SUSTAINABLE TOURISM INFRASTRUCTURE PLANNING: A GIS BASED APPROACH

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Abstract
This paper presents a conceptual GIS-supported sustainable tourism infrastructure planning approach (STIP). This approach aims at integrating a comprehensive set of sustainability criteria (i.e., dealing with development objectives, preferred visitor experiences, and carrying capacity standards) in tourism planning, using GIS. STIP involves three phases: a visitor segmentation phase, a zoning phase, and a transportation network planning phase. To demonstrate the integration of these phases, STIP was applied to the Sinharaja Forest Reserve, a tropical rainforest in Sri Lanka's southwestern wet-zone. The area is experiencing increasing visitor use and requires additional trail development, as to mitigate resource stress. The resulting trail networks, which were mapped conform the sustainability criteria, provide directives for the area’s sustainable development.

1.0 Introduction
For many decades, tourism destination development has been dominated by a philosophy of “promoting established attraction- and service facilities.” The assumption was that the development of transportation facilities would follow (Gunn 1994). However, as transportation facilities are in general not revenue producing, common property, and governmental business, new destinations usually lack new transportation facilities. At the same time commercial attraction and service facilities establish themselves, independent of other developments and sectors, along transportation routes that formerly used to serve general community and economic development needs (Inskeep 1991). Nowadays, it is generally acknowledged that these ‘unplanned’ types of development are the ones most likely to be associated with low levels of visitor satisfaction and adverse impacts on resources. Since visitor experiences depend upon these very resources, ‘too much’ resource degradation leads to a decrease in visitor satisfaction, implying declining visitor arrivals. Unfortunately, tourists seem to require ever more specialized and spatially dispersed forms of development, aggravating the above mentioned problems (Williams 1998).

In response to threats ensuing from poor planning, considerable advancements have been made in the development of methodological processes for planning tourism destinations (e.g., Gunn 1965, 1972, 1994; Inskeep 1988, 1991; Lawson and Boyd-Bovy 1977). Nevertheless, today’s tourism planners cope with a lack of spatial concepts, models and theories that they can draw from (Dredge 1999). An explanation hereto lies according to Pearce (1995) in the fact that many have been developed independently of one another, with little or no recognition of or attempt to build on previous efforts. Fagence (1995) adds that these models have merely established the relevance of geographical concepts, rather than that they conclude on rules regarding these concepts’ functioning. In the absence of such geographical models, researchers (e.g., Itami, Raulings, Maclaren, Hirst, Gimblett, Zanon, & Chladek 2002; van der Knaap 1997) studied the factors (e.g., visitor education and information, regulation and enforcement, and markers and guides) that determine ‘visitor network-use.’ While these studies contribute to understanding revealed visitor behavior, their use in identifying spatially preferred visitor transportation network structures remains limited. Up till now destination-planning research has not reached much further than identifying the spatial entities (e.g., nodes, paths, and networks) that make up a destination’s tourism infrastructure and explaining what is where and why. However, destination planning requires knowledge of the entities’ ‘sustainable’ spatial configurations (i.e., considering the nature of and hierarchies within the entities, and the functional relationships among them).

To acquire better insights in the structure and functioning of sustainable visitor transportation networks and to plan more sustainable forms of tourism development, geographic information systems (GIS) are believed to...
have great potential (Culbertson, Hershberger, Jackson, Mullen, & Olson 1994). GIS can be described as hardware, software, and procedures, which support the collection, input, storage, retrieval, manipulation, transformation, analysis, and presentation of georeferenced data (Malczewski 1999). GIS technology couples common database operations such as query and statistical analysis to geographically represented object and field data and hence can be thought of as a decision support system involving spatially referenced data in a problem-solving environment (Malczewski 1999).

Although GIS has yet served a variety of tourism analysis purposes (see Bahaire & Elliott-White 1999) tailor-made GIS-applications with respect to tourism planning are scarce, and so is their use (McAdam 1999). However, GIS allow particularly for tourism planning, as tourism is above all a spatial phenomenon; it implies travel from one place to another. Consequently, tourism planning requires much spatial data collecting and processing, as all locations and their interrelations should be defined and analyzed within a spatial context. For this purpose GIS can describe and identify tourism infrastructure elements geometrically, thematically, and topologically. Moreover, GIS can deal with both object data (e.g., visitor centers, trails, forest patches) as well as field data (e.g., humidity, slope, altitude) of which both types can be represented in either grid or vector data format (Malczewski 1999).

In this paper, elements of both tourism and geo-information sciences are integrated to set out a new GIS-supported tourism planning approach. Tourism planning refers to the integrated planning of attraction (i.e., natural, cultural, man-made), service- (e.g., accommodation, shops, restaurants, visitor information, tour and travel operations, money exchange, medical facilities, postal services, entry and exit facilitation, etc.), and transportation facilities (i.e., both material infrastructure and transportation services) here referred to as ‘tourism infrastructure’ (Gunn 1994).

Sustainable tourism infrastructure planning (STIP) is introduced as the GIS-supported approach for planning sustainable tourism infrastructure. A “sustainable tourism infrastructure” can be defined as tourism infrastructure that enables sustainable tourism development. By means of this approach natural, cultural, and economic resources can be allocated or used in a sustainable manner. ‘Sustainable’ tourism development achieves its prime objectives, enables visitors to realize desired and expected experiences, while maintaining ‘carrying capacity standards’ and limiting overall resource impacts.

2.0 Purpose
The purpose of this paper is to investigate STIP’s potential—as a tourism planning approach—to incorporate ‘sustainability criteria’: realize development objectives; enable desired and expected visitor experiences; do not exceed carrying capacity standards; and minimize overall resource impacts. The overall goal was to map sustainable trail development locations by integrating (i.e., using a GIS) social (visitor preferences and managerial objectives) with biological (natural resource) data. When the three-phase GIS-supported methodology (Figure 1) set forward here allows realizing these goals, STIP can be considered a comprehensive and operational sustainable tourism planning tool.

3.0 Methods
During a field visit to Sri Lanka’s Sinharaja Forest Reserve (SFR) (February - April 2000), case study data were acquired via personal observations, informal stakeholder interviews, and a quantitative exploratory
survey to profile visitors at SFR. However, as data were not originally collected to set up a STIP-approach, data quality is limited and only suitable to illustrate STIP's methodology. Non-reliable or incomplete data was either omitted or fictively included for demonstration. Hence, the purpose of this case study is not to make recommendations for tourism infrastructure development in SFR, but to demonstrate a comprehensive and operational STIP-approach for planning sustainable tourism infrastructure in protected areas.

STIP integrates the 1) visitor segmentation; 2) zoning; and 3) visitor transportation network planning phases (see Figure 1). The integration of these phases allows for directing visitors through preferred zones, to undertake preferred activities at preferred facility locations, while accounting for development objectives and resource constraints.

3.1 Phase 1 - Visitor Segmentation

The notion of accounting for visitor characteristics in destination planning is not new. In 1979, Cohen was among the first to recognize that tourists vary in terms of needs and motivations, and thus behavioral patterns. Hence, the incorporation of such differences in destination planning is likely to result in higher visitor satisfaction levels, and may even reduce resource impacts, or induce protected area (PA) benefits (Haider 2002).

A visitor survey (n=60) was conducted at the Kudawe entrance, prior to visitors entering the SFR. First, principle component analysis (PCA) was used to derive orthogonal components from a set of ten variables dealing with desired and expected experiences, expected visitor impacts, and expected PA benefits. Next hierarchical cluster analysis was applied to group the respondents on the basis of similarity in principle component scores. PCA and hierarchical cluster analysis were used since these techniques provide better insights for matching desired and expected experiences with the area-specific opportunities that provide these experiences, resulting in enhanced visitor satisfaction (Smith 1995).

From the PCA three factors with eigenvalues over 1.0 were extracted. Accumulated these components explained 65 percent of the variance in the data. These were interpreted as follows: factor 1—preferences for cultural activities; factor 2—preferences for nature-related activities; and factor 3—preferences for bird-watching. The first two components were used for this case-study since factor 3 had items loading on factor 1 and 2 with factor scores >.40. Cluster-analysis using Ward's method with a five-cluster (segment) solution turned out to be the most meaningful. When comparing respondents per cluster with their principle component scores, a ‘culture’ and ‘nature’ segment were selected for planning trail networks due to management goals to provide nature and cultural experiences in the area. A birdwatcher segment was not included because they can use the same trails as the other two segments, since they tend to visit the forest at different times during the day. The ‘nature’ segment has a strong preference for learning about nature; both through education as well as through real-life experiences, yet not a lot of physical activity. The ‘culture’ segment wants to visit local communities, cultural markers, and viewpoints, and use food and beverage facilities at various instances. This information was used to locate, per segment, SFR’s places of interest. These can be attraction and service facilities (i.e., to plan trails in between in phase 3) or zones of interest (i.e., to use as input for creating STIP zones in phase 2).

3.2 Phase 2 - Zoning

The purpose of zoning is to demarcate specific areas for different types of land use and the development of standards to be applied within each land use zone to control land use according to the plan and to ensure standard compliance (Inskeep 1991). Zoning is particularly important since locations, regions, resources, amenities, and infrastructure have unequal potential and capacity for particular forms, types and scales of development (Fagence 1991). When planning for sustainable tourism infrastructure, it is argued that zones should be planned on the basis of twofold criteria groups ‘carrying capacity criteria’ and ‘visitor opportunity criteria,’ both having their own purpose and applying
their own set of indicators and standards. Once these criteria are combined, zones useful in guiding the planning of sustainable tourism infrastructure can be derived (Lindberg & Hawkins 1993).

In the context of this paper carrying capacity is defined as “the types, densities, and patterns of tourism infrastructure development a ‘zone’ can sustain indefinitely without degrading its natural, cultural, and economic resources beyond certain thresholds.” The purpose of carrying capacity-based zoning can subsequently be described “to protect natural, cultural, and economic resources through letting future development depend upon the most sensitive natural, cultural, and economic indicators (Ceballos-Lascuráin 1996). These premises have also been incorporated in STIP. However, STIP makes use of indicators, which can be expressed as ‘maximum infrastructure density’. Each indicator is supposed to possess a ‘maximum infrastructure density value’ for each PA-grid cell. Next, these indicator maps are superimposed (i.e., overlaid in Arc/Info 8.1) computing for each cell the lowest maximum infrastructure density value. Carrying capacity zones can then be derived through classifying these lowest maximum infrastructure density values, and depicting these classes - as ‘zones’ of contiguous cells - geographically in a GIS.

Which indicators to be included in the process depends on managers’ choice of relevant and available data, and the indicators’ suitability to be expressed in terms of infrastructure density and being merged with other indicators. It is recommended to define composite indicators through conjoint analysis (i.e., composite indicators represent multiple environmental processes or conditions) as these render a more meaningful result. For example, setting maximum infrastructure density values for the variables ‘precipitation’ and ‘slope’ as two separate indicators for visitor-induced soil runoff is not that meaningful, as this approach does not tackle the detrimental effects of visitors trampling on steep slopes with high precipitation levels.

For the SFR case-study, carrying capacity-based zoning relied on two natural indicators: forest cover and slope gradient. Hard-copy forest cover data were drawn from a reprinted (1997) thematic map (1:40,000) published by Sri Lanka’s Department of Forestry. Slope data were derived from a digital elevation model (DEM) based on a reprinted (1966) topographic map (1:63,360) of the Rakwana region. Maximum infrastructure density values, attached to the various classes of forest cover, were abstracted from the visitor survey. For the indicator ‘slope’ these were fictively included (Table 1).

Although carrying capacity zones provide the natural, cultural, and economic guidelines for STIP, they provide no insights in visitor preference areas. Consequently, tourism infrastructure development, guided primarily by carrying capacity zones, would most likely not meet

<table>
<thead>
<tr>
<th>Forest cover</th>
<th>Nature Visitor</th>
<th>Culture Visitor</th>
<th>Slope gradient</th>
<th>Nature Visitor</th>
<th>Culture Visitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary forest</td>
<td>20</td>
<td>14</td>
<td>0 – 5</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Secondary forest</td>
<td>33</td>
<td>25</td>
<td>5 – 10</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Degraded forest</td>
<td>25</td>
<td>20</td>
<td>10 – 14</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Encroachment</td>
<td>33</td>
<td>33</td>
<td>14 – 19</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Forest plantation</td>
<td>13</td>
<td>13</td>
<td>19 – 24</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Ridge forest</td>
<td>11</td>
<td>11</td>
<td>24 – 29</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Agriculture</td>
<td>17</td>
<td>17</td>
<td>29 – 33</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Scrubland /</td>
<td>25</td>
<td>25</td>
<td>33 – 38</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>grassland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.—“Forest cover” and “slope gradient” maximum infrastructure density values in square meters infrastructure per hectare - per visitor segment

1Defining maximum infrastructure density, the types and patterns of infrastructure to be developed should be considered.
2For all indicator grid maps a cell-size of 30 x 30 meters was applied.
3A zone in tourism terminology (i.e., the terminology of this paper) is called a region in GIS-terminology.
4The processes of creating, standardizing, and merging (composite) indicators require considerable follow-up research.
the needs of visitors or host regions. To provide ‘all’ visitors the experiences that most closely match their reason of visit, STIP not only considers zones of carrying capacities, but also zones of “visitor opportunities.” Visitor opportunity is defined as a preferred attraction, service, or transportation facility within a setting that allows the realization of desired and expected experiences (Ceballos-Lascuráin 1996).

Visitor opportunities can be described along four different setting or zoning perspectives, all of which contribute to the overall visitor opportunity: the experience setting, social setting, physical setting, and managerial setting (Lindberg and Hawkins 1993). This case-study however only incorporates the experience and managerial setting perspectives, as these can, unlike the social and physical setting perspectives, easily be represented by typical ‘zonal’ features such as lines and polygons5 within a GIS. Experience setting zones can be described as geographical zones that indicate (i.e., for one or more criteria or indicators) the extent to which desired and expected visitor experiences can be realized by one or more existing or latent available attraction, service, and transportation facilities. Managerial setting zones merely represent PA management’s development objectives through pointing out preferred development areas.

Similar to carrying capacity, visitor opportunities can be defined with respect to various indicators or ‘setting attributes’, expressed for each PA grid cell (i.e., in terms of ‘relative importance’ weights) the visitor or managerial ‘preference’ for that particular setting attribute. Overall opportunity zones result from overlaying (i.e., compute per cell the accumulated weight of the individual setting attribute weights) the various setting attribute weight maps, classifying the weights in the resulting weight map, and depicting these classes, as ‘zones’ of contiguous cells, geographically in a GIS.

For the SFR case-study, polygon-featured experience setting zones (i.e., visitor preference areas) were derived through attaching an experience setting weight to the various types of forest cover for the ‘nature’ and ‘culture’ visitor segment (Table 2). These weights were extrapolated from the visitor segment profiles.

Next, line- and polygon-featured managerial setting zones were created through attaching purely hypothetical managerial setting weights (Table 3) to the various managerial setting attributes. Since setting attributes do not necessarily cover every PA’s grid cell, the managerial setting attributes were attached a ‘weight if’ and a ‘weight if not’, in case certain setting attributes ‘did’ or ‘did not’ occur.

Line features: existing roads and trails to minimize both environmental impact as well as capital investments; rivers avoided as much as possible to minimize additional infrastructure costs.

Polygon features: a 1000 meter buffer in- and outside the SFR to stimulate tourism development on the peripheries so as to protect the core area and minimize forest fragmentation; a 250 meter buffer on the river plains of SFR’s major rivers, as these plains are well-drained, have a lower ground water table and better-suited for infrastructure development; a 4000 meter buffer around both entrances, especially for high-use attraction features, in order to prevent transportation facility development in the PA’s backcountry areas; a 500 meter buffer on encroachments to stimulate tourism development in these highly forest-dependent regions and to provide

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Table 2.—Experience setting weights, per visitor segment, for setting attribute ‘forest cover’ (i.e., lower the weight the higher the preference)

<table>
<thead>
<tr>
<th>Forest cover</th>
<th>Visitor Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferences</td>
<td>Nature</td>
</tr>
<tr>
<td>Primary forest</td>
<td>100</td>
</tr>
<tr>
<td>Secondary forest</td>
<td>200</td>
</tr>
<tr>
<td>Degraded forest</td>
<td>300</td>
</tr>
<tr>
<td>Encroachment</td>
<td>600</td>
</tr>
<tr>
<td>Forest plantation</td>
<td>800</td>
</tr>
<tr>
<td>Ridge forest</td>
<td>400</td>
</tr>
<tr>
<td>Agriculture</td>
<td>500</td>
</tr>
<tr>
<td>Scrubland / grassland</td>
<td>700</td>
</tr>
</tbody>
</table>

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5Vector features such as lines and polygons were converted to grid maps prior to the overlaying process.
local communities with a substitute source of income for their current activities, and to open up the market economy through better access to outside markets and better facilities on the village level; and a 5000 meter buffer around SFR’s nearest medical centre, to stimulate development in places where visitor safety can be guaranteed.

In order to plan segment specific trail networks (phase 3), carrying capacities zones need to be overlaid with visitor opportunity zones. It is suggested that PA-development objectives guide the relative importance to be awarded to carrying capacity- and visitor opportunity zones in the overlaying process, to obtain a ‘STIP-zone’ map (see Lindberg and Hawkins 1993). Having development objectives direct the relative influence of carrying capacities versus visitor opportunities allows future costs and benefits associated with tourism development to arise in the right places and in the right proportions. In this case-study maximum infrastructure density values were translated into ‘appropriate’ weights by $\frac{10,000}{\text{maximum infrastructure density}}$. The lower the STIP-zone’s weight, the higher the zone’s potential for sustainable tourism infrastructure development.

### Table 3.—Managerial setting weights (i.e., the lower the weight, the higher the managerial preference)

<table>
<thead>
<tr>
<th>Weight if</th>
<th>Weight if not</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads and trails (line)</td>
<td></td>
</tr>
<tr>
<td>Foot path</td>
<td>5</td>
</tr>
<tr>
<td>Logging road</td>
<td>10</td>
</tr>
<tr>
<td>Cart track</td>
<td>50</td>
</tr>
<tr>
<td>Minor road</td>
<td>100</td>
</tr>
<tr>
<td>Former logging road</td>
<td>100</td>
</tr>
<tr>
<td>Rivers (line)</td>
<td></td>
</tr>
<tr>
<td>Stream</td>
<td>400</td>
</tr>
<tr>
<td>River</td>
<td>1000</td>
</tr>
<tr>
<td>Buffers (polygon)</td>
<td></td>
</tr>
<tr>
<td>River plain buffer</td>
<td>0</td>
</tr>
<tr>
<td>Medical centre buffer</td>
<td>0</td>
</tr>
<tr>
<td>Encroachment buffer</td>
<td>0</td>
</tr>
<tr>
<td>Entrance point buffer</td>
<td>0</td>
</tr>
<tr>
<td>PA-boundary buffer</td>
<td>0</td>
</tr>
</tbody>
</table>

### 3.3 Phase 3 - Transportation Network Planning

Once visitor segments have been identified (phase 1), and STIP-zones have been created (phase 2), visitor segments need to be directed to these STIP-zones that together provide a satisfying experience. However, in practice not all preferred zones will or can, due to visitor and resource constraints (see Hägerstrand 1979), be made accessible. Consequently, just these zones that are expected to result in a management-preferred composition and spatial distribution of costs and benefits should be connected through a ‘visitor transportation network’. A visitor transportation network refers to the coherently organized transportation facility linkages in between STIP-zones (i.e., with attraction- and service facilities) enabling the transportation of visitors between these zones (Ritsema van Eck 1993).

In this definition ‘coherently’ refers to visitor preferences on the interwoven coherence levels (see Elands 2002). A substantial (i.e., considering the preferred combination of preferred attraction- and service facilities), spatial (i.e., considering the preferred spatial characteristics of preferred attraction- and service facilities), and temporal (i.e., considering the preferred temporal characteristics of preferred attraction- and service facilities) coherence level. However, segmenting visitors integrating these levels of coherence is currently impossible, as there is yet no statistical technique available that can deal with the many combinations of variables that this would require (Elands 2002). As a consequence, STIP is restricted to incorporating substantial coherence level information only. With respect to the SFR case-study, this information is ‘captured’ (i.e., Phase 1) in the ‘nature’ and ‘culture’ visitor segment profiles.

Since tourism transportation network development implies various costs (e.g., construction, maintenance, and resource-related) STIP should account for these in terms of impedance or resistance weights.\textsuperscript{6} This is closely related to ‘network resistance’ is ‘network capacity’. Although this relationship greatly depends on the types of attraction-, service- and transportation facilities to be planned, and the types of visitors for whom these are planned, generally it could be stated that the higher the required capacity, the stronger the resistance. Network capacity is not further considered here.

\textsuperscript{6} Closely related to ‘network resistance’ is ‘network capacity’.
achieved through the application of Arc/Info’s grid-based ‘minimum cost path’ function, which computes ‘minimum cost paths’ in between visitor preferred attraction- and service facilities (i.e., phase 1), using STIP-zone weights (i.e., phase 2) as a measure of resistance. However, while computing minimum cost paths on a cell-by-cell basis, this function does not allow integrating ‘zonal’ side conditions. Therefore, the concept of carrying capacity (i.e., read maximum infrastructure density), which applies to zones of contiguous cells, could not be implemented as originally intended.\footnote{In case zonal side-conditions could have been implemented, carrying capacity zones would not have been overlaid with visitor opportunity zones.} Instead, cells with a low carrying capacity value were simply attached a ‘high-resistance’ weight (see section 3.2) to reduce the chance of being selected - by the minimum cost-path function for trail development. This drawback can possibly be resolved through adaptation of the minimum cost-path algorithm. However, this is beyond the scope of this paper.

For each computed minimum cost path the accumulated costs (i.e., resistance) were divided by the path’s length. Subsequently, the paths were classified into six interval-scaled ‘cost’ classes (i.e., the same for both visitor segments). However, as these classes do not represent the costs associated with transportation network development, but rather from an indicator for trail sustainability, these were attached via an ordinal scale, ranging from ‘sustainable’ to ‘non-sustainable’.

4.0 Results

A PCA-cluster analysis procedure, using visitor survey data, rendered a ‘nature’ and ‘culture’ visitor segment. Segment specific preferences and associated behavior served, next to natural resource conditions and managerial objectives, as input for the development of carrying capacity and visitor opportunity zones. These were created through grid-overlays in Arc/Info 8.1. In addition, visitor preferences were directly translated into the SFR’s attraction and service facility locations. Together, these zones and locations served as input for computing, using Arc/Info’s minimum cost-path function, the most ‘sustainable’ trail routes (colored light green) to accommodate ‘nature’ and ‘culture’ visitors’ experiential needs (Figures 2-3).

5.0 Conclusions

This study was done to investigate STIP’s potential as a tourism planning approach to incorporate the sustainability criteria. Through integrating social with natural resource data STIP aims at planning infrastructure at sustainable locations (identified spatially) rather than planning tourism development along existing transportation structures, which are not necessarily sustainable.
Although the generated maps depict for two visitor segments the most ‘sustainable’ trail development locations, a number of problems still need to be resolved. First, literature reviewed shows a lack of understanding about ‘network morphology’ and ‘network connectivity’ in relation to visitor satisfaction in specific and sustainable tourism development in general. Further research on these topics is required to come to sustainable trail networks. Second, there is no statistical technique available for analyzing visitor preferences on a substantial, spatial, and temporal coherence level simultaneously (see Elands 2002). Consequently, spatial and temporal visitor preferences were not accounted for in the depicted trail networks. The integration of spatial-temporal preferences is a prerequisite for sustainable trail development. Third, current GIS (Arc/Info 8.1) do not allow computing minimum cost-paths while applying zonal side-conditions. Hence, the concept of carrying capacity could not be fully implemented. However, this ‘sustainability’ constraint can possibly be resolved through adaptation of the minimum cost-path algorithm.

Considering the above-mentioned constraints, and the poor quality and availability of case-study data, no conclusions should be drawn regarding sustainable tourism infrastructure development in SFR. This does not mean STIP has no potential as a tourism planning tool. STIP’s three-phase GIS-supported methodology does yet (up to a certain level) allow incorporating the sustainability criteria in tourism planning. Provided that identified constraints are overcome, STIP allows directing visitors to preferred attraction and service facilities, using trails that: accommodate visitors’ experiential needs; minimize adverse impacts on resources; and have been developed in line with PA development objectives. Hence, higher levels of visitor satisfaction can be achieved and sustained, while development-associated costs and benefits can be directed to the right places.

Furthermore, STIP can readily be improved through the inclusion of additional indicators in the zoning process. The more indicators included in the zoning process, the more variation in the STIP-zone weight map, and curvature in the transportation network linkages can be observed (i.e., which is more interesting from a visitor point of view). However, the inclusion of additional indicators does not necessarily improve the reliability of the output zones. This depends among other factors on the indicator’s comprehensiveness. Although indicators that represent for example a single environmental process or condition can be overlaid relatively easily, this does not yet account for the interrelations between the various environmental processes or conditions. Therefore, to derive more reliable and meaningful carrying capacity and visitor opportunity zones, it is suggested rather to define composite indicators, through conjoint analysis, as an aggregate of environmental processes and conditions. A disadvantage of such analysis is that it requires considerably more effort in data acquisition, because such data is seldom available. The processes of creating, standardizing, and integrating (composite) indicators require considerable follow-up research. Obviously, there are theoretical and practical limits to these processes.

### 6.0 Recommendations

As shown in Figures 2 & 3, not all transportation network trails are equally sustainable. Hence, STIP’s trail networks might be very useful in assisting managers to decide, on a substantial coherence level, which trails to develop and for whom. Optionally, PA management may impose a ‘quality threshold’ as a constraint to trail development. That is, a trail’s accumulated experience setting weights (i.e., assuming non-reversed weights), are supposed to exceed this threshold in order to speak of satisfying visitor experience. If a trail does not exceed this threshold, it does not have enough potential to accommodate a segment’s experiential needs. Similarly, PA-management may incorporate a ‘resource impact upper limit’ (or a ‘quality threshold’ in combination with a ‘resource impact upper limit’). If a trail exceeds this limit, too many resources have been allocated to tourism infrastructure development.

### 7.0 Citations


Ceballos-Lascuráin, H. 1996. Tourism, ecotourism and protected areas – The state of nature-based
tourism around the world and guidelines for its development. IUCN, Cambridge, UK.


Citation: