Scenario analysis of Þingvellir national park in Iceland

Identification and assessment of possible impacts from 1.6 million visitors in 2025

Semester project

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"More than 2 million people coming to the park? Have you imagined what that will look like?" Author

"No, I don't want to" Einar Á. E. Sæmundsen interpretive manager of Þingvellir national park

Photo on title page by Einar Á. E. Sæmundsen

ABSTRACT

In this study possible impacts from 1.6 million annual visitors in Þingvellir national park in Iceland were identified and assessed. Three different scenarios were constructed as to compare different operating and management conditions in the park in 2025. Identification of impacts was performed by constructing three cause-effect relationship maps, one for each scenario, which presented a visual expression of where impacts originate and what their effects are. The cause-effect relationships were then graded qualitatively and the scenarios compared. Impacts resulting from the visitor increase were determined to be increased risk of eutrophication, decreased local air quality, overcrowding, decreased visitor safety, deterioration of original natural conditions and aesthetic pollution among others. The first scenario saw the park head into large scale deterioration, scenario two improved the conditions with increased infrastructure but neither were determined sustainable in the long term. Scenario three which presented an alternate view of the park's operations proved to be the only one with a promising future. A short quantitative assessment on NOx emission increase showed that it might contribute measureably to nitrogen inflow in to Lake Þingvallavatn via precipitation. Finally, a development path focusing on visitor management and protection of the lake was thus recommended to ensure a sustainable future for the park.

TABLE OF CONTENTS

Figures

Tables

INTRODUCTION

Iceland has in the recent decade gained more attention as an interesting international travel destination. In 2014 almost one million visitors came to Iceland while in 2004 they were roughly 360’000 (Icelandic Tourist Board, 2015). In 2015 the total number is expected to reach 1.3 million visitors which is roughly 4 times the Icelandic population. The majority of visitors arrive at Keflavík International Airport and from there they can reach the capital, Reykjavík, in 40 minutes by car. Reykjavík is situated in the South-West corner of Iceland and from there visitors can take day tours to many attractions with one of them being Þingvellir national park.

Iceland lies on the Mid-Atlantic Ridge where two tectonic plates are gliding apart. In Þingvellir national park, this gliding is evident as divergence has not been accompanied by significant volcanic activity for more than 100’000 years (Þingvellir national park, 2004). Thus, the rift valley is very visible and deep fissures in the surface can also be seen widely. Along with its distinctive natural features the park is also a place of unique cultural heritage and is recognized as a UNESCO World Heritage Site since 2004. Moreover, the Þingvellir area is protected by Icelandic law as a national shrine for all Icelanders and its features shall be preserved so that future generations can enjoy it the same way as people do today.

Since the park’s establishment in 1931, it has been open to everyone to enjoy, and no admission fee collected to this day. With the recent boost in tourism in Iceland, and proximity to the capital area, Þingvellir national park has been experiencing unprecedented annual visitor increase rates. In 2014, almost 570’000 visitors came to the park which was a 20% increase from the year before (Einar Á. E. Sæmundsen, oral communication, 2015). Analysts project that the tourism growth in Iceland will continue in the coming years but will decrease to a long term average growth of 8% in 2017 (Landsbankinn, 2015). To accommodate this possible growth, managers of natural visitor attractions in Iceland will have to plan ahead and assess how and if these attractions can welcome future tourists. Currently, 80% of foreign tourists state that Icelandic nature was an important factor in their decision to visit the country (Icelandic Tourist Board, 2014). If these natural attractions start deteriorating to a level where visitors find them not attractive any more, they will stop coming. Considering that over one third of the GDP growth since 2010 and one third of the nation's exports of goods and services resulted from tourism, the stakes are high (Íslandsbanki, 2015).

Þingvellir has many roles to play. A major tourist attraction, a national park, a national shrine, a UNESCO World Heritage Site. To be functional in all of these roles it needs to make a compromise between protection and utilization. When utilization has increased at a rate where protection can't keep up, the situation becomes unsustainable in the long term. Thus, an equilibrium between these two actions must be reached to ensure the sustainability of the park.

SCOPE AND OBJECTIVE

In a requirement analysis for the enlargement of the main visitor center in the national park, Hakið, a projection of future visitor numbers to the year 2025 was made using annual growth rates of 5%, 10% and 15%, counting from the year 2014. A comparsion of visitor numbers in 2025 using these growth rates can be seen in Table 1.

Table 1. Visitor numbers in 2025 using different growth rates

Annual growth rate	Visitor numbers in 2025
5%	974'002
10%	1'624'790
15%	2'649'439

The annual growth rate used in this scenario analysis is 10% as it is closest to the estimated long term tourism growth rate in Iceland, which is 8% according to analysts. Currently there are 570'000 people visiting Þingvellir national park annually, and they might be 1.6 million in 10 years. This possible reality raises many questions regarding what that will look like, how the park shall welcome all of these people, and if it is in fact possible without undesired consequences.

The objective of this study is thus to identify and assess qualitatively the possible impacts of 1.6 million visitors in Þingvellir national park in 2025 by comparing three possible scenarios of future development and park operations. Focus will be put on impacts that occur in the national park, especially in terms of the environment and visitor satisfaction. Specific economic and social impacts will be excluded from the analysis but will be mentioned if relevant. Furthermore, a recommended development path for the national park will be put forward based on the results of the scenario analysis.

BACKGROUND AND CURRENT SITUATION

Impacts of tourism

Environmental impacts related to tourism have been recognized for a long time. In 1872 Yellowstone national park in the USA was established with two main purposes, protection and preservation of natural features and to be "*a pleasuring ground for the benefit and enjoyment of the people*". With the establishment and the following attention that the area got, many started to visit but often with intentions that were contradictory to the park's objectives. Birds were shot, game was hunted, they fished excessively and destroyed thermal features in order to find the correct souvenirs (Rydell & Culpin, 2006). These impacts were obviously a result from individual actions and it was not until 70-80 years later that the mass tourism and it's related impacts that we know today came to being. With the introduction of commercial and affordable air travel in the 1950's and 1960's, tourism established itself as a new industry in many areas, bringing increased tax and GDP revenue, employment and foreign exchange. However, tourism had at this time already earned itself a bad image due to thoughtless development, disrupting local values and culture. Environmental concerns accompanied this development of tourism as utilization of the environment was a big part of tourism in many areas (Ceballos-Lascuráin, 1996). Today, enjoyment and utilization of the environment is an ever bigger part of tourism as demand for nature tourism increases worldwide (Sæþórsdóttir, 2014).

According to the United Nations Environment Programme, three main impact categories can be related to tourism, environmental impacts, socio-cultural impacts and economic impacts, which all can be positive and negative. They further say that "*negative impacts from tourism occur when the level of visitor use is greater than the environment's ability to cope with this use within the acceptable limits of change*" (UNEP, 2015). Glenn Kreag (2001) added four mour impact categories to the ones defined by UNEP, namely crowding and congestion, services, taxes and community.

To conclude this background chapter, a theory from R. W. Butler (1980) will be presented which in the author's opinion is very relevant to Þingvellir. Butler said that when places become more popular and attract more visitors, they move closer to a limit, their carrying capacity, which can be defined in terms of environmental, social or physical plant factors. When this limit is reached, these places start deteriorating as their natural attraction has faded resulting in decreasing visitor satisfaction and visitor numbers start dropping.

Þingvellir in 2015

Infrastructure and forms of visitation

Þingvellir national park covers an area of 237 km^2 but only few places within the park bear the visitor load. The Old Parliament Site which is the most visited place in the park covers for example only five hectares. The visitors that arrive in Þingvellir mainly arrive by motor vehicles, from small rental cars to large buses and super jeeps. The most common form of visitation is to arrive at the visitor center, Hakið, where there are some 90 parking spots and separate parking lanes for buses. Along with the visitor center, there are lavatory facilities and a panoramic platform at this location. From there a path leads down in to the main fissure, Almannagjá, which is where the Old Parliament Site is located. Most visitors arriving with tour operators only do a short stop as they often continue to other attractions afterwards. Other visitors, both foreign and local, which come by themselves stop for a period of 1-3 hours or even stop overnight. This type of visiting, where people come by rental cars, has been increasing much faster than the organized tour type. Diving has also been increasing in popularity in recent years and locals come regularly from April to August to fish in the lake. An overview of Þingvellir national park can be seen below and an enlarged view of Hakið and the Old Parliament Site on the next page.

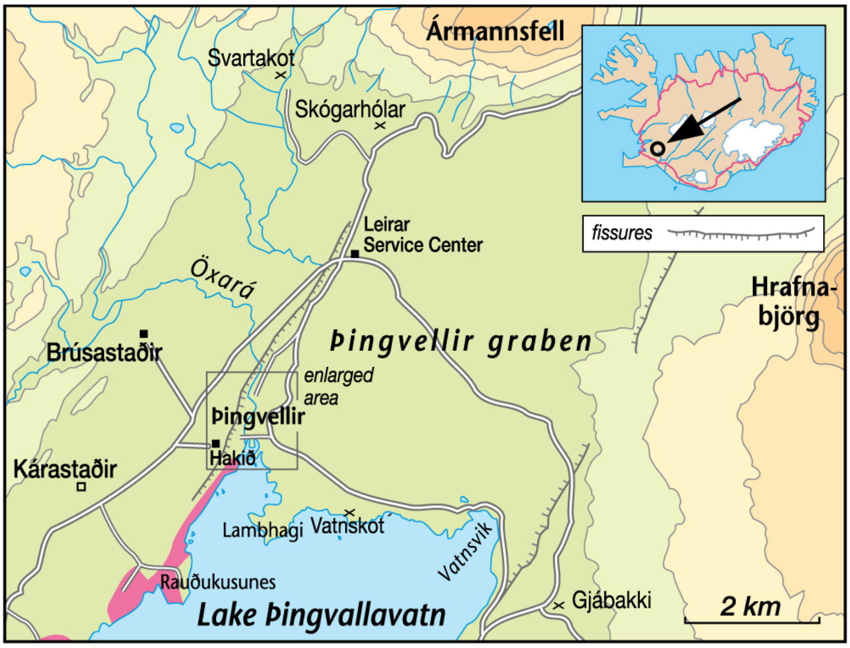

Figure 1. Overview of the part of Þingvellir national park under study

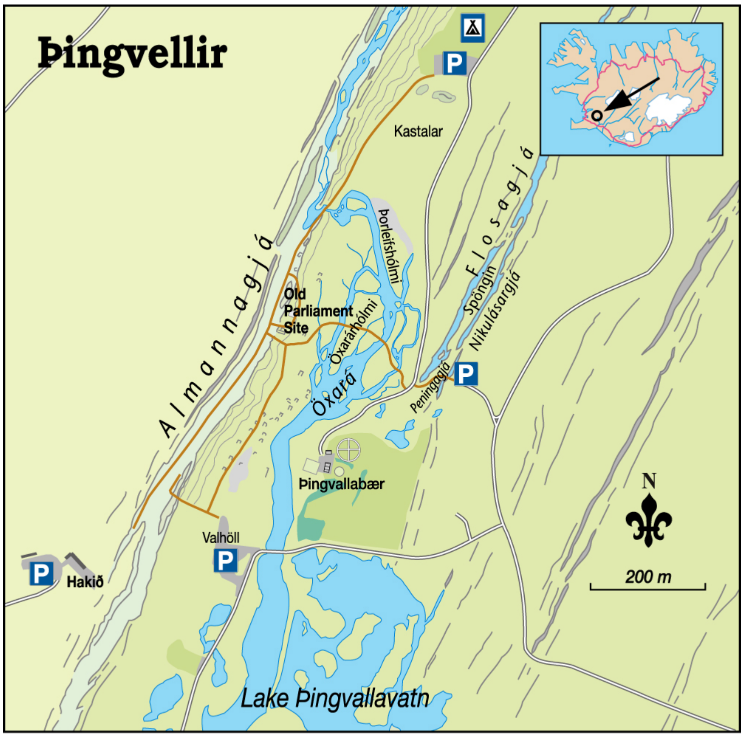

Figure 2. Enlarged view of Hakið and the Old Parliment Site

Along with the visitor center at Hakið, the park also operates a service center at Leirar (approximately 3 km from Hakið), two camping sites, four parking areas in proximity of the Old Parliament Site and other parking areas accounting for an approximate number of 350-400 parking spaces in the park (Þingvellir national park, 2004). According to Einar Á. E. Sæmundsen, interpretive manager of the park, the staff have seen up to 250 cars parked simultaneously in the vicinity of the Old Parliament Site, using every possible parking spot in those areas. At Hakið, cars regularly park on the edge of the access road as can be seen in the figure below.

Figure 3. Cars parking on the access road to Hakið (Sæmundsen, 2015)

Environmental conditions and visitor experience

Park authorities have already realized problems arising with increasing number of visitors, one being the increased off-path traffic causing vegetation trampling. Á. Elmarsdóttir and L. Ásbjörnsdóttir from the Icelandic Institute of Natural History conducted an assessment in 2014 on the impacts of visitors on natural conditions in the park. Their main conclusions were that groups of visitors had more impacts on vegetation than visitors travelling on their own, damage to sensitive vegetation like moss was evident in many places and ways to prevent off-path traffic are not sufficient when many people are present.

Another problem that has been identified is wastewater treatment at Hakið. There the park operates septic tanks with secondary treatment but diurnal load variations and temperature conditions in colder months result in non-optimal treatment. Currently, the capacity of the septic tanks is insufficient and the tanks are emptied weakly and the sludge transported to a wastewater treatment plant in Reykjavík. As these septic tanks are not capable of removing nitrogen from the wastewater, it can make its way via groundwater to Lake Þingvallavatn and contribute to eutrophic conditions as the lake is nitrogen limited (Dr. Hrund. Ó. Andradóttir, personal communication, 2015).

In 2014 Anna Dóra Sæþórsdóttir did a study on visitor experience in several popular tourist attractions in Southern and Western Iceland. Þingvellir was one of those places and according to her results, 90% of visitors were either happy or very happy with their visit to Þingvellir, 20% said they thought too many tourists were at Þingvellir and 12% said that other tourists affected their experience in a negative way. Also, visitors who expected more tourists at Þingvellir were as many as those who expected less. This gives an indication that Þingvellir is still a strong attraction to tourists and has not yet reached a limit to where decreased visitor satisfaction has become a significant issue.

Strategic documents

Þingvellir national park made a 20 year management plan in 2004 which was meant to serve as a guiding document on how to accomplish the objectives of the park which are stated by Icelandic law nr. 47/2004 and by ordinance nr. 848/2005. The intention of the ordinance is "*to promote the preservation of the Þingvellir national park, a protected shrine of the Icelandic nation, the protection of its nature, biosphere and historical heritage with the goal to preserve its appearance and maintain original natural conditions*" (Alþingi, 2005, author's translation). Criteria set forward in the management plan to assess whether the operation of the park are in accordance with laws and ordinances are two and are presented as questions. The first one asks: "*Has the special value of the national park been successfully safeguarded, so that the potential for equivalent use has been ensured for the future?*" and the second one asks: "*Have visitors to the national park had the opportunity to enjoy its unique character and learn about it, in an accessible manner?*" These criteria will be used as reference when assessing the impacts later.

The second strategic document in use is the environmental policy of the national park which was formulated in 2008. It is meant to ensure that the internal operations within the park area are in accordance with the management plan and to ensure respectful conduct of the environment. The policy takes into account the nature and extent of the operations within the park and possible environmental impacts which might occur. It focuses mainly on daily operations and material flows going in and out of the park with the aim that it be used systematically in decision making and administration of the national park.

METHODS

Assumptions on visitor numbers and distribution

As previously stated, it is assumed that 1.6 million people will visit the park in 2025. Currently the ratio between foreign and local visitors is 80% foreign and 20% local (Einar Á. E. Sæmundsen, oral communication, 2015). It is assumed that this difference will increase and that 90% of visitors in 2025 will be foreign. Current distribution of visitors in Þingvellir by season in 2013 was as follows: 51% in Summer, 21% in Autumn, 11% in Winter and 17% in Spring (Guðmundsson, 2014). This distribution is not expected to change in 2025. Assuming roughly 1.6 million visitors annually and that 51% of them come during Summer (June-August), that means that 828'600 people will visit the park during these three months. A daily average visitation rate over this 90 day period is 9'200 people. The same calculations were made for the other seasons. To estimate the maximum daily visitation rate, data from 2010 showing daily visitor load at Hakið in July was used. It showed that the maximum daily visitation rate was in the range of 27%-31% higher than the average. In this study 30% will be used for all seasons. A summary of these assumptions can be seen in Table 2.

Table 2. Visitor number assumptions and distributions

Variables		2014	2025
% Foreign visitors		80%	90%
% Local visitors		20%	10%
% Summer visitors		51%	51%
% Autumn visitors		16%	16%
% Winter visitors		11%	11%
% Spring visitors		17%	17%
Summer visitors	Daily av.	3'230 pers.	9'200 pers.
	Daily max	4'200 pers.	**11'960 pers.**
Autumn visitors	Daily av.	900 pers.	1'470 pers.
	Daily max.	1'170 pers.	1'910 pers.
Winter visitors	Daily av.	700 pers.	1'010 pers.
	Daily max.	910 pers.	1'310 pers.
Spring visitors	Daily av.	1'080 pers.	1'560 pers.
	Daily max.	1'400 pers.	2'030 pers.
Annual nr. of visitors		570'000 pers.	**1'624'790 pers.**

Scenarios

To identify the possible impacts of 1.6 million tourists in Þingvellir, three possible scenarios were constructed and compared. To construct the three scenarios in a comparitive way, parameters that describe the situation of the park today were used. In addition, actions taken in multiple national parks in the USA were added as well as the author's ideas. Values and/or descriptions of the parameters were then chosen so to make three different scenarios, one worst case scenario, one "business as usual" and one extreme case.

Scenario 1 – worst case

With increasing number of visitors coming to the park, the capacity of park infrastructure does not keep up. The same visitation routine is used, parking spaces, lavatory facilities and paths do not meet demand. Same limitation technique used to prevent visitors from stepping out of designated paths, with signs and rope crossings. No limitation of visitors to the park, monitoring of visitor behaviour within the park is minimal and no entrance fees are collected.

Scenario 2 – business as usual

All necessary infrastructure to accommodate maximum visitor intensity has been ensured. Entrance fees have been collected to finance the improvement of infrastructure. No limitation of number of visitors in the park and minimal monitoring of visitor behaviour within the park. Paths under the most load have been rebuilt and widened to the extent possible. Where previously visitors had to step out of designated raised or non-raised pathways because of crowding, it is no more necessary and elsewhere it is difficult to step off path. Visitor load is not spread more than it is today and same visitation routines are used.

Scenario 3 – management of visitors and limitations

In this scenario a completely different operation reality is set forward for the national park. The park's goal is to be able to welcome all of these 1.6 million annual visitors but restricting completely off path access and limiting vehicle traffic in the park. To accomplish this the park has increased all infrastructure at Hakið which will continue to be the main access point and visitor and service center. More panoramic platforms have been built to provide the known scenic experience from that location. Lavatory facilities have been added and to minimize nitrogen pollution from wastewater, urine is collected separately and used as fertilizer. Diurnal variations in wastewater load have been reduced significantly by adding a load regulating chamber for wastewater before it enters the septic tanks. Also, a factor reducing the diurnal load is cooperation with the main travel agencies to arrive with groups at given intervals instead of everyone coming in the morning and afternoon like today, creating peak loads. Waste separation bins are situated at Hakið and all visitors are required to separate their waste before continuing their trip to the Old Parliament Site. They are also educated on benefits of efficient waste separation and recycling and the effects of littering. Those who are busted littering will be fined.

Before heading down to the main fissure to the Old Parliament Site, visitors can choose from multiple different routes to take. Some routes end up at the former parking lots at Kastali and Flosagjá and others lead again to Hakið. These routes are one direction lanes i.e. once a visitor starts a route, he must follow it, he can not walk the same way back. On the way, there will be emergency exits and junctions where there is a possiblity to change routes. For safety and conservation reasons a real time monitoring system has been set up to account for the number of tourists in the Old Parliament Site. Visitors will receive a small token with a GPS location device which shows the visitor's real time position and alerts park staff if visitors wander away from designated routes. These tokens are to be returned before visitors leave the park.

For visitors that arrive in groups at Hakið and continue their journey further after visiting the park, they have two options. Either to visit the panoramic view and enter the group vehicle again or take a route down to the Old Parliament Site and end at Kastali or Flosagjá. From there a shuttle system operated by the park transports visitors, if willing, to the service center at Leirar (ca. 2 km away).

At Leirar the park has built the second main parking lot. There, group vehicles pick up visitors that have walked from Hakið to Kastali or Flosagjá. Visitors travelling on their own are prohibited to drive their vehicles closer to the lake than Leirar except if they intend to camp, for which they must have made a reservation in time. If visitors want to go closer they can travel with the shuttle buses, which is what divers would have to do. Fishermen are allowed to drive their vehicles to the lake. Fees for travelling with the shuttle system are included in the entrance fee to the park.

To distribute load and minimize stress on the Old Parliment Site, a panoramic platform has been built on the other side of the graben, opposite from Hakið at an area called Gjábakki (ca. 5 km away). No parking spaces are there but the shuttle system transports visitors back and forth from that location. To inform visitors of situation on paths within the Old Parliament Site, a real time digital information screen will be presenting the relevant information and advice, such as number of visitors, recommendation of alternate places to visit within the park etc. The parameters of each scenario can be seen in the table below.

Table 3. Parameters defining the scenarios

Parameter	Sc. 1	Sc. 2	Sc. 3
Capacity of walking paths	Insufficient	Sufficient	Sufficient
Capacity of parking lots	Insufficient	Sufficient	Sufficient
Most common form of visitation	Same as today	Same as today	Same as today with new routines
Capacity of lav. facilities & sewage treatment	Insufficient	Sufficient	Sufficient
Off-path access limitation	Same as today	Waist high fences	Waist high fences
Limitation of traffic in park	None	None	Yes
Limitation of nr. of visitors in the park	None	None	None
Monitoring of visitor behaviour	None	None	Yes
Real time accounting of visitors in park	None	None	Yes
Park shuttle system	None	None	Yes
Reservation system for camping	None	None	Yes
Location of parking lots	Same as today	Same as today	Hakið and Leirar
Design of path network	Same as today	Same as today	Same with new one direction routes
Entrance fees	None	Yes	Yes

External experts

Questionnaires were prepared and sent out to experts in the field of tourism research, environmental engineering, transportation engineering and geology/biology to acquire their answers and opinions on main factors relevant to include in this scenario analysis. The national park's interpretive manager Einar Á. E. Sæmundsen provided assisstance with his local expertise and knowledge of the day to day park operations. Interviews with him were conducted in a meeting in Iceland in early September 2015 and via Skype during the course of the project.

Identification and assessment of impacts

Identification of possible impacts in each scenario was performed by looking at the concept "Increased tourism in Þingvellir" and establishing cause-effect relationships based on the scenario parameters until impacts were identified. To establish the cause-effect relationships the theory of concept mapping was used as reference. There, concepts are written down and linked together with lines and text describing their relation. The impacts were then linked to one or more final impact categories which were chosen to represent the total impacts. These categories can be seen below

Table 4. Impact categories

Visitor satisfaction
Lake water quality
Image of Þingvellir
Original natural conditions

Eventually these categories also have some cause-effect relationship as well, but for the purpose of this analysis these impact categories are assumed to be independent. This procedure led to three concept maps or cause-effect relationship maps like they will be called later, which provided a visual expression of where impacts originate and what their effects are. In the discussion, content in the blue boxes in the maps will be called concepts.

To assess the impacts in each scenario, the evaluation criterions from the management plan were used as reference along with information from experts and the author's own opinion. As some impacts had more than one source their cause-effect relationships were differentiated by relevance in the scenario maps. Each cause-effect relationship was expressed with a line with negative relationships being red, and positive being green. These relationships were then graded via Table 5.

Table 5. Cause-effect grading

Grade	Line weight & color	Interpretation
1	Thick – red	Very negative effect
2	Medium – red	Moderately negative effect
3	Thin – red	Fairly negative effect
4	Thin – green	Fairly positive effect
5	Medium – green	Moderately positive effect
6	Thick – green	Very positive effect

All impacts were then linked to the four main impact categories seen on the bottom of each map. To compare the scenarios the four categories were then put in a table which showed the aggregated grades for each category and for the scenarios as a whole. These aggregated grades were made to compare impact categories between scenarios and to compare the scenarios themselves. These aggregated grades have no scale and do not give any useful information. Impact categories within a scenario should not be compared using these aggregated results i.e. a lower aggregated grade in one impact category than another for a certain scnenario does not give an indication that the impacts on the former are worse than for the latter for that scenario. This kind of statement can not be made based on this analysis.

To facilitate the interpretation and understanding of the cause-effect relationship maps in the next section, a guide on how to read them can be seen in Appendix. This guide also describes shortly how the aggregated grades were found.

RESULTS

Impact identification and assessment

Scenario 1 – worst case

The first scenario, which was supposed to present a worst case scenario sees the park head in to a situation which would put the laws and ordinances that protect the park to the test. Impacts from insufficient wastewater treatment are of concern as the ecology of Lake Þingvallavatn is very sensitive to increased nutrient levels and other contaminants as previously stated. The increased NOx emissions from vehicles also contribute to increased nutrient levels as well as decreased air quality because of emissions of carbon monoxide and particle matter. Permanent damage to vegetation from off path traffic and consequent soil erosion significantly alters the original appearance of the park, which is meant to preserve by law. The increased number of vehicles which are not accomodated with more parking lots results in an increased risk of collision with pedestrians when visitors park their cars on access roads and walk to the attractions. Vehicle collisions also become more common with increased risk of spilling of oil and chemicals which can leach into the porous geographical layers in the park and make their way via groundwater to the lake.

Visitor satisfaction is low with frequent overcrowding, chaos at parking lots and visitors performing open defecation because of lack of lavatory facilities. Aesthetic pollution because of overfilled parking lots, parking on access roads and littering also negatively affect visitor satisfaction. Visitors start wandering away from crowded areas creating unplanned routes and risking injury in an unpredictable landscape. In the end the image and reputation of Þingvellir national park collapses with negative consequences for the Icelandic tourism industry. The cause-effect relationship map for scenario two can be seen in Figure 4 on the next page.

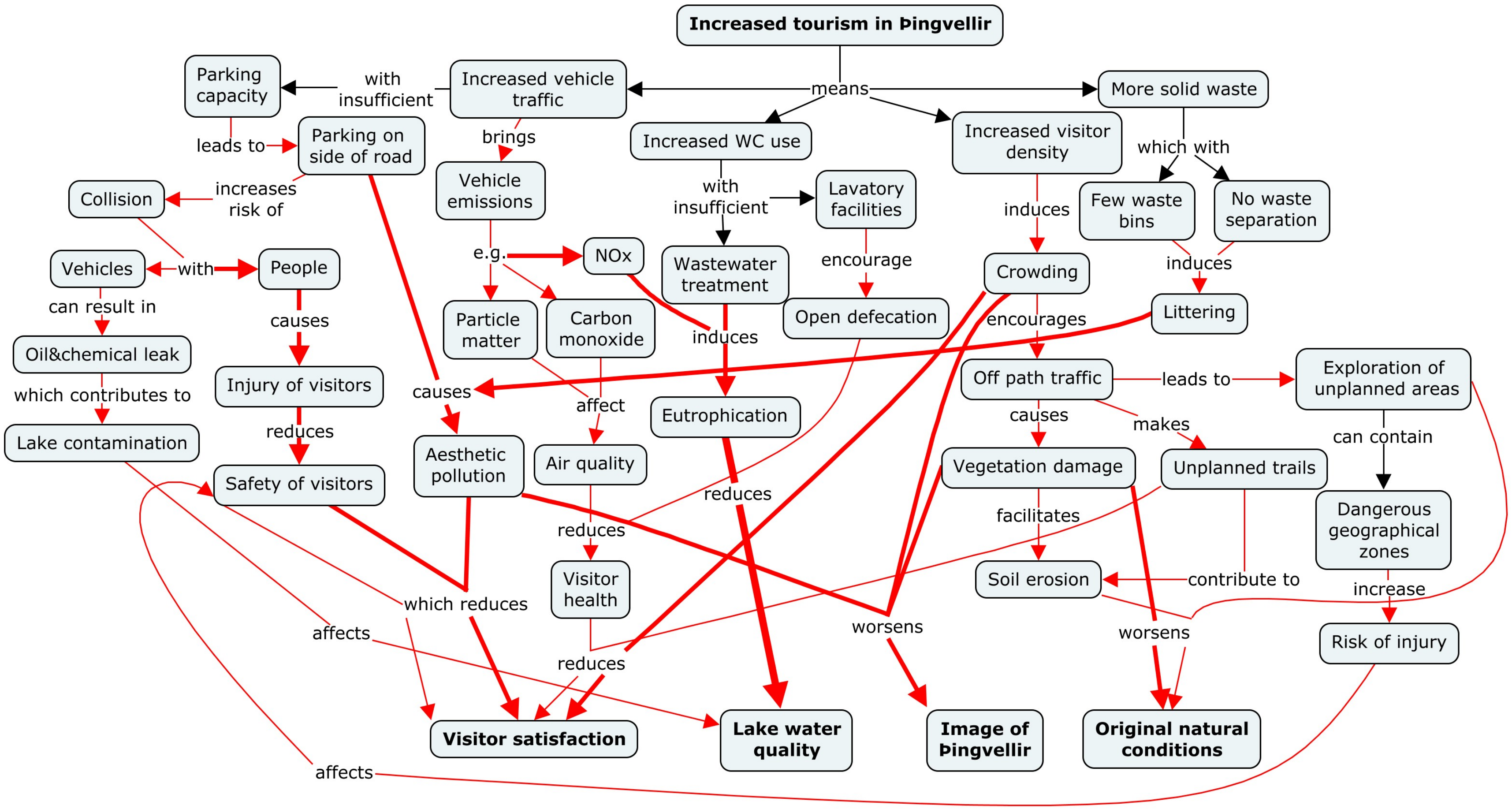

Figure 4. Cause-effect relationship map for scenario one

Scenario 2 – business as usual

In the second scenario infrastructure has been improved at the same rate as usual. More lavatory facilities have been built, visitor center and parking lots expanded, paths improved and more efficient fences set up to limit off path traffic. However, the area is still frequently overcrowded as visitor management is minimal. Entrance fees have been implemented, but revenue is mainly going into maintenance of infrastructure and not increased management. The risk of eutrophication in the lake is large as increase of lavatory facilities has not been accommodated with improved wastewater treatment. NOx emissions from vehicles continue to contribute to eutrophication in the lake and other emissions cause odours and affect air quality at main attractions.

Risk of vegetation damage has been decreased with limitation techniques and paths with higher capacity. These improvements have contributed to increased visitor safety by keeping them within places in the park which are planned for visitors and not wandering off and exploring other areas. Visitor safety has also been increased with the enlarged parking lots, thus preventing need for parking on access roads. However, the location of the parking lots, especially those below Hakið increasingly reduce the chance of a natural view of the graben as they are most often filled with vehicles. Littering is a problem as no waste separation has been implemented and waste bins are too few and frequently overfilled.

A part from the benefits of the new and improved infrastructure the original appearance of the park has further changed from what it is today. The unique character of Þingvellir is under great stress, general visitor satisfaction has decreased from what it is today and a status quo in management and operations will only further reduce the value and image of the national park. The cause-effect relationship map for scenario two can be seen in Figure 5 on the next page.

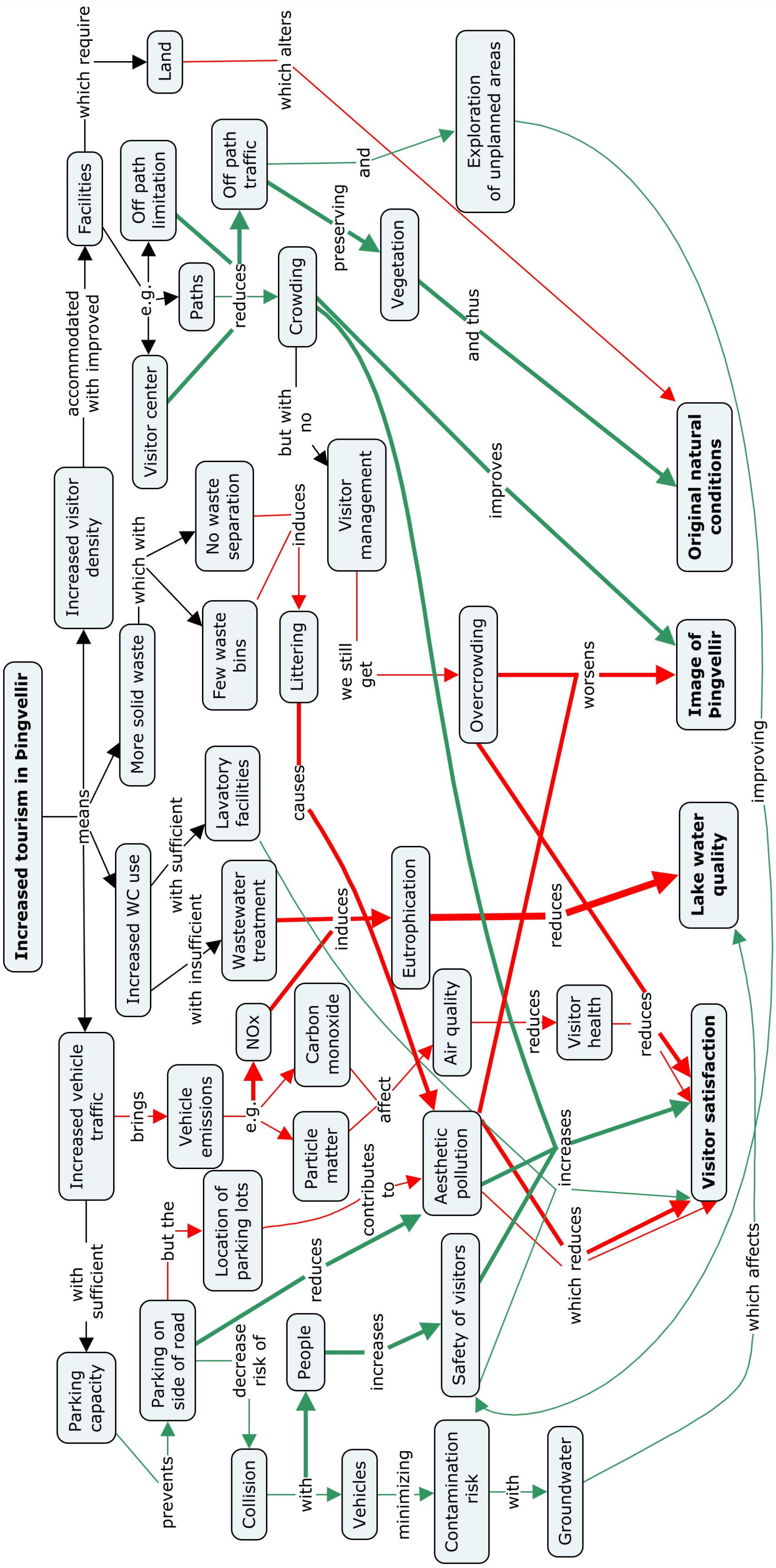

Figure 5. Cause-effect relationship map for scenario two

Scenario 3 – management of visitors and limitations

In the third and last scenario infrastructure has been increased with accompanying changes of natural appearance. New strategies have resulted in a better flow of visitors through the most visited sites at the park. The two main parking areas are well organized with separate lanes for pedestrians and vehicles which facilitate the coming and going of visitors. Improved lavatory facilities and wastewater treatment solutions have minimized nitrogen and other contaminants in the effluent, leaving the only risk of eutrophication from tourism activities being vehicle emissions. Risk of crowding has significantly decreased with new panoramic platforms, one-direction paths and spreaded load of visitor groups throughout the day via cooperation with group operators.

Education about environmental awareness and the possible impacts from visitors, with improved infrastructure has decreased off path traffic, littering and other spoiling behaviour from visitors. Limiting vehicle traffic in the Þingvellir graben has introduced a more natural view and brought back a sense of tranquillity to the area, increasing visitor experience. The shuttle system, operated with electrically driven shuttles, has also contributed to a quieter environment in the graben, increasing local air quality and providing safe transportation of visitors to the service center at Leirar. To those who wanted only to get a panoramic view of the park have now the opportunity to travel with the shuttles to the Gjábakki platform, enjoy the view, and walk a designated hiking trail through the low forested graben back to the service center. This option has decreased the stress on Hakið and widened the activity range of the park.

The situation in the park is adequate to say the least, visitor satisfaction is high and the natural and cultural features of the park are effectively protected and preserved. The management activities within the park have encouraged the national tourism industry to apply better management as the results are very good. The image and reputation of Þingvellir as a national park and a UNESCO World Heritage Site has significantly increased and the park is now an example of excellent management and operations. The cause-effect relationship map for scenario three can be seen in Figure 6 on the next page.

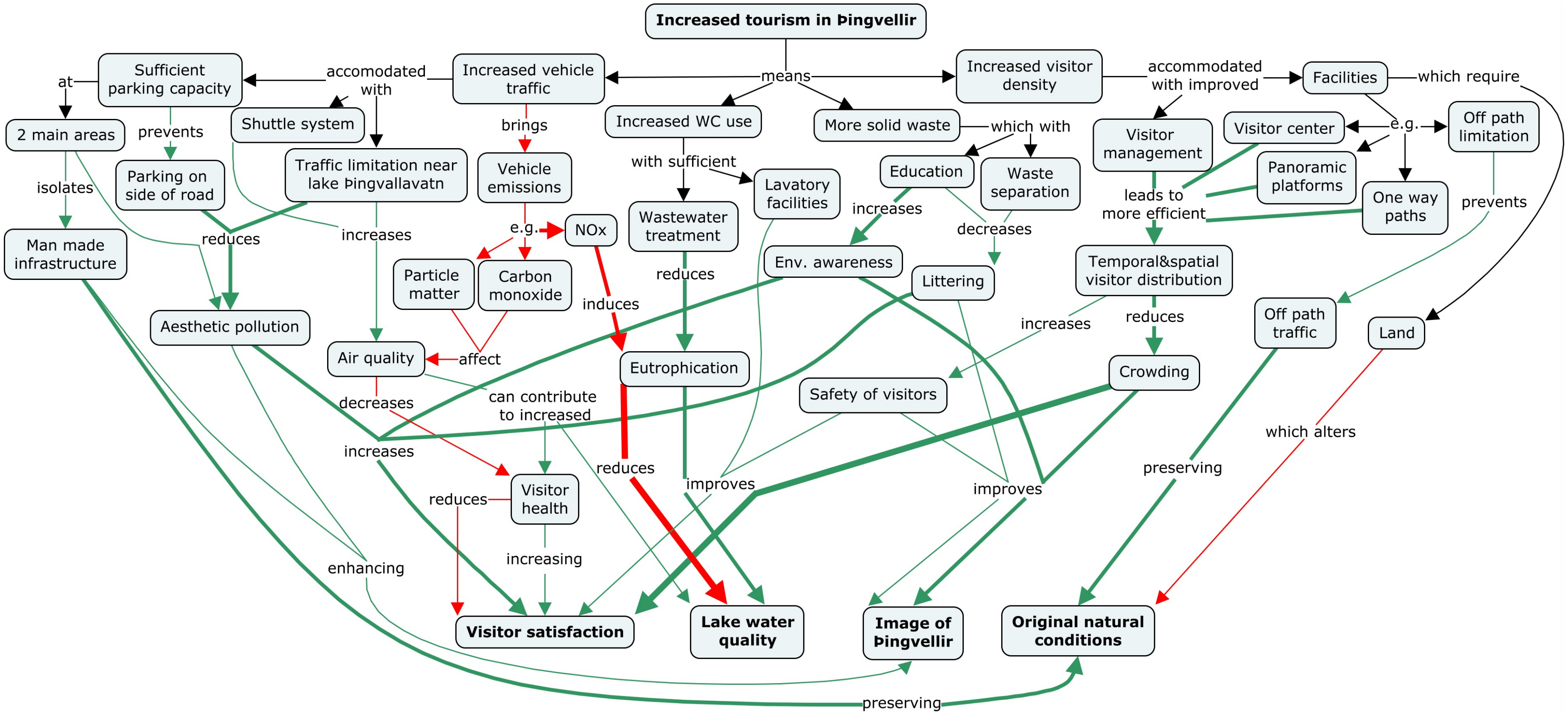

Figure 6. Cause-effect relationship map for scenario three

Scenario comparison

The situation in Þingvellir national park in 2025 is quite different between the three scenarios. From visual inspection of the maps all scenarios had in common that increases in NOx affected the lake water quality in a negative way and air quality was reduced because of increased particle matter and carbon monoxide emissions. Scenario one was the only scenario which had only negative impacts with insufficient wastewater treatment, crowding, littering, unorganized parking, vegetation damage and more contributing significantly to the deterioration of the park. Scenario two obviously brought improvements compared to scenario one, but critical factors such as wastewater effluent, littering and crowding were still present. In scenario three, the only negative impacts additional to the ones from vehicle emissions were on original natural conditions because of increased infrastructure.

To compare the scenarios further the grades in three cause-effect relationship maps were used. For each impact category the grades of the cause-effect relationship lines leading to an impact category were summed up. If grades of the lines changed between concepts before connecting to the impact category, the grade of the line which connected to the category was used. These grades were given according to the table presented in the methods chapter. The aggregated grades for each category in each scenario were compared in Table 6.

According to the aggregated grades scenarios one and two are relatively similar in terms of impacts on lake water quality, original natural conditions and image of Þingvellir. Scenario two however proves to be much better than scenario one in terms of visitor satisfaction and it is in that category very similar to scenario three. As expected, scenario three is better in all categories than the other two scenarios, especially in terms of the image of Þingvellir and lake water quality. When looking at the aggregated grades for each scenario we can see that there is a significant and similar difference between scenario two and the other two scenarios. This give an indication that the three scenarios where adequately constructed so to get a noticeable difference in impacts.

Table 6. Scenario comparison using aggregated grades

Impact category	Scenario 1	Scenario 2	Scenario 3
Visitor satisfaction	15	33	36
Lake water quality	4	5	10
Image of Þingvellir	6	9	22
Original natural conditions	8	8	13
Total	**33**	**55**	**81**

Discussion

The decision to assess all cause-effect relationships qualitatively and not quantitatively was taken based on two main factors. Firstly, some relationships like the ones affecting visitor satisfaction could only be assessed qualitatively. Secondly, for some relationships a quantitative assessment would have needed modelling and data gathering which would likely have been sufficient for another project thesis. Some simplifications could have been performed to do a quantitative assessment but then it is not even clear if a quantitative assessment would provide better results than the qualitative one for many relationships. For others, such as effects of NOx emissions and wastewater on eutrophication, and impacts of particle matter and carbon monoxide on air quality, a quantitative assessment would have fitted better than a qualitative one. After some research, it became clear that a coarse quantitative assessment on NOx increase from vehicles could be performed and it's results can be seen in the following chapter.

The qualitative grading scheme implemented in this comparison does not provide a unique result as was known beforehand. Differentiating between positive or negative effects was quite straight forward, but the relevance of the effects was often difficult to determine when confronted with the question "is this impact worse than the other?". To skip the grading scheme and show ungraded cause-effect relationship lines would also have been possible. However, the information acquired from experts and the management plan gave in the author's opinion a sufficient basis to perform a logical grading. This then allowed for a numerical comparison of the impact categories and the scenarios which provided a short and clear summary of the results from the three cause-effect relationship maps. Presenting the cause-effect relationship maps ungraded to a group of stakeholders and experts and asking them to grade each relationship would definitely result in different individual scores than here, but the final result would in the author's opinion not change.

With the comparison of total grades we can finally establish a preference order of the scenarios, with scenario one being the least preferable, scenario two being a better choice and scenario three the scenario the one to strive for. As the description of scenario three in the Methods chapter on page 9 was a blend of the author's brainstorming and ideas from the national park the scenario might not be a realistic one in every sense. Even so, based on the analysis performed in this study a similar scenario with focus on visitor management and protection of the lake will be the most likely one to ensure a sustainable future for the park.

Quantitative assessment of NOx emission increase

In addition to the qualitative assessment described before, a short quantitative assessment of the increase in NOx (nitrogen oxides) emissions from vehicles was performed to get a glimpse of the magnitude of one environmental impact which is common for all scenarios. A detailed description of the assumptions and estimates used to calculate the emission increase can be seen in Appendix.

Based on them the increase of NOx emissions from vehicles used to transport roughly 1 million more visitors to Þingvellir than today was found to be 1.31 tonnes. According to OECD statistics the total NOx emissions from mobile sources in Iceland was 16'770 tonnes in 2012. Thus, this increase of vehicle NOx emissions has an insignificant effect on the total NOx emissions from mobile sources nationwide. However, the assessment was made to estimate the amount of nitrogen which ends up in Lake Þingvallavatn. That is why the vehicles were only assumed to drive a certain distance in proximity of the lake and not a round trip from Reykjavík which is the most typical routine.

The total annual inflow of nitrogen into Lake Þingvallavatn is estimated 320 tonnes, of which 19 tonnes are precipitation onto the lake. Of these 19 tonnes, an estimated 8 tonnes are long-distance transboundary emissions, which means that 11 tonnes are locally produced (Jónsson, 2015). The total amount of nitrogen in the increased NOx emissions is in the range of 0,40-0,61 tonnes depending on the composition of the nitrogen oxides (NO or NO_2). If only 10% of these emissions reach the lake and deposit there, that would increase the total inflow of local nitrogen via precipitation by 0,36%-0,55%. Table 7 summarizes the numbers presented above.

Table 7. NOx increase compared to relevant nitrogen flows

Parameters	Values
NOx increase from vehicles in Þingvellir [t NOx]	1.31
Iceland NOx emissions from mobile sources in 2012 [t NOx]	16'770
Est. annual N inflow in to lake Þingvallavatn [t N]	320
Of which is est. precipitation [t N]	19
From long-distance trans boundary sources [t N]	8
From local sources [t N]	11
Min nitrogen in NOx increase (all NO_2) [t N]	0.40
Max nitrogen in NOx increase (all NO) [t N]	0.61
% reaching lake	10%
min % local N precipitation increase	0.36%
max % local N precipitation increase	0.55%

This does not sound like a big increase, but the majority (89%) of the nitrogen inflow comes from rivers and springs which can be assumed to be relatively constant. So precipitation along with runoff from agriculture and sewage are the main variables which can cause increased nitrogen levels in the lake. As the lake is nitrogen limited, any increase in nitrogen in the lake will contribute to eutrophication which could have adverse effects on water clarity, water quality and the lake's ecosystem.

It should be noted that the values for NOx increase obtained in this assessment are likely underestimated by a factor of 5-10 as real life NOx emissions in many cases do not meet standards for NOx emissions. A study published by the International Council on Clean Transportation (ICCT) in 2014 showed that 27% of test vehicles emitted more than 10 times the amount of NOx stated in the EURO6 standard. 27% of vehicles emitted 5-10 times more NOx and 47% emitted up to 5 times more NOx than allowed (Franco, Sánchez, German, Mock, 2014). A more detailed assessment of the amount and effects of increased NOx emissions is thus recommended in order to prevent undesireable and possibly irreversible consequences to Lake Þingvallavatn.

CONCLUSION

This scenario analysis was performed with the intention to identify and assess possible impacts from 1.6 million visitors in 2025. In most literature which was reviewed, impacts from tourism were mainly addressed for places which were becoming tourist destinations, often in developing countries. Also, these impacts were often related to activities like safaris, cruise sailings, scuba diving etc., thus these impacts were often not relevant for the national park, which is already an established tourist destination in a developed country. Known environmental impacts from todays activities in the park were on Lake Þingvallavatn and on the local vegetation but a method to look at more factors was needed to gain a comprehensive understanding of the future situation. This was successfully done with the cause-effect relationship maps which were able to present different impacts from different sources and their often long cause-effect chains. The maps for each scenario are by no means complete and other impacts are surely yet to be identified and assessed e.g. the reaction of locals to this foreign visitor increase. Nevertheless they provide an example of what can be achieved through this kind of an analysis.

The qualitative assessment for the cause-effect relationships and impacts in the maps was performed using the information acquired and the author's opinions on which impacts were most relevant. By doing this assessment and representing it in the cause-effect relationship maps an important feature was added to assist in visual interpretation of impact relevance. Since no feedback came from the national park authorities on this assessment the grading only represents the values of one stakeholder, which is the author.

The results of this analysis show that there is much to lose and much to gain with increased tourism in Þingvellir and Iceland in general. In Þingvellir, better and more frequent monitoring of both environment and visitor experience are essential to have the time to act when things seem to be heading in the wrong direction. Visitor surveys like those that have been performed in the past in Þingvellir are an essential tool to assess visitor experience and satisfaction. In a growth phase like the one expected, these surveys will however need to be performed more frequently. Better monitoring of effluent from wastewater treatment, as well as NOx monitoring would then significantly improve the understanding of how much nitrogen is going to the lake and causing euthrophication.

To conclude, it is clear that with insufficient planning and management, many tourist attractions in Iceland might well lose their value with severe consequences for Icelandic nature, society and economy. Looking to the future is a key element in sustaining a powerful tourism industry in Iceland while protecting and preserving it's foundation, Icelandic nature. The approach used in this scenario analysis has in the author's opinion a potential to become a useful tool in this process and can help prevent the realization of the quote from D.E. Hawkins which says: "*Tourism is a goose that not only lays a golden egg, but also fouls its own nest*".

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APPENDIX

A guide to the cause-effect relationship maps and aggregated grades

All three scenario maps start with the statement "Increased tourism in Þingvellir" as seen in the maps which then leads to four effects with a text in between describing their relation, here we call it relation text. From each of these effects which can be now thought as causes, other effects occur and so forth. Black lines which connect concepts describe connections which have no negative or positive meaning, they are just intermediate lines which connect concepts. As soon as the effects start to be positive or negative, the lines change to green or red. At some point some lines also start to increase in line weight which means their relevance increases. When two or more lines with the same line color and weight connect to the same concept or relation text they are combined and leave as one line. This was done so to reduce the the number of lines criss crossing. When two or more lines with different line color and line weight enter a concept, they leave the concept or relation text separately.

When finding the aggregated grades the lines connecting to the final effect categories were followed back to the last previous concept. That enabled a clear view of how many concepts were contributing to the final effects. Using Table 5 the line color and weight was transferred to a value between one and six and then these values were aggregated to reach the final values in Table 6.

Assumptions and calculations for NOx assessment

First, a differentiation between foreign and local visitor increase was determined because their means of travel are different (Guðmundsson, 2014). Two types of vehicles are considered here, a five person passenger car and a bus with a carrying capacity of at least 25 passengers. Out of all gasoline or diesel driven passenger vehicles in Iceland in 2014, 75% are gasoline driven and 25% diesel driven (Icelandic Traffic Authority, 2015). It is assumed that all buses are diesel driven. Amount of passenger in passenger vehicels are assumed to be 2,5 for foreign visitors and 3,5 for local visitors. For both foreign and local visitors travelling by bus, a number of 25 passenger in each bus is assumed. To estimate the NOx emissions from passenger cars the European exhaust emission standard EURO4 (EC2005) was used. For buses, the diesel limit of passenger cars from EURO4 was doubled. These vehicles are assumed to drive a total of 30 km within a 15 km radius of Lake Þingvallavatn. The calculations were performed in excel using the values in the table below (pax=passengers, pc=passenger car).

Table 8. Calculations for NOx emissions increase

	Foreign	**Local**
Increase of visitors	1'006'311	48'479
% travel by passenger car	75%	92%
% travel by bus	25%	8%
Average pax in pc	2.5	3.5
Average pax in bus	25	25
Increase of pc	301'893	12'743
Of which gasoline	226'420	9'557
Of which diesel	75'473	3'186
Increase of buses	10'063	155
Of which diesel	10'063	155
PC NOx gasoline [g/km]	0.08	0.08
PC NOx diesel [g/km]	0.25	0.25
Bus NOx emission [g/km]	0.5	0.5
Kilometers driven	30	30
NOx emission [t]	1.26	0.05
Total increase in NOx [t]	**1.31**	

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