The CLD in Figure 5.16 summarizes all the CLD discussed above and show thus the causal relations between visitors, visitor experience, tourist activities, pollution and service and infrastructure.

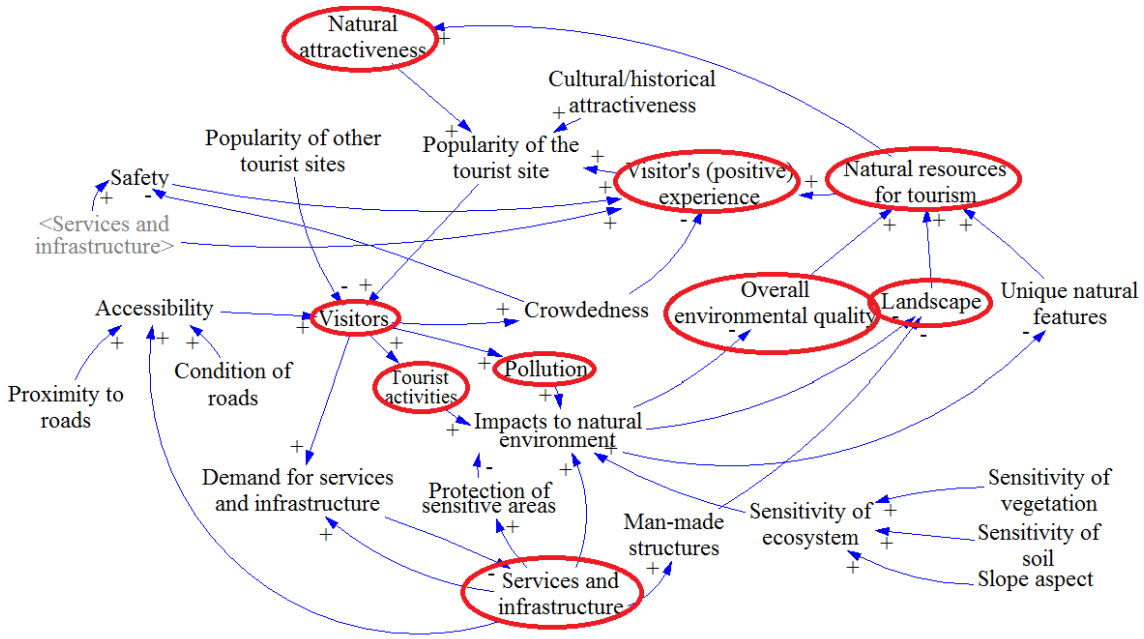

Figure 5.16: Overview CLD showing the effects from tourism and recreation on the system in Þingvellir National Park. Key variables are circled in red.

Overall environmental quality and landscape are the main natural resources for tourism in the park, and when they are affected negatively, the natural attractiveness will decrease. Impacts from recreational activities and pollution cause the aquatic and land ecosystem as well as the landscape to degrade, decreasing the natural attractiveness. Natural attractiveness and visitor's experience will thus both decrease, and this is leading to a decreasing popularity of the site. This will in turn lead to a lower number of visitors, thus a balancing loop can be detected here. More visitors also cause more crowdedness, leading to a lower visitor experience, which will decrease the popularity of the tourist site and hence attract less visitors. Another balancing loop is thus seen here.

Services and infrastructure have both positive and negative effects. On the one hand, through the protection of sensitive areas and through the contribution to the visitor safety, accessibility and visitor experience, the number of visitors will increase (reinforcing loops). On the other hand, services and infrastructure impacts the natural environment negatively through the construction, and services and infrastructure also degrade the visual appearance of the natural landscape, leading to a decrease in the visitor experience as well as to a lower popularity of the tourist site (balancing loops).

5.3 System success indicators and success goals

Variables that indicate the success of the tourism environmental subsystem are both indicators related to the special natural and geological value of the park, as well as the visitor experience (see Section 2.3.2). The special natural value of the park lies in the presence of unique geological features, as well as fauna and flora that deserves protection. In order to safeguard the integrity and authenticity of the park, the overall environmental quality and the visual appearance of the landscape are important indicators for the system success.
System success indicators found as a result in this study are:

- biodiversity of the lake
- lake water quality
- soil condition
- condition of flora
- condition of fauna
- overall environmental quality
- visual appearance of the landscape
- condition of infrastructure
- visitor experience
- spread of visitors

For each of these indicators, the goal is to achieve an optimal condition of the indicator, so that the system will keep its vital functions and characteristics, so that equivalent use of the park in the future will be possible. System success indicators are indicated in green in Figures 5.17, 5.18, 5.19 and 5.20 success goals are indicated in orange and management and policy options in blue.

5.4 Management and policy implementations on environmental quality

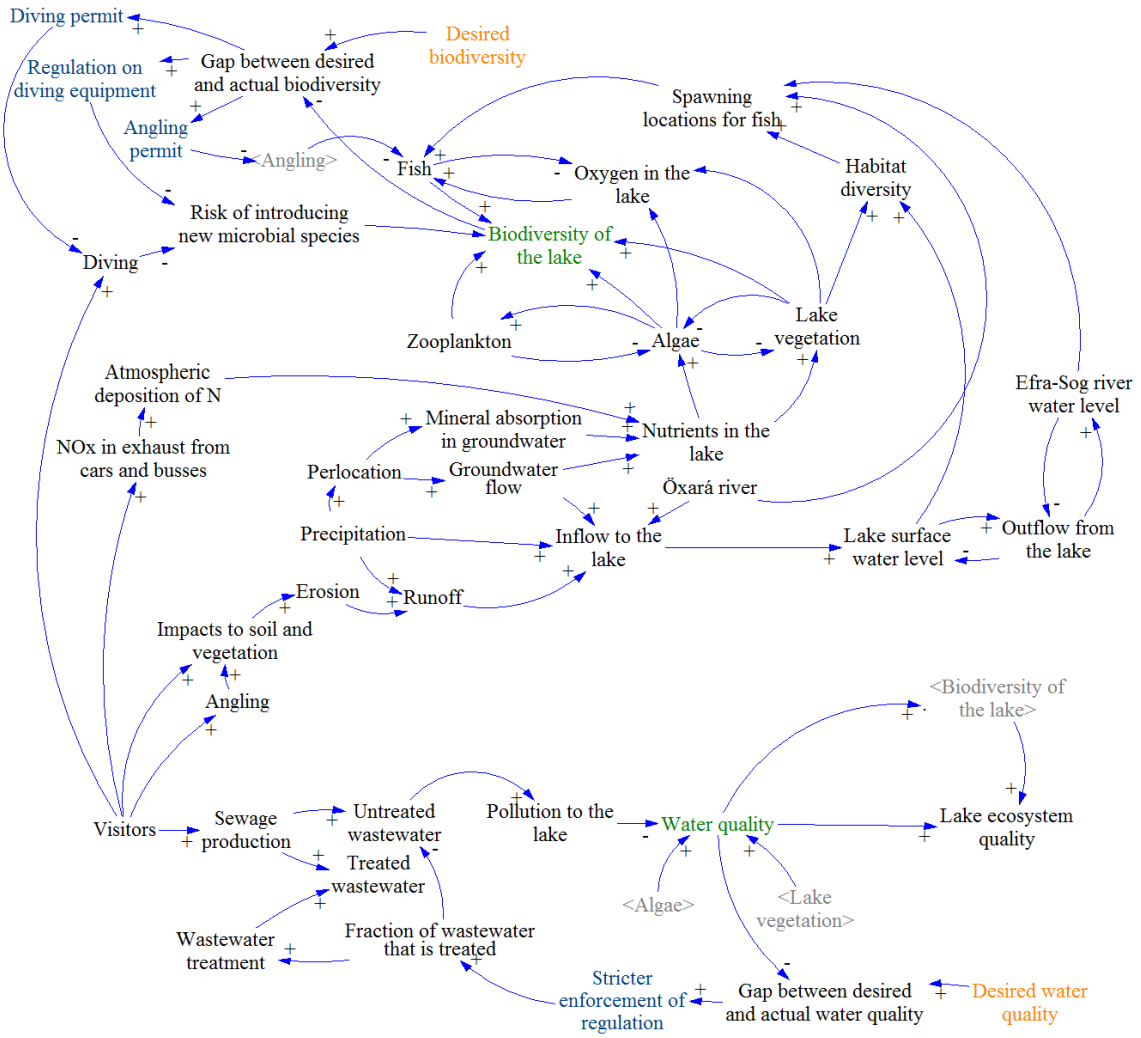

Figure 5.17: Policy implementations in the CLD for the lake subsystem in Þingvellir National Park. Key variables are circled in red, system success indicators are written in green, success goals in orange and management measures in blue.

Several possible management measures and policy actions to achieve the success goals in the aquatic subsystem can be taken (Figure 5.17). The water quality can be improved by decreasing pollution to the lake, coming from untreated sewage produced by visitors. Even though the regulation that is in place concerning treatment of wastewater produced in the park is already very strict, none of the summer cabin for example fulfills the requirements of the regulation. Therefore, when pollution to the lake is too high, a stricter enforcement, e.g. through sanctions,

of the regulation could help fulfilling the requirements. Angling is regulated through angling permits, which could have the effect of lowering the pressures from angling. However, the angling permits in Þingvellir are inexpensive, hence probably not having a significant effect. Changing the price for angling permits has the possibility of decreasing pressure from angling when needed. Diving is also regulated by permits, but no legislation on importing equipment exists. Implementing legislation on this will decrease the effect of introducing possibly harmful or invasive new species in the lake, benefiting the biodiversity of the lake.

Restoration of natural vegetation and soil conservation works can improve the condition of the vegetation and the soil (Figure 5.18). Improved condition of soil and vegetation will also positively affect the visual appearance of the landscape. Moreover, a better condition of flora will improve the soil condition through decreased soil erosion, and vice versa, a better soil condition will be beneficial for the condition of flora. When the overall environmental quality goes below a desired level, the decision can be made to restrict visitor numbers (Figure 5.18) in order to reduce impacts to the natural environment. Alternatively, restrictions to certain activities could be applied, or activities could be restricted to certain zones where soil and vegetation are less sensitive. Different factors can drive the decision to restrict the number of visitors, as a restriction of visitor numbers can have multiple effects. A restricted visitor number will decrease impacts from activities and impacts from pollution. Less trampling of soil and vegetation will lead to a better condition of soil and vegetation, increasing the biodiversity and the visual appearance of the landscape. Also, less disturbance of wildlife will have a positive effect on the condition of wildlife. When the visitor number is limited, less transport to the park will occur, leading to less noise pollution and less local air pollution, which will be beneficial for the water quality, as less nitrogen will be deposited to the lake, lowering the risk for eutrophication. Less visitors will also lead to less littering, which has a positive effect on the pristineness of the landscape.

An indirect effect on the visitor number can be caused by economic measures (Figure 5.19). The introduction of an entrance fee or services fees will reduce the popularity of the park. Visitors who are not willing to pay the price of the entrance fee may find that other tourist sites, that have no entrance fee or a lower price, become more attractive to them, and based on considering the popularities of other tourist sites, visitors might decide to go elsewhere. Less visitors to the park have the effects described above, namely less impact to soil, vegetation, wildlife, i.e. thus a better overall environmental quality in general, less disturbance of the landscape, less pollution, and less crowdedness, resulting in a better visitor experience.
A multi-access card will have a different effect. When access to multiple sites, both popular and less known sites is combined, other sites might become more popular, so that some tourists might decide to not visit the park. On the other, a multi-access

card has the potential of increasing the popularity of the park, as visitors might consider this money's worth compared to separate entrance fees.

Infrastructure can be a way to support environmental conservation (Figure 5.20). When the overall environmental quality is assessed as too low, investment in services and infrastructure can be a remedy to reduce the damage to sensitive soil and vegetation. Investment in maintenance of infrastructure will improve the condition of infrastructure, and hence the visitor safety and visitor experience.

Educational activities and the provision of information and instruction also has several beneficial effects. Firstly, it will cause a better spread of visitors, reducing the pressure on sensitive soil and vegetation and also reducing crowdedness, both leading to a better visitor experience. Secondly, it will enhance the visitor safety. Thirdly, when visitors are better educated about the fragility and special value of the soil and vegetation, and better informed (e.g. through markings and signage of paths) and instructed about the consequences of their behaviour (e.g. littering, leaving paths), a more positive visitor attitude will lead to less damage to soil and vegetation.

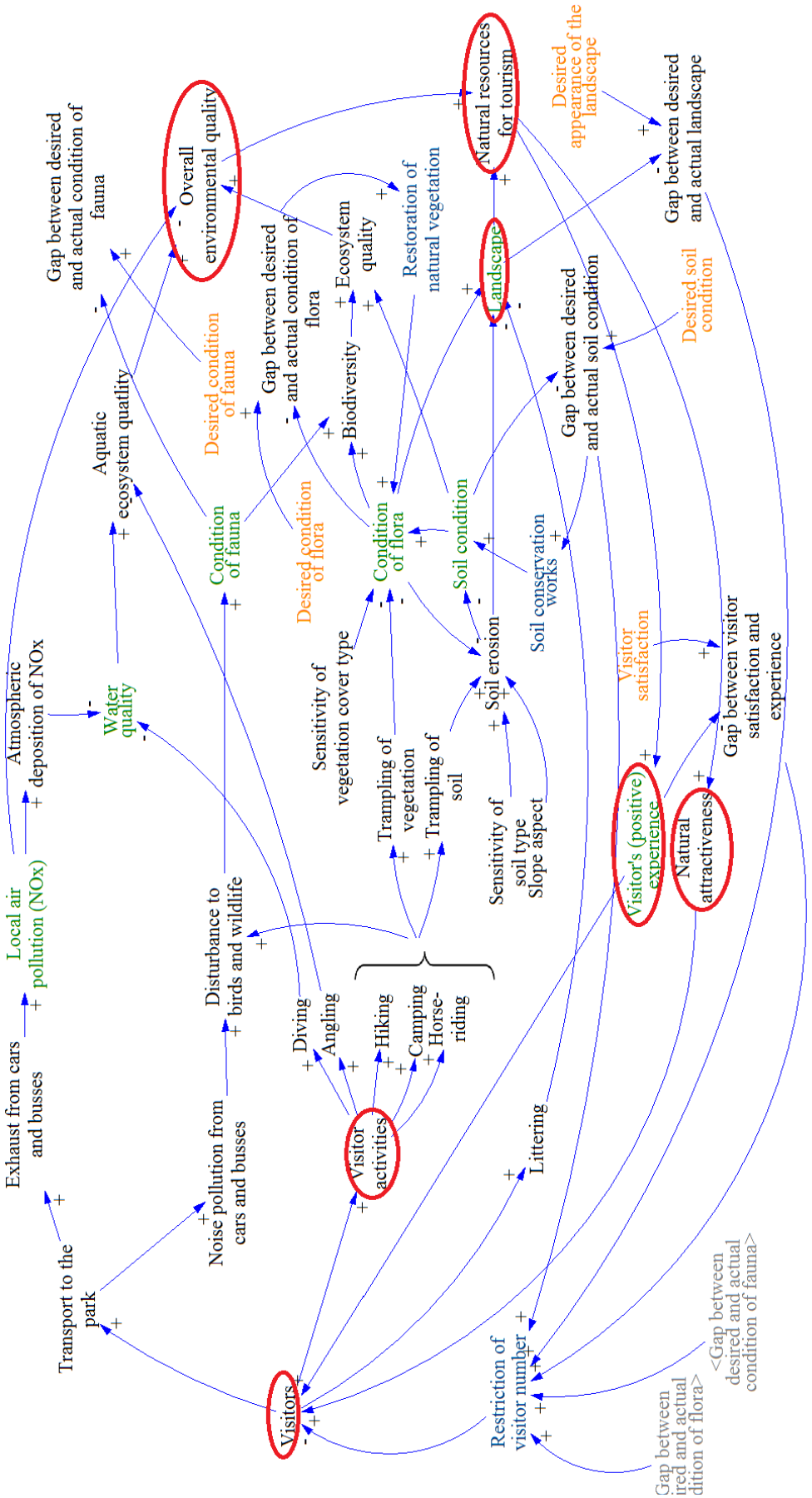

Figure 5.18: CLD showing the effects of restriction of visitor number, soil conservation works and restoration of natural vegetation in Þingvellir National Park. Key variables are circled in red, system success indicators are written in green, success goals in orange and management measures in blue.

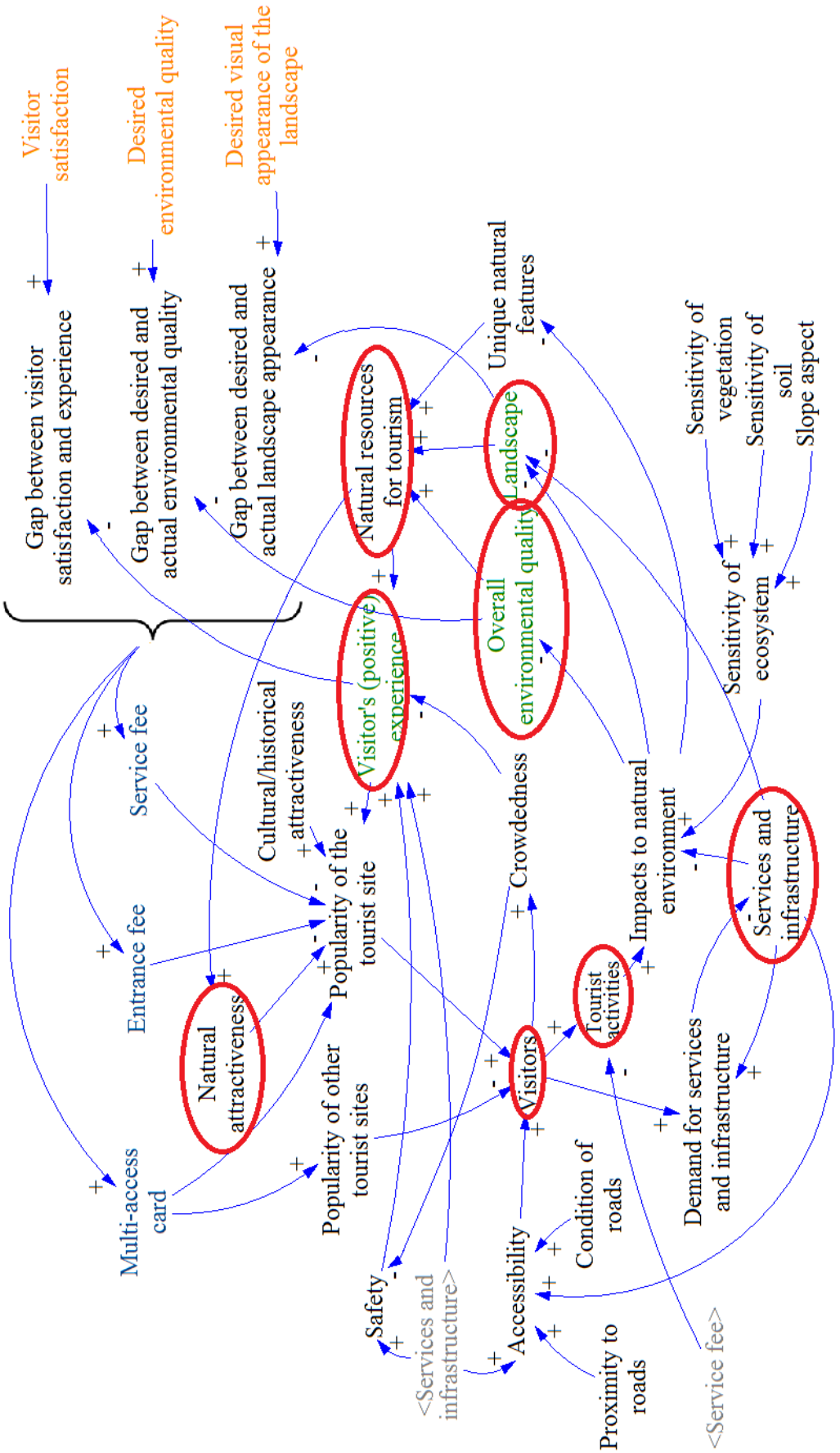

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Figure 5.19: CLD showing the effects of economic measures on the system in Þingvellir National Park. Key variables are circled in red, system success indicators are written in green, success goals in orange and management measures in blue.

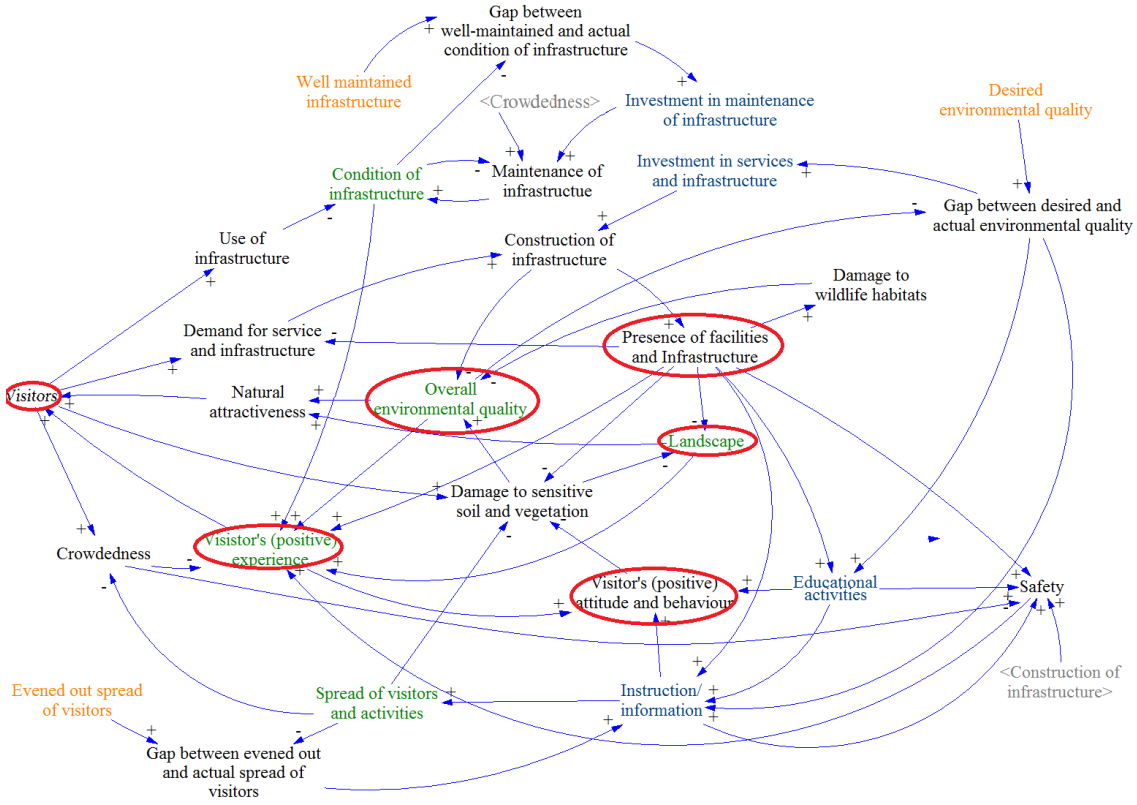

Figure 5.20: CLD showing the effects of infrastructure related management measures in Þingvellir National Park. Key variables are circled in red, system success indicators are written in green, success goals in orange and management measures in blue.

5.5 Policy outputs for sustainable tourism management in protected areas

Table 5.2 summarizes the potential management measures, their effects and side effects, on which variable in the system the effect will be noticed eventually, i.e. the system success indicator and a categorization of their risks or uncertainties and costs. The management options in Table 5.2 are arranged according to prioritisation. Measures that both positively affect the overall environmental quality and the visitor experience are of high priority, as these measures are most effective in achieving the park's objectives. Further are proactive measures of higher priority than curative measures, as it is easier to avoid impacts to occur than the restoration of impacted areas.

Educational services and the provision of instruction and information change the visitor attitude and behaviour, as well as the spread of visitors, without having side effects. This managment measure positively affects the success indicators overall environmental quality and visitor experience. Investment in services and infrastructure and in the maintenance of infrastructure improve the success indicators overall environmental quality and visitor experience, and as a side effect also improve the visitor safety and the spread of visitors. Investment in new infrastructure influences also the visual appearance of the landscape as a side effect. Entrance and service fees have similar effects: they reduce the popularity of the park, but are beneficial for almost all the success indicators. An entrance fee will also have the side effect of decreasing crowdedness, while services fees will decrease recreational activities. A multi-access card might either increase or decrease the popularity of the park, and has as a side effect also an influence on the popularity of other tourist sites. Regulations concerning wastewater treatment and diving equipment, and diving and angling permits will increase the water quality and the biodiversity of the lake, while having no undesirable side effects. A restriction of the visitor number will have side effects on the transport to the park, crowdedness and recreational activities, but has the potential of influencing almost all success indicators in a positive way. Curative measures such as restoration of natural vegetation and soil conservation works have a direct effect on the success indicator they are aimed for, i.e. condition of flora and soil condition respectively. A side effect of these measures is they will affect the visual appearance of the landscape positively.

Table 5.2: Overview of the potential management measures, their effects and side effects, on which success indicators in the system they will have an impact and categorization (low-medium-high) of their costs and risks. Management measures are arranged according to prioritisation.

Management measure	**Direct effect = policy entry point**	**Side effect**	**Success indicator**	**Risk/ uncertainty**	**Cost**
Educational services, instruction and information	Visitor attitude and behaviour Spread of visitors		Visitor experience Spread of visitors Overall environmental quality	low	low
Investment in maintenance	Maintenance of infrastructure	Safety	Condition of infrastructure Overall environmental quality Visitor experience	medium	medium
Investment in services and infrastructure	Construction of infrastructure	Landscape Safety Spread of visitors	Overall environmental quality Visitor experience	high	high
Multi-access card	Popularity of the park	Popularity of other tourist sites	Condition of soil Condition of flora Condition of fauna Landscape Water quality Visitor experience	medium	low

Service fee	Popularity of the park	Recreational activities	Condition of soil Condition of flora Condition of fauna Landscape Water quality Visitor experience	medium	low
Entrance fee	Popularity of the park	Crowdedness	Condition of soil Condition of flora Condition of fauna Landscape Water quality Visitor experience	medium	low
Stricter enforcement of regulation on sewage treatment	Fraction of wastewater treated	/	Water quality	low	medium
Angling permit	Angling	/	Biodiversity of the lake	low	low
Diving permit	Diving	/	Biodiversity of the lake	low	low
Regulation on diving equipment	Risk of introducing new microbial species	/	Biodiversity of the lake	low	medium
Restriction of number of visitors	Visitors	Recreational activities Transport to the park	Soil condition Condition of flora Condition of fauna Landscape Water quality	medium	low

		Crowdedness	Local air pollution Visitor experience		
Restoration of natural vegetation	Condition of flora	Landscape	Condition of flora Soil condition	low	high
Soil conservation works	Soil condition	Landscape	Soil condition Condition of flora	low	high

Educational services, instruction and information are of high priority and are easy to implement as they have low costs and low risks. Services and infrastructure are also of high priority, but have a high cost and a high risk or uncertainty regarding the effect on visitor experience. The risk of economical measures is medium, as the exact effect on visitors is uncertain, depending on their willingness to pay. Moreover, economical measures can be a source of revenue and can be used to fund the managing of the pressure on the natural environment. Regulations and permits have a low risk and in general a low or medium cost. A restriction of the visitor number is not meeting the park's objective that as many people as possible can enjoy what the park has to offer, so should therefore only be applied when it clearly serves the interest of conservation and sustainability. Curative measures, i.e. restoration of natural vegetation and soil conservation works are hard to implement, as their cost is high.

6 Discussion and Conclusions

6.1 Effect and impacts of tourism activities and infrastructure on visitor expierence

In this research, the environmental impacts of tourism activities and tourism infrastructure were evaluated by the use of CLDs, clarifying the cause-and-effect relationships between the key variables in the tourism environmental subsystem. From the results it can be seen that all tourism activities have some impact on the natural environment, by either degrading the condition of soil, flora, fauna, the water quality or the aquatic ecosystem. However, the overall goal of the park is to protect the special value of it, while at the same time enable visitors to enjoy their visit, according to the Þingvellir National Park Management Plan 2004-2024 (2004). The purpose of conservation is to safeguard the possibility of equivalent use in the future. Thus, achieving a reasonable compromise between conservation and utilization will enable present and future generations to experience the most benefits. Next to conservation, in its services to visitors the park places emphasis on outdoor activity and instruction on nature. Thus, however having impacts on the natural environment, visitor activities are an essential part of the park's objective.

Providing visitors to the park with an enjoyable and meaningful experience can only be done if the variables affecting visitor experience are managed properly. As shown in the results, decisive variables for visitor experience are crowdedness, presence of services and infrastructure, safety and natural resources for tourism. Visitors search experience and need services and infrastructure, but the level of expected services and infrastructure is different for different tourist types, however only one type of tourists is used in this research. As no distinction is made between different types of tourists expecting different levels of comfort or pristine conditions, the effect of service and infrastructure on visitor experience is twofold in this case: on the one hand, services and infrastructure will cause an improved visitor experience, both directly by fulfilling visitors' needs, as well as indirectly by improving visitor safety and the spread of visitors through providing instruction and information, causing less crowdedness. On the other hand, provision of more facilities and services, will lead to an increase in man-made structures, affecting the landscape and in that way also the visitor experience. Research by Sæþórsdóttir and Ólafsson (2010)

however pointed out that the quality of tourism in the Icelandic Lowlands depends on good infrastructure and a variety of good service, so an increase in services and infrastructure is likely to have an overall positive impact on the visitor experience in this case.

As shown in Figure 5.8 and Figure 5.16, more visitors, and thus more pressures and impacts from tourism will lead to more environmental degradation, which will decrease the natural attractiveness. However, natural attractiveness is a relative concept. Not every tourist experiences the environment he visits in the same manner and values naturalness in the same way. As the environment is perceived in as many different ways as people that are visiting, there is no objective way to quantify attractiveness. Some people are more sensitive to man-made structures or human influences, while others are not bothered by signs of antropogenic disturbances. However, as the majority of tourists indicated to travel to Iceland based on nature as one of the main reasons, it was here assumed that more man-made structures or human influences decreases the natural attractiveness.

A qualitative modeling approach to clarify cause-and-effect relations between variables was used in this study. When these relationships are clearly presented, they can be used to analyze how the impact of tourism to the natural environment can be minimized, while at the same meeting the visitors' needs. Qualitative modeling thus has its merits and is useful in its own right, as for example emphasized by Coyle (2000). However, including empirical data into a quantitative model would allow, through model simulations, a more detailed assessment of the impacts. Because environmental impact not only differs with the type of activity but also with the intensity of use, as pointed out by several researchers (e.g. Sun & Walsh, 1998; Cole, 2004), a quantitative method to assess environmental impacts and to describe the quantitative relationship between the environmental impacts and the level of use for different tourism activities might be useful. Moreover, when a quantitative model is applied, sensitivity analysis could be used to determine which variables have the highest impact on the natural environment. In this respect, maximizing visitor experience by optimizing the amount and size of infrastructure so that the environmental impact is low and the landscape is not disturbed too much could for example also be achieved by a quantitative analysis.

6.2 Potential of system analysis form sustainable tourism management

The general aim of this research was to investigate the potential of system analysis for sustainable tourism management in naturally fragile conservation areas. This was done by analyzing the effects of different management techniques/tools in reducing negative environmental impacts of tourism and maximizing positive impacts.

Economic measures, i.e. service fees, entrance fee or multi-access card, are often used principally to raise revenue rather than to influence visitor behaviour. In the case of Þingvellir national park, service fees are used as a source of revenue, but these fees also have the mean of managing the burden on nature caused by these services. Economic measures need to be in accordance with the value of assets and service that are provided. The price should be set according to the users pay principle, so that revenue generated by economic measures can be used for provision of services and maintenance of facilities, and as a means of managing the pressure on the natural environment originating from these services, through conservation and restoration purposes and visitor management. There is limited evidence in Iceland for what an appropriate price should be, however, a study by Reynisdottir, Song, and Agrusa (2008) concluded that tourists have a willingness to pay entrance fees to natural sites. They also noted that modest fees would not significantly decrease the demand for natural attractions. However, there might be an issue of social equity with the implementation of economic measures, as fees may discriminate against people with lower ability to pay.

A multi-site access card could be implemented, for example charging visitors to visit Þingvellir, Gullfoss and Geysir in one combined fee. An efficient distribution of revenues among these sites could be a useful injection of funding into environmental conservation, be beneficial for the quality of the tourist site and hence for the visitor satisfaction. A multi-access card could also provide access to a combination of both popular and less well known sites, with a view to reducing pressures on the most visited sites. People who are not willing to pay for visiting these well-visited tourists sites would be redistributed to other, less visited sites, distributing the load. A report by the Group (2013) notes that a multi-access card has been successfully implemented by tourism authorities in for example the national parks of South Africa and the USA.

A more even distribution of visitor flows and activities to spread the impact could be one of the approaches, but Cole (2004) notes however that in many situations, the total magnitude of impact, which is the combination of the area of impact

and intensity of impact, increases more as a result of new places being disturbed, than from the deterioration of places that have already been disturbed for a longer time. This underscores the need to focus attention on the spatial distribution of use. The same remark should be made for the approach of a better distribution of visitors around the country, by marketing of other areas and making other areas more accessible.

Setting a ceiling on the number of visitors would probably encounter a lack of acceptance due to several reasons. The idea of maximum permissible numbers of visitors is however accepted in many forms of leisure, as illustrated by Butler (1996): it is accepted that most leisure facilities have fixed capacities, and it is acknowledged that infrastructure is sometimes beyond capacity limits, as traffic jams or congestions at airports illustrate. Similarly, natural and heritage areas can receive too much use, that it can be necessary to restrict the number of visitors. This could be implemented by creating the requirement to book a visit to the park in advance, as is the case for campsites at many popular parks in the USA. But, since the aim of the park is still that as many people as possible can enjoy what the park has to offer, restrictive management should only be applied when it clearly serves the interest of conservation and sustainability. It is also important to realize that while impact often occur rapidly, recovery occurs more slowly. Proactive management is thus important, in order to avoid impacts to occur, as this is much easier than the restoration of impacted areas. Curative measures, such as soil conservation and restoration of natural vegetation, even though having a direct effect on the succuess indicators they are aimed at, are thus not preferable to the other management measures. Moreover, implementation of management actions must be checked through monitoring of the success indicators, and improvement needs to be assessed so that measures can be adjusted or refined.

The most promising approach is probably to combine tourism and nature conservation, through funding from tourism for conservation, through education and raising environmental awareness, and through better alignment of the governance of tourism and environment, to enable a better integration of nature conservation and tourism development objectives. Educational services and information will result in visitors adopting a more appropriate behaviour that will reduce environmental impacts and provide visitors with a better experience. A better understanding of the natural environment at the tourist site can also lead to a higher appreciation of the area, which in turn can help reduce visitor impacts to the natural environment, and possibly even provide greater public support for the park.

A holistic understanding of all influencing factors for the management and the causal relationships between them is needed for sustainable tourism management. By looking at the environmental tourism subsystem as a whole, it can be identified which measures or policies could most effectively or quickly achieve the desired goal.

Therefore, system analysis in management for environmental sustainable tourism could be used to help prioritize the implementation of measures. As mentioned before, a quantitative modeling approach would allow for a more straightforeward evaluation of the effectiveness and performance of managament measures, as it would for example give the possibility of a sensitivity analysis of the implementation of different measures. Quantitative model simulations would also allow to include the cost of different measures, allowing a cost-benefit analysis of the implementation of possible management measures and policy actions. System analysis is however promising as a qualitative tool as well, for the identification and formulation of possible management measures or policy actions to achieve success goals, via the approach of backcasting. With the use of the backcasting approach, the temporal aspect of environmental management and planning is addressed. A systemic approach in environmental management is thus useful, because tourism environmental management needs a combination of visitor management, impact management and land use management. The spatial aspect of environmental management and planning is however not included by the system analysis approach used in this research.

As could be seen from the study area and data description, some areas are more inherently more sensitive, or are under greater pressure from nature-based tourism. A combination of the sensitivity, the natural value and level of tourism use and impact for different areas within a protected area could help in tourism management. When seen that a certain level of impact is too high for a certain area, system analysis in combination with a geographical information system (GIS) could be used to find out management measures that could be used to distribute visitors to other less sensitive areas. When appropriate levels of use for eache zone are defined, specific measures or restrictions for differnt zones can be used.

6.3 Further research

As already indicated, there is a need to focus attention on the spatial distribution of the use of natural assets in tourism and recreation. A GIS approach, documenting natural conditions and resources, determining the most sensitive areas and distribution of visitor flows and activities could be important in determining the suitability of certain areas for tourism.
Quantitative simulation modeling could further add value, both for the analysis of the environmental impacts of tourism in protected areas, as well as for the analysis, implementation and assessment of possible management and policy measures. Further research regarding thresholds of indicators below which damage to the ecosystem would be irreversible and regarding the desired states of the success goals is needed. Methods to monitor and assess the system success indicators

need further investigation. In another perspective, an economic valuation of the ecosystem services provided by the National Park could help assessing the impact of tourism and could assist in making management and planning decisions, based on what management option would generate the highest value of ecosystem services.

6.4 Concluding remarks

Management measures that both improve the visitor experience and the environmental quality are the most effective, as a compromise between tourism use and environmental conservation is what needs to be achieved. As protected areas are experiencing increasing visitor use, the importance of provident management and planning is becoming more critical. This study concludes that many of the negative environmental impacts of nature-based tourism could be mitigated with proper environmental management. System thinking and system analysis can help to deal with this challenge of balancing use and protection of natural resources in tourism in order to ensure long-term environmental sustainability, and can help provide management tools that reduce negative environmental impact from nature-based tourism and offer the visitor to natural tourist site a fulfilling experience.

References

European Charter for Sustainable Tourism in Protected Areas. (2002). *Guide to sustainable tourism in protected areas.* (Ways to sustainable management - Socio-economic benefits of conserving nature)

Act on the Þingvellir National Park no. 47. (2004). *No. 47, 1 June 2004.*

Adalsteinsson, H., Jónasson, P., & Sigurjón, R. (1992). Physical Characteristics of Þingvallavatn, Iceland. *Oikos*, *64*(1/2), 121-135.

Adams, W. M. (2008). *Green development: Environment and sustainability in a developing world (third edition).* London: Routledge.

AlÞing. (2005). *Regulation on the Þingvellir National Park, its Protection and Management.* (Reykjavik)

Arnalds, O., Þórarinsdóttir, E. F., Metúsalemsson, S., Jónsson, A., Grétarsson, E., & Árnason, A. (2001). *Soil erosion in Iceland.* Reykjavik: Agricultural Research Institute, Soil Conservation Service.

Azar, C., Holmberg, J., & Lindgren, K. (1996). Socio-ecological indicators for sustainability. *Ecological economics*, *18*(2), 89-112.

Batta, R. N. (2000). *Tourism and the environment: A quest for sustainability : with special reference to developing countries, and policy analysis on himachal pradesh*. Indus Publishing.

Briassoulis, H. (2002). Sustainable tourism and the question of the commons. *Annals of Tourism Research*, *29*(4), 1065 - 1085.

Buckley, R. (2000). Tourism in the most fragile environments. *Tourism Recreation Research*, *25*(1), 31-40.

Buckley, R. (2003). Ecological indicators of tourist impacts in parks. *Journal of Ecotourism*, *2*(1).

Buckley, R. (2004). Environmental impacts of ecotourism. In R. Buckley (Ed.), (chap. Impacts Positive and Negative: Links Between Ecotourism and Environment). CABI Publishing, Cambridge.

Butler, R. (1996). The concept of carrying capacity for tourism destinations: Dead or merely buried? *Progress in Tourism and Hospitality Research*, *2*, 283–293.

Casagrandi, R., Rinaldi, S., & Mattei, F. E. E. (1997). *A theoretical approach to tourism sustainability*. Fondazione ENI Enrico Mattei.

Cessford, G. R., & Dingwall, P. R. (1999). *An approach to assessing the environmental impacts of tourism*. Conservation Advisory Science Notes No. 247, Department of Conservation, Wellington.

Choi, H. C., & Sirakaya, E. (2006). Sustainability indicators for managing community tourism. *Tourism management*, *27*(6), 1274-1289.

Ckeckland, P. (1981). *Systems thinking, systems practice*. Wiley, New York. (330 pp.)

Cole, D. (2004). Environmental impacts of ecotourism. In R. Buckley (Ed.), (chap. Impacts of Hiking and Camping on Soils and Vegetation: a Review). CABI Publishing, Cambridge.

Coyle, G. (2000). Qualitative and quantitative modelling in system dynamics: some research questions. *System Dynamics Review*(16), 225-244.

Dreborg, K. H. (1996). Essence of backcasting. *Futures*, *28*(9), 813-828.

Drexhage, J., & Murphy, D. (2010). *Sustainable development: from brundtland to rio 2012. background paper prepared for consideration by the high level panel on global sustainability at its first meeting 19 september 2010.* New York United Nations 2010 Sep.

Eagles, P. F., McCool, S. F., & Haynes, C. D. (2002). *Sustainable tourism in protected areas: Guidelines for planning and management*. IUCN - International Union for Conservation of Nature. Gland, Switzerland and Cambridge, UK.

EAI. (2015). *Environment agency iceland.* Retrieved 2015-02-04, from `http://ust.is/the-environment-agency-of-iceland/`

Espiner, S., & Becken, S. (2014). Tourist towns on the edge: Conceptualising vulnerability and resilience in a protected area tourism system. *Journal of Sustainable Tourism*, *22*(4), 646-665.

Ferraro, P., & Hanauer, M. (2014). Quantifying causal mechanisms to determine how protected areas affect poverty through changes in ecosystem services and

infrastructure. *Proceeding of the National Academy of Sciences of the United States of America*, *111*(11), 4332-4337.

Font, X., Flynn, P., Tribe, J., & Yale, K. (2001). Environmental management systems in outdoor recreation: a case study of a forest enterprise (uk) site. *Journal of Sustainable Tourism*, *9*(1), 44-60.

Group, B. C. (2013, September). *The future of tourism in iceland.* (Independent report by The Boston Consulting Group (BCG))

Guð mundsson, K. (2014). *Environmental microbial diversity and anthropogenic impact on lake þingvallavatn basin* (Unpublished master's thesis). University of Iceland.

Gunn, C. (n.d.). *Vacationscape: Designing tourist regions.* Van Nostrand Reinhold Company, New York. (Second Edition), year=1988)

Höjer, M., & Mattsson, L.-G. (2000). Determinism and backcasting in future studies. *Futures*, *32*(7), 613-634.

Holling, C. S. (2001). Understanding the Complexity of Economic, Ecological, and Social Systems. *Ecosystems*, *4*(5), 390-405.

Holmberg, J. (1998). Backcasting: A Natural Step in Operationalising Sustainable Development. *Greener Management International*(23), 30.

Holmberg, J., & Robèrt, K.-H. (2000). Backcasting - A framework for strategic planning. *International Journal of Sustainable Development & World Ecology*, *7*(4), 291-308.

Huber, C. (2014). *Visitor's satisfaction of recreational trail conditions in Þingvellir national park, Iceland* (Unpublished master's thesis). University of Iceland.

Hughey, K. F., Ward, J. C., Crawford, K. A., McConnell, L., Phillips, J. G., & Washbourne, R. (2004). A classification framework and management approach for the sustainable use of natural assets used for tourism. *International Journal of Tourism Research*, *6*(5), 349-363.

Icelandic Act no. 59. (1928). *Icelandic Act on Protection of Þingvellir [Lög um friðun Þingvalla] no.59/1928.*

Þingvellir National Park. (2015). Retrieved 2015-02-12, from `http://thingvellir.is/english`

Þingvellir National Park Management Plan 2004-2024. (2004). (Agreed by the Þingvellir Commission, June 2nd 2004)

ITB. (2014). *Icelandic tourism board. tourism in iceland in figures - april 2014.* Retrieved from `http://www.ferdamalastofa.is/en/recearch-and-statistics/tourism-in-iceland-in-figures` (Brochure published by the Icelandic Tourist Board (author: Oddný Þóra Óladóttir))

ITB. (2015). *Icelandic tourist board.* Retrieved 2015-02-04, from `http://www.ferdamalastofa.is/en`

IUCN. (1994). *International Union for Conservation of Nature. Guidelines for Protected Area Management Categories.* Cambridge,U.K., and Gland, Switzerland.

Jafari, J. (1977). 'editor's page'. *Annals of Tourism Research*, *5*(6), 6-11.

Jägerbrand, A. (2004). Patterns of species richness and vegetative performance in hetah ecosystems at þingvellir, southwest iceland. *Icelandic agricultural sciences*, *16-17*, 29-38.

Jóhannesdóttir, H. M. (2010). *Economic valuation of ecosystem services: The case of lake elliðavatn and lake vífilsstaðavatn* (Unpublished master's thesis). University of Iceland.

Jóhannesson, G. T., Huijbens, E. H., & Sharpley, R. (2010). Icelandic tourism: Past directions—future challenges. *Tourism Geographies*, *12*(2), 278-301.

Jónasson, P. (1992). The Ecosystem of Þingvallavatn: A Synthesis. *Oikos*, *64*(1/2), 405-434.

Lacitignola, D., Petrosillo, I., Cataldi, M., & Zurlini, G. (2007). Modelling socio-ecological tourism-based systems for sustainability. *Ecological Modelling*, *206*(1), 191-204.

Leung, Y.-F., & Marion, J. (2000, 23-27 May). Recreation impacts and managment in wilderness: A state-of-knowledge review. In D. Cole, S. McCool, W. Borrie, & J. O'loughlin (Eds.), *Wilderness science in a time of change conference* (Vol. 5). (Proceedings RMRS-P-15- VOL-5, 2000.)

Liao, Z., Jin, M., Ren, P., & Luo, Y. (2014). Research on scenic spot's sustainable development based on a sd model: A case study of the jiuzhai valley. *Sustainability*, *6*(7), 4632-4644.

Manning, R. E. (2002). How much is too much? carrying capacity of national parks and protected areas. In *Monitoring and management of visitor flows in recreational and protected areas. conference proceedings* (p. 306-313).

McCool, S. F., Clark, R. N., & Stankey, G. H. (2007). An assessment of frameworks useful for public land recreation planning. *General Technical Report-Pacific Northwest Research Station, USDA Forest Service*(PNW-GTR-705).

McCool, S. F., & Lime, D. W. (2001). Tourism carrying capacity: tempting fantasy or useful reality? *Journal of Sustainable Tourism*, *9*(5), 372-388.

Nature Conservation Act no. 44. (1999). *No. 44, 22 March 1999, Ministry for the Environment.*

Nelson, M. P. (1998). The great new wilderness debate. In J. Callicott & M. Nelson (Eds.), (p. 154-198). Athens: The University of Georgia Press.

Neto, F. (2003). A new approach to sustainable tourism development: Moving beyond environmental protection. In *Natural resources forum* (Vol. 27, p. 212-222).

Nieto, C. C. (1996). *Toward a holistic approach to the ideal of sustainability.* Digital Library and Archives of the Virginia Tech University Libraries.

NLSI. (2015). *National Land Survey of Iceland [Landmælingar Íslands].* Retrieved 2015-05-22, from `http://www.lmi.is/en/`

Nomination of the Þingvellir National Park for Inclusion in the World Heritage List. (2003). (Reykjavik: Þingvellir Þjóðgarður)

OECD. (2014). *Environmental performance reviews: Iceland 2014.* OECD Publishing. Retrieved from `http://dx.doi.org/10.1787/9789264214200-en`

Ólafsdóttir, R., & Haraldsson, H. (2015). A systemic approach to assessing the environmental impacts of tourism and the attractiveness of tourism destinations. *Tourism managment, submitted*.

Ólafsdóttir, R., & Runnström, M. (2009). A gis approach to evaluating ecological sensitivity for tourism development in fragile environments. a case study from se iceland. *Scandinavian Journal of Hospitality and Tourism*, *9*(1), 22-38.

Pierce, M. F. (1996). *People and tourism in fragile environments*. Chichester; New York: Wiley c 1996. (Published in Association with the Royal Geographical Society)

Pisano, U. (2012). *Resilience and sustainable development: Theory of resilience, systems thinking and adaptive governance.* (Quarterly Report 26, European Sustainable Development Network)

Randers, J. (1980). *Elements of the system dynamic method*. Productivity Press, Cambridge. (320 pp.)

Resilience thinking: sustaining ecosystems and people in a changing world. (2006). Island Press, Washington D.C.

Reynisdottir, M., Song, H., & Agrusa, J. (2008). Willingness to pay entrance fees to natural attractions: An icelandic case study. *Tourism Management*, *29*(6), 1076-1083.

Richardson, G. P., & Pugh, A. L. (1981). *Introduction to System Dynamics Modeling*. Pegasus Communications. (413 pp.)

Richardson, R. (1991). *Feedback thought in social science and systems theoryd*. Philadelphia: University of Pennsylvania Press.

Sæþórsdóttir, A. D., & Ólafsson, R. (2010). Nature tourism assessment in the Icelandic Master Plan for geothermal and hydropower development. Part I: rapid evaluation of nature tourism resources. *Journal of Heritage Tourism*, *5*(4), 311-331.

Saveriades, A. (2000). Establishing the social tourism carrying capacity for the tourist resorts of the east coast of the republic of cyprus. *Tourism Management*, *2*(21), 147-156.

Sonnette, L., Angelier, J., Villemin, T., & Bergerat, F. (2010). Faulting and fissuring in active oceanic rift: Surface expression, distribution and tectonic-volcanic interaction in the Þingvellir Fissure Swarm, Iceland. *Journal of Structural Geology*, *32*(4), 407-422.

Stankey, G., Cole, D., Lucas, R., Petersen, M., & Frissell, S. (1985). *The limits of acceptable change (lac) system for wilderness planning.* (Gen. Tech. Rep. INT-176. USDAFS, Ogden UT. 37pp.)

Statistics Iceland. (2015). Retrieved 2015-02-04, from `http://www.statice.is`

Sterman, J. D. (2000). *Business Dynamics Systems: Thinking and modeling for a complex world*. McGraw-Hill, New York. (982 pp.)

Sun, D., & Walsh, D. (1998). Review of studies on environmental impacts of recreation and tourism in Australia. *Journal of Environmental Management*, *53*(4), 323-338.

Sverdrup, H., & Svensson, M. G. (2005). Defining the concept of sustainability-

a matter of systems thinking and applied systems analysis. In *Systems approaches and their application* (p. 143-164).

Tourist Site Protection Fund. (2015). Retrieved 2015-02-04, from http://www.ferdamalastofa.is/en/quality-and-environment/the-tourist-site-protection-fund

UNEP. (2015a). *United nations environment programme: Impacts of tourism.* Retrieved 2015-02-27, from http://www.unep.org/resourceefficiency/Business/SectoralActivities/Tourism/FactsandFiguresaboutTourism/ImpactsofTourism/tabid/78774/Default.aspx

UNEP. (2015b). *United nations environment programme - tourism and environmental conservation.* Retrieved 2015-02-27, from http://www.unep.org/resourceefficiency/Home/Business/SectoralActivities/Tourism/WhyTourism/ImpactsofTourism/EnvironmentalImpacts/tabid/78775/Default.aspx

UNEP and UNWTO. (2005). *United nations environmental programme and world tourism organization. making tourism more sustainable - a guide for policy makers.*

UNESCO. (2015). *World Heritage List.* Retrieved 2015-05-22, from http://whc.unesco.org/en/list

UNWTO. (2015a). *World tourism organisation network.* Retrieved 2015-02-04, from http://www2.unwto.org/content/why-tourism

UNWTO. (2015b). *World tourism organisation network. over 1.1 billion tourists travelled abroad in 2014.* Retrieved 2015-02-04, from http://media.unwto.org/press-release/2015-01-27/over-11-billion-tourists-travelled-abroad-2014

UNWTO. (2015c). *World tourism organisation network. sustainable development of tourism.* Retrieved 2015-02-04, from http://sdt.unwto.org/content/about-us-5

Van Mai, T., & Bosch, O. (2010). Systems thinking approach as a unique tool for sustainable tourism development: a case study in the cat ba biosphere reserve of vietnam. In *Proceedings of the international society for the systems sciences* (p. 827-845).

Veal, L. (2008). New road will threaten the ecology of iceland's second largest lake. *NoticiasFinancieras.* (Newpaper article)

Walker, P. A., Greiner, R., McDonald, D., & Lyne, V. (1998). The tourism futures simulator: a systems thinking approach. *Environmental Modelling & Software*, *14*(1), 59-67.

Wamwara-Mbugua, L., & Kamau, E. (n.d.). *A systems dynamics view of tourism development in kenya.*

WCED. (1987). *World Commission on Environment and Development. Our Common Future.* Oxford: Oxford University Press.

Wolstenholme, E. F., & Coyle, R. G. (1983). The development of system dynamics as a methodology for system description and qualitative analysis. *Journal of the Operational Research Society*, 569-581.

World Bank. (2015). *International tourism, number of arrivals.* Retrieved 2015-05-18, from `http://data.worldbank.org/indicator/ST.INT.ARVLx`

Zelenka, J., & Jaroslav, K. (2014). The concept of carrying capacity in tourism. *Amfiteatru Economic*, *16*(36), 641–654.