Systems approach to residents' irritation in urban tourism destinations

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Abstract

This paper focuses on the highly demanding issue of managing residents' attitudes towards tourism development in urban tourism destinations. The objective of this study was to find efficient solutions in how to manage residents' attitudes systematically to reduce residents' irritation in urban destinations, which are considered as complex systems. Therefore, the systems approach methods such as system dynamics and simulation modelling were used. The presented system dynamic model represents the main theoretical contribution of this paper and fills a gap in the current theory of using systems approach to manage residents' attitudes and reduce residents' irritation. The model enables wide range of simulations and can be applied in practice in urban destinations with high tourism intensity to find suitable solutions for a particular destination. The case of Český Krumlov Town, the Czech Republic, show that regulating the number of visitors helps to reduce the overall irritation of residents, especially in peak times when overcrowding occurs, but this alone may not be sufficient to keep residents' irritation lower in the long-term. Therefore, it is necessary to use a more advanced approach by combining visitor management with benefits for residents.

Keywords: System Dynamics; Simulation Modelling; Urban Destination; Resident; Irritation

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Introduction

Sustainable tourism development has become a subject of interest to international, national, regional, and local governments which usually create a specific tourism policy to influence tourism development by particular management and marketing instruments. However, as Kuščer and Mihalič (2019) note, many destinations fail in managing tourism development in time of rapidly growing tourism demand and its concentration in time and single space. Thus, high number of tourism arrivals impose a significant pressure on destination environment and may negatively influence quality of resident's life (Dioko, 2017; Kuvan & Akan, 2012; Srivastava, 2017).

As tourism is a complex social phenomenon having significant impacts on economic, social, cultural, and physical environment of tourism destinations, the concept of tourism carrying capacity has been widely discussed. We can find many definitions of tourism carrying capacity in the literature (Kayat & Radzi, 2012; McCool & Lime, 2001; R. Sharma, 2016; Srivastava, 2017).

Zelenka and Kacetl (2014) note that tourism carrying capacity has many dimensions due to a complexity of tourism impacts. McCool and Lime (2001) see the relationship between utilization of tourism destination and resulting impacts as non-linear and complex. Many variables interfere with this relationship, such as visitor numbers, destination area, time of tourist season, tourist behavior, site conditions, or visitor management practices (McCool & Lime, 2001). Lindberg and McCool (1998) point that number of visitors is only one of many factors determining carrying capacity and may have just limited effect when comparing with other factors, such as visitor management. Thus, tourism carrying capacity can be considered as a multidimensional concept covering physical, socio-cultural, and economic environment of tourism destination. Each capacity dimension has its own limits which, if overrun, may lead to negative effects (Srivastava, 2017).

This paper focuses on a social dimension of tourism carrying capacity which is usually associated with reaction of residents to tourism development (Srivastava, 2017). Many authors stress the importance of residents' support for sustainable tourism development and consider their support as a key condition for successful implementation of a tourism policy in a destination (Byrd *et al.*, 2009; Kuvan & Akan, 2012; B. Sharma & Dyer, 2009). However, the negative impacts of tourism and disruptions of residents' life can easily negatively affect their attitudes and turn them against further tourism development (Koens *et al.*, 2018). Therefore, the issue of residents' attitude towards tourism development plays a significant role in the policy-making and planning process.

Many scholars have been attempting to analyze their attitudes towards tourism development in the hope of gaining a better understanding (Farstad, 2013; Gursoy & Rutherford, 2004; Kuvan & Akan, 2012; Lu *et al.*, 2006; Lundberg, 2015). These authors work with resident's attitude rather than resident's irritation (Choi & Sirakaya, 2005; Gerritsma & Vork, 2017; Gursoy *et al.*, 2002; S. Wang, 2016). In our study, we consider the irritation as the level of annoyance more than the Doxey's (1975) Irrindex stages. We use the Doxey's theory to validate the relationship between the tourism intensity and resident's irritation in the model. The destination carrying capacity is considered as a maximum level of tourism development which does not harm the economic, socio-cultural, and physical environment of tourism destination, residents' quality of life, and experience of visitors. The irritation itself is then influenced by other factors, both positive and negative. We work with the irritation rather than the attitude because we do not want to examine if the general attitude is positive or negative. Our aim is to find the way how to deal with the existing and rising irritation (annoyance) and how to reduce or stabilize it over time in a specific destination, where the irritation (annoyance) has been proven.

The objective of this study was to find efficient solutions in how to manage residents' attitudes systematically resulting in residents' irritation reduction in urban destinations with high tourism intensity. The research question is defined as follows:

RQ: How and to what extent can various policies reduce the residents' irritation in urban destinations with high tourism intensity?

The case of the Český Krumlov Town, Region of South Bohemia, the Czech Republic, is presented in this study. The town ranks among Czech top urban destinations. The intensity of tourism has been rising steeply and constantly since 1992, when the historical center was listed in the UNESCO World Heritage List (Štumpf & Dvořák, 2014). Although the city has only 13,000 inhabitants, it evinced nearly 300,000 guests in accommodation facilities and nearly 400,000 overnights in 2019 (*Czech Statistical Office*, 2020). Thus, due to high intensity of tourism, Český Krumlov has been suffering from overtourism during the last decade. The situation in the town is typical for the cities suffering from the "Venice Syndrome" mentioned by Capocchi *et al.* (2019). Such "syndrome" relates to many negative effects of overtourism, such as lack of free housing, increasing of housing prices, over-traffic, noise pollution, street crime, etc., resulting to depopulation of the city centres.

Even though overtourism is relatively new term, still not having clear boundaries, standardized characterization and classification, its relation to sustainable tourism development and the concept of social carrying capacity is obvious. Kuščer and Mihalič (2019) state a wide definition in which overtourism describes destinations where locals or visitors feel that there are too many visitors and that the quality of life in the area, or the quality of the experience has deteriorated unacceptably. As the opposite, the authors mention the responsible tourism. Koens *et al.* (2018) consider overtourism to be a social issue. The authors stress the fact that rapid and uncontrolled tourism growth resulting in high concentration of visitors on relatively small area can negatively affect attitudes of residents and is able to turn their mind against tourism development in the area. It forces residents to carefully weigh the positives and negatives of tourism for their homes and can easily lead to "antitourism flare-ups" (Kuščer & Mihalič, 2019). Thus, managing the attitudes of Český Krumlov residents resulting in reduction of their irritation has become a crucial task for local politicians and the local DMO. because the negative impacts of tourism on the community has been rising in this destination recently (Štumpf & Dvořák, 2014; Valtrová, 2018).

The presented system dynamic model fills a gap in the current theory of using systems approach to manage residents' attitudes and to reduce residents' irritation. The model enables wide range of simulations and can be applied in practice in urban destinations with high tourism intensity to find suitable solutions for a particular destination.

To the best of our knowledge, there seems to be a research gap in understanding the dynamics of negative attitudes within the process of managing tourism development in urban destinations. This study contributes to the current theory using system dynamics for modelling policies aimed at residents' attitudes in a broader context.

Literature Review

A literature review suggests that residents are considered to be one of the main actors in the tourism development process (Beritelli *et al.*, 2007; Laws *et al.*, 2011) and they have the power to influence planning and sustainable development in tourism destinations (Gursoy & Rutherford, 2004).

Managing residents' attitudes towards tourism development

Economic impacts are important for destination development, and thus, can influence the stakeholders' support of tourism policy to the greatest extent (Gursoy & Rutherford, 2004; Xie *et al.*, 2014). Most studies view the economic impacts of tourism positively (see Table 1), as an opportunity for economic growth and the resulting development of a destination. Nevertheless, many authors point out the economic cost and negative effects associated with tourism development, such as: the crowding out effect; seasonality of jobs; lower wages in the tourism sector; inappropriate investments for the local environment; and the possibility of increased inflation.

The socio-cultural impacts of tourism appear as positive long-term changes in a society and usually take the form of a higher standard of living; the community's appearance; a better quality of public services; restoration of historical buildings; and the preservation of local culture. Conversely, the authors quoted in Table 1 identify many negative impacts related to the socio-cultural sphere, such as: a higher crime rate; vandalism; prostitution; gambling; traffic congestion; and disruption of everyday life.

Tourism also affects the environment. The quality of the environment in a destination is essential to sustainable tourism development. Therefore, the interaction between tourism development and environmental change is a matter of interest to many authors, such as Stylidis *et al.* (2014) or Xie *et al.* (2014). They try to classify and examine mainly the negative impact of tourism to destination environment, such as: air and water pollution; undesirable changes in natural processes; increasing waste production; increasing consumption of natural resources; disproportionate land use; devaluation of natural beauty; or interventions into the life of animals. However, some of them also mention the positive effects, such as: the emergence of nature reservations and open-air museums; protection of natural heritage; and residents' higher environmental awareness.

Table 1 highlights the most significant tourism impacts derived from selected research papers in connection with residents. It also includes the most important research characteristics of the papers as (R₁) the data source; (R₂) the data collection method; and (R₃) the data analysis method.

The residents' attitudes represent their beliefs, intentions, and behaviour toward tourism support and are influenced by positive and negative tourism effects, as well as other factors such as self-esteem and self-efficacy at the same time (Gerritsma & Vork, 2017; Gursoy *et al.*, 2002; Sheehan & Ritchie, 2005; S. Wang, 2016). According to Gerritsma and Vork (2017), attitudes are considered as hypothetical constructions that consist of a cognitive component, a conative component (behaviour), and an affective component (feeling). We can distinguish several groups of residents in each destination according to their attitudes towards tourism development. For instance, Lundberg (2015) divides residents into *development supporters*, *prudent developers*, *ambivalent/cautious*, and *sceptics*.

Table 1. The impacts of tourism

Author(s)	Tourism impacts	Research Characteristics
Lu et al., 2006	<i>Positive:</i> employment, income, infrastructure, living standard, improvement of community reputation and status, understanding of different culture, improvement of local culture, preserving environment, people's conservation awareness <i>Negative:</i> impairity in sharing tourism benefits, higher commodity price and living costs, crime, alcoholism, prostitution, gambling, pollution, traffic jam and accidents, destruction of natural resources	R1: residents, tourism managers, tourists R2: interviews (Likert scale) R3: Fuzzy Synthetic Evaluation
Dyer et al., 2007	<i>Positive:</i> more parks and other recreational areas for local residents, restoration of historical buildings, conservation of natural resources, preservation of the local culture, higher standard of roads and public services, more jobs, more investment, more business for local people, additional tax revenue, cultural exchange, cultural identity, valuable experience <i>Negative:</i> negative effect on the way of life, changes in culture, suffering from living in a tourist destination, overcrowded public facilities, more pressure on local services, increase in prices of goods and services, destruction of the natural environment, crime rate, traffic congestion, noise and pollution, prostitution	R1: residents R2: self-administered questionnaires (Likert scale) R3: Exploratory Factor Analysis, Confirmatory Factor Analysis
Byrd et al., 2009	<i>Positive:</i> quality of life, community appearance, recreational opportunities, local economy <i>Negative:</i> environment, crime, property taxes, traffic problems	R1: entrepreneurs, government officials, residents, tourists R2: self-administered questionnaires (Likert scale) R3: ANOVA test, Scheffe test
Sharma & Dyer, 2009	<i>Positive:</i> create more jobs, attract more investment, provide more business for local people, create additional tax revenue, cultural activities, cultural exchange, recreational opportunities, restoration of historical buildings, conservation of natural resources, preservation of local culture <i>Negative:</i> change in local culture, change in local way of living, suffering from living in tourist destination, overcrowded beaches, more pressure on local services, increase in price of goods and services, increase in price of real estate, crime rate, traffic congestion, vandalism, noise, pollution, prostitution, destruction of natural environment	R1: residents R2: self-administered questionnaires (Likert scale) R3: descriptive statistics, t-test, mean score, correlation analysis
Brida et al., 2011	<i>Positive:</i> more economic investments and spending, higher standard of living, employment opportunities, environmental conservation, higher standard of public services, more services and facilities for residents, positive experience, cultural exchange, restoration of historical buildings, new environmentally-oriented programs, new cultural attractions <i>Negative:</i> increase in prices, crowds and accessibility problems, traffic congestion, noise, destruction of the environment, undesirable effect on local habits, changes in local culture and traditions, reduction in the quality of life, crime problems	R1: residents R2: self-administered questionnaires (Likert scale) R3: cluster analysis
Kuvan & Akan, 2012	<i>Positive:</i> employment opportunities, standard of living, quality of public services, support for the local economy, quality of services,	R1: residents, managers R2: self-administered questionnaires (Likert scale), interviews

Author(s)	Tourism impacts	Research Characteristics
	cultural activities, understanding between cultures, recreational opportunities <i>Negative:</i> outflow of financial resources, unequal distribution of income, damage to local culture, conflicts with tourists, noise, restriction in using recreational facilities, negative environmental impacts, air, water and soil pollution, less agricultural land, negative impact on natural resources, devaluation of natural beauty	R3: t-tests for independent samples, two-tail test, Levene test
Presenza & Sheehan, 2013	<i>Positive:</i> economic benefits to the local economy, creation of community spirit, benefits for residents, improvement in the environment, positive image <i>Negative:</i> prices of goods and services, crime, brawls, drugs, prostitution, sexual harassment, gambling, vandalism	R1: residents R2: self-administered questionnaires (Likert scale) R3: K-means ipsative clustering method
Stylidis <i>et al.</i> , 2014	<i>Positive:</i> community services, entertainment, social environment, standard of living, number of jobs, infrastructure, revenue in the economy, availability of recreational facilities, cultural activities, meeting people from other cultures, community spirit, public finance <i>Negative:</i> prices of goods and services, crowding, traffic congestion, noise, environmental pollution	R1: residents R2: self-administered questionnaires (Likert scale) R3: Exploratory Factor Analysis, Confirmatory Factor Analysis
Xie <i>et al.</i> , 2014	<i>Positive:</i> employment opportunities, income, local economic development, sociocultural development, town construction, development of local culture, fame of the town <i>Negative:</i> environmental degradation, soil and water pollution, degradation of local eco-environment, rubbish, loss of traditions, lower moral standard, reduced trust between people	R1: residents R2: self-administered questionnaires (Likert scale) R3: multiple-group analysis in structural equation modeling
Sinclair-Maragh <i>et al.</i> , 2015	<i>Positive:</i> quality of public services, transportation service, recreational opportunities, cultural identity, traditions, cultural activities, employment opportunities, personal income <i>Negative:</i> traffic problems, crime rate, price of goods and services	R1: residents R2: self-administered questionnaires (Likert scale) R3: cluster analysis

Note. R1 = the data source; R2 = the data collection method; and R3 = the data analysis method

From this perspective, it seems clear that managing residents' attitudes towards tourism development may play a key role in tourism policy making and planning. This is considered such an important topic that has been the matter of interest in numerous research papers (Byrd *et al.*, 2009; Brida *et al.*, 2011; Ghasemi, 2019; Kuvan & Akan, 2012; Lu *et al.*, 2006; B. Sharma & Dyer, 2009; Sinclair-Maragh *et al.*, 2015; Stylidis *et al.*, 2014; S. Wang, 2016; Xie *et al.*, 2014). However, most studies are theoretically-based on the social exchange theory (SET) developed by Ap (1992), and largely descriptive at the same time.

An essential approach, how to measure the residents' attitude towards tourism, is Doxey's irritation index (Doxey, 1975). It describes on a pre-defined scale (euphoria - apathy - irritation - antagonism) of the level of residents' attitude toward tourists and tourism development in different stages of a destination's life cycle (Butler, 1980). Although the index was developed in 1975, in some nuances it is still a popular method of describing the interaction changes between residents and tourists over time (Gerritsma & Vork, 2017; Irandu, 2004; Milman, 2004; Zhang *et al.*, 2018). However, this approach has

been widely criticised by academics because of its simplistic interpretation, assuming that more tourists is the only factor leading to a higher degree of irritation (Gerritsma & Vork, 2017). Therefore, some authors work with resident's attitude rather than resident's irritation (Choi & Sirakaya, 2005; Gerritsma & Vork, 2017; Gursoy *et al.*, 2002; S. Wang, 2016). In our study, we consider the irritation as the level of annoyance more than the Doxey's (1975) Irrindex stages. We use the Doxey's theory only to validate the relationship between the tourism intensity and resident's irritation in the model. The irritation itself is then influenced by other factors in our case. The residents' irritation (annoyance) has been proven in the case of Český Krumlov (Valtrová, 2018). Therefore, we work with the irritation rather than the attitude because we do not want to examine if the attitude is positive or negative. Our aim is to find the way how to deal with the existing and rising irritation (annoyance) and how to reduce or stabilize it over time.

As Choi and Sirakaya (2005) and Khazaei *et al.* (2015) suggest, there is a need for a progressive research approach, development of innovative frameworks and analytic tools enabling destination managers to effectively manage residents' attitudes towards tourism development and reduce residents' irritation over a long-term horizon. Therefore, approaches, such as the study of the complex systems and their dynamics, enabling high quality development and the simultaneous provision of resource-efficient tourism services, are required.

Systems Approach and System Dynamics in Tourism

System theory and cybernetics play an important role in different fields of scientific research since Ludwig von Bertalanffy published his manifesto on General System Theory (Bertalanffy, 1968) and Norbert Wiener his Cybernetics (Wiener, 1948). The word "system" denoted a whole consisting of parts and was the axiom for ancient philosophers (Jere Lazanski & Kljajic, 2006). System theory and cybernetics indicate the relevance of the order and structure of elements within a whole for its behaviour.

Systems thinking is, then, the art of simplifying complexity and it seems to be suitable to solve managerial issues in a real world. "*We see the world as increasingly more complex and chaotic because we use inadequate concepts to explain it. When we understand something, we no longer see it as chaotic or complex*" (Gharajedaghi, 2006, p. 25). This was the reason for the involvement of a range of powerful system approaches in management (Jackson, 2003). The theory of Learning Organization (Senge, 1990) is considered as one of the most representative.

System dynamics is a method to enhance learning in complex systems which often uses computer simulation models to help us learn about dynamic complexity, understand the sources of policy resistance, and design more effective policies. System dynamics is fundamentally interdisciplinary. Because we are concerned with the behaviour of complex systems, this method is grounded in the theory of nonlinear dynamics and feedback control developed in mathematics, physics, and engineering (Sterman, 2000). Therefore, system dynamics can be understood as a computer-based approach to understand and analyse a system's behaviour over time. Using this approach we can break a system into pieces and examining each element of the system to find the impacts and outcome of changes on these elements at a macro-level (Sedarati *et al.*, 2018).

System dynamics methodology represents a part of systems thinking, even though the system dynamics is an historically older discipline (Forrester, 1961). System dynamics is linked to computer simulation models that are often used as a support for decision making, especially in business and commerce (Sterman, 2000).

The system dynamics searches for an explanation of phenomena (variables within the boundaries of the system). The endogenous approach creates system dynamics through the interaction of variables and agents represented in the model. By specifying the structure of the system and the rules of interaction (decision-making rules in the system), it is possible to reveal behaviour patterns created on the basis of these rules and this structure, and to discover how behaviour can be changed following the alternation of the structure and rules (Sterman, 2000). For example, Jere Lazanski & Kljajic (2006) or Mai & Smith (2018) have used this approach in dynamic modelling of tourism destinations.

On the other hand, the approach based on the exogenous variables (variables beyond the model boundaries) explains the dynamics of given variables in the sense of other variables whose behaviour is anticipated. Endogenous explanation of the system dynamics does not mean that the models should never contain any exogenous variables. However, the number of external inputs should not be high, and each "exogenous input candidate" must be carefully verified. Careful consideration must be given to the fact whether there is significant feedback from endogenous elements to the considered exogenous input in the system. If so, the boundaries of the system must be extended, and this variable must be modelled as endogenous (Sterman, 2000). An approach based on exogenous variables has been used in tourism destination research by, for example, Patterson *et al.* (2004).

The process of building a system dynamic model consists of following steps: (1) problem articulation; (2) formulating a dynamic hypothesis; (3) formulating a simulation model; (4) testing the model, and (5) policy design and evaluation (Sterman, 2000). Jackson (2003) presents a modified system dynamics modelling process that consists of: (1) problem structuring; (2) causal loop modelling; (3) dynamic modelling; (4) scenario planning and modelling; and (5) implementation and organizational learning. This approach includes the learning potential in the process, based on Senge's (1990) theory of Learning Organization. It was already used in destination management theory by Schianetz *et al.* (2007), who present the concept of Learning Tourism Destination (LTD) using system dynamics as a tool for implementing and reinforcing collective learning processes. The results show that system dynamics methodology can support communication among crucial stakeholders in tourism destinations and stimulate organizational learning.

Even though, the first system dynamics models were used for simulations in businesses (Forrester, 1961), these models enable to evaluate not only the economic impacts, but also the socio-cultural and environmental impacts and their mutual interactions (Jackson, 2003).

The use of the systemic approach in tourism originates from the fact that tourism destinations are considered as complex systems (Baggio & Sainaghi, 2011; Kaspar, 1976; Laesser & Beritelli, 2013; Mai & Smith, 2018; Štumpf & Vojtko, 2016). Systems approach to tourism has been increasingly discussed by researchers (Baggio & Sainaghi, 2011; Jere Jakulin, 2017; Jere Lazanski & Kljajic, 2006; Ropret *et al.*, 2014). As a complex system, tourism has multiple positive economic, socio-cultural, and environmental impacts on tourism destinations and is widely recognized as an important factor in its development (Lu *et al.*, 2006; Mazhenova *et al.*, 2016; Vanhove, 2005).

Based on systems theory, a tourism destination is defined as an open, complex, and adaptive system, in which numerous relationships and impacts in the economic, socio-cultural, and environmental spheres are generated. The tourism destination as a complex system is needed to be modelled properly to achieve efficient destination management (Bieger, 2008; Farrell & Twining-Ward, 2004; Lew & McKercher, 2006; Rodriguez-Diaz & Espino-Rodriguez, 2007).

Complex systems can be understood as a phenomenon consisting of a large number of elements organised in a multi-level hierarchical structure. Extremely complex systems can be characterized as having a large number of subsystems that are involved in many more loosely structured interactions, the outcome of which is not predetermined (Jackson, 2003; Jere Lazanski & Kljajic, 2006). The description of the system depends on the viewpoint of the researcher and research goals (Jere Lazanski & Kljajic, 2006). While, natural science has discovered “chaos”, social science has encountered “complexity”. However, chaos and complexity are not characteristics of the world and reality; they are features of our perceptions and understanding (Gharajedaghi, 2006). Complex systems are in disequilibrium and evolve over time (Jackson, 2003; Sterman, 2000). However, the word “complex” is used to point out that the described problem cannot be expressed only in quantitative relations because many relevant values are qualitative (Jere Lazanski & Kljajic, 2006). We consider a complex system as a system within which a complexity of interaction among system elements plays a main role.

Several research studies have been published in the field of travel and tourism, using systems approach and system dynamics as the main theoretical approach (Borštnar *et al.*, 2011; Janeček, 2016; Jere Jakulin, 2016, 2017; Lazanski & Kljajic, 2006; Mai & Smith, 2018; Patterson *et al.*, 2004; Ropret *et al.*, 2014; Schianetz *et al.*, 2007; Sedarati *et al.*, 2018; Štumpf & Vojtko, 2016; Tan, 2017; Tegegne *et al.*, 2018; Vojtko & Volfová, 2015). Moreover, Romero-García *et al.* (2019) present an extensive review of the urban tourism literature that uses the systems approach. However, many of previous studies regard residents as one of the stakeholders in the model; none focuses the residents’ irritation dynamics and its reduction. Therefore, we see a gap in using system dynamics for modelling policies for residents’ irritation reduction in tourism destinations in a broader context and in a more complex way.

Methodology

The method used in this study, was system dynamics modelling. The model according to the previous studies was built based on the system dynamics methodology (Jackson, 2003), as shown in Figure 1, and discussed below.

Problem structuring

The first step consists of the identification of a research problem and variables, which have a crucial influence on the defined problem according to literature and existing theories. The variables create the boundaries of the system and were defined based on the literature review and current knowledge.

We used the case of Český Krumlov because the irritation of local community has been proven in this destination, as described in the Introduction. Therefore, we use this town as the representative urban destination with high tourism intensity, where a need of managing negative residents’ attitude towards tourism development exists.

Causal Loop Modelling

In the second step, the Causal Loops Diagram (CLD) has been built as a synthesis of the literature review findings, and available secondary data. The CLD reveals the interactions among the defined variables. Jere Lazanski & Kljajic (2006) defined the relationship among the model, the object, and the subject of the modelling. Based on this approach, the object of the model was defined as the dynamics of residents’ irritation towards tourism development in the destination of Český Krumlov. The subject of the model is then represented by the researchers (authors) as the observers/descriptors of the model. To ground the model structure properly, searching for the support for each relation in the previous studies was necessary.

Figure 1. *Process of Model Building*

The system consists of elements (variables) and is greater than its parts. An element is the smallest part of the whole necessary for system description, which cannot or will not be divided further. The essence of the elements is particularly beneficial from the epistemological point of view. From the general point of view, a system is defined by the set: $S = (E, R)$, where $e_i \in E$, $i = 1, 2, \dots, n$ represents the set of elements, that we consider as variables in the system dynamic model (these include: *Irritation of Residents*; *Tourism Intensity*; *Natural and Cultural Tourism Potentials*; *Demand*; *Price level*; *Tourists Satisfaction*; *Economic Impacts*; *Public infrastructure capacity*; *Reinvestments*; *Available activities*; and others as shown in Figure 2) and $R \subseteq E \times E$ relations among elements (represented by symbols + and -, where plus shows increasing and minus decreasing mode of relationship between the two elements). The construction of systems requires some procedure $K(e_i) \in E$, knowledge, to identify the elements of the systems and theory $T(e_i, e_j) \in R$ to find the relationship between the elements (Ropret *et al.*, 2014). If the set of elements is connected, on a base of their descriptions with a pointed arrow in the same direction and mark this with a symbol (+), and the opposite with a symbol (-), it is possible to develop an influence diagram of the qualitative model of the simplified system. The model is kept as simple and general as possible to emphasize the interactions and their impact on tourism (Alavalapati & Adamowicz, 2000).

Dynamic Modelling

In the next step, the CLD was converted in the mathematical simulation model in the form of Stock and Flows Diagram (SFD) and validated in comparison to real-world behaviour. SFD consists of stocks that represent accumulations within a system and flows that increase (inflows) or decrease (outflows) stocks. Auxiliary variables and stocks control the flows. Therefore, a stock can be changed only via its flows, and stocks and auxiliary variables control the flows (Mai & Smith, 2018). The interrelations were constructed following the CLD structure, however, not all the variables were replicated in the feedback loops, due to the following: (1) we did not have enough information to quantify the stocks, flows and

auxiliary variables (e.g. *Satisfaction of visitors*; *WOM*); (2) we used the variables as exogenous in the SFD to use them for changing initial values and scenario simulations (e.g. *Regulation*, *Demand*); (3) to use the variable as an output indicator (e.g. *Political pressure*).

After the SFD structure construction, the model must be calibrated with parameter values to run the simulations. These parameters include (a) the initial value for stocks at the beginning of the simulation, (b) constants that are stored as auxiliary variables, and (c) graphical functions that represent the influence of one variable on another. The remainder of the SFD is parametrised using equations (Mai & Smith, 2018; Sterman, 2000). The time step of the simulation is one month, and the simulations run for 120 time-steps (10 years).

A wide set of primary and secondary data about the numbers of destination visitors, residents' attitudes, and residents' irritation from tourism in the UNESCO World Heritage tourism destination of Český Krumlov were collected to calibrate the simulation model.

The primary data was collected between 7th February and 7th March 2018 using online and face-to-face interviews. 342 responses from residents were obtained. Quotas from the viewpoint of the respondents' age and gender were used for weighting the results and ensuring their representativeness. Statistical analysis of the results was conducted using descriptive statistics, correlation analysis and chi-square tests for testing the statistical significance of the differences between various groups of residents. The results of the survey were used for calibration and validation of the simulation model.

The results of the quantitative survey show the dynamics of the residents' irritation over a year depending on the seasonality. The irritation from the time point of view is the highest, of course, in the high season (from May to September, partly in December) as shown in Figure 2.

Figure 2. Level of Residents' Irritation Over a Year (monthly)

The level of residents' irritation over a year very strongly correlates with the number of guests in collective accommodation facilities (Pearson correlation coefficient = 0.95, p-value <.0001). This measure was used as a proxy because there is no data on the number of overall visitors. One crucial finding in relation to the irritation dynamics is that there is no delay between the number of guests and the perceived level of residents' attitude over a year – the one-month delayed time series shows a lower Pearson correlation coefficient of only 0.77. These findings support our decision to deal with the irritation and its dynamics in the simulation model.

The attitudes of residents in relation to the situation of tourism intensity in the town (ten statements defined in Table 2) have been quantified using the 7-option Likert scale (Figure 3).

Table 2. *Statements defining residents' attitudes*

Statement Code	Statement
S1	Overcrowding of the town annoys me.
S2	I am annoyed at the rising prices due to the high number of visitors to the town.
S3	There are too many visitors in the town, and they are the reason for overcrowding.
S4	The bad traffic situation is caused by visitors.
S5	I am satisfied with life in the town.
S6	Local government should support tourism development.
S7	Visitors' expenditure is important for the municipal budget.
S8	I am proud that the town is frequently visited.
S9	The tourism situation influences my decision for whom to vote for in local elections.
S10	The value of my property increases due to the development of tourism in the town.

Figure 3. *Factors and attitudes affecting the residents' irritation*

The main factors related to the residents' irritation are overcrowding (Statement 1), where tourists are the reason for that (Statement 3), rising prices (Statement 2), and the traffic situation (Statement 4). However, several benefits from tourism are perceived by residents because they are generally satisfied

with life in the town (Statement 5) and mostly agree with the statement, that local government should support the development of tourism (Statement 6), and that the revenues from tourism are important for the municipal budget (Statement 7). In general, they are proud that the town is so attractive for tourists and frequently visited (Statement 8). There are also differences among some groups of residents, especially if they are somehow connected with or dependent on the tourism industry. Calibration of the simulation model, as well as the initial values, and equations are shown in Appendix 1.

Scenario planning and modelling

Based on consultation with the representatives of the town and regional Destination Management Organisation (DMO), we simulated two possible scenarios (Scenario 1 and Scenario 2) of the future tourism development in connection with the politics for reducing residents' irritation in Český Krumlov. We compare the results of these two scenarios with the base situation (Scenario 0), where no politics were presumed. Using Vensim 6 Professional software, we utilize the *SyntheSim* tool for scenario simulations.

Implementation and organizational learning

In the last step, according to the system dynamics methodology (Jackson, 2003), the recommendations for DMOs, in how to manage the rising irritation of locals from tourism as one of the crucial stakeholders in the destination, were formulated. The recommendations as well as the implementation of LTD concept, developed by Schianetz *et al.* (2007), are discussed later in the paper.

Results

Following the methodology, the presented system dynamic model represents one of the main results of the study and a holistic solution for reducing residents' irritation in urban tourism destinations. Using this complex model, a wide range of scenarios can be simulated, and variety of policies and its combinations can be tested as it is shown further in the presented case study. The simulations of various scenarios help to find the optimal solutions for particular destinations.

The System Dynamic Model as a Tool in Reducing Irritation

The system is defined by variables in the form of CLD which include several variables: *Irritation of Residents*; *Tourism Intensity*; *Natural and Cultural Tourism Potentials*; *Demand*; *Price level*; *Tourists Satisfaction*; *Economic Impacts*; *Public infrastructure capacity*; *Reinvestments*; *Available activities*; and others. The relations among variables are represented by arrows signed with symbols + and -, where plus shows increasing and minus decreasing mode of relationship between the two variables.

Figure 4 shows the CLD which maps the interactions between visitors and residents. The model consists of 16 endogenous variables (linked to any other element) and 6 exogenous variables, directly or indirectly influencing the residents' irritation. Exogenous variable means that they are not the components of any causal loops and there is no link entering this variable. The reason is that this variable is intended as external factor and cannot be influenced within the structure of the model, or this variable is used for scenario analysis in the next step of simulation modelling, for example, *Visitor management*, or *Dependence of locals on tourism*).

Figure 4. *System Dynamics Model of Residents' Irritation (Causal Loops Diagram)*

The CLD includes various feedback loops influencing the dynamics of residents' irritation. The loops can be both balancing and reinforcing and the interconnections (arrows) are marked with positive polarity (+), for example, *Destination visitors* increase (+) *Tourism intensity*; or negative polarity (-), for example, *Irritation of residents* causes a negative (-) *Welcoming behaviour of the residents*. The delay is marked with an interruption of the arrow ($\neq$). The CLD presents the qualitative (conceptual) descriptions of the systems to identify the complexity of the researched problem.

The *Irritation of residents* variable plays a dominant role in the model. A deeper look at the model can distinguish four clusters of primary importance, which strongly interact with other components of the model: (a) irritation of residents; (b) destination visitors; (c) tourism intensity; and (d) demand. Table 3 briefly describes the particular interactions under the main CLD clusters and contains references to information sources on which the variables and interactions were defined.

Table 3. Interactions between the Main CLD Clusters

Main Cluster	Interaction	Polarity	References
<i>Irritation of residents</i>	Irritating behaviour of visitors	+	Andereck et al., 2005; Byrd et al., 2008;
	Tourism intensity	+	Brida et al., 2011; Gursoy & Rutherford, 2004; McCartney & Weng In, 2016;
	Price level	+	Ozturk et al., 2015; Page, 2007; B. Sharma & Dyer, 2009; Simão & Partidário, 2012; Stylidis et al., 2014
	Effect of value on local property	-	
	Public infrastructure	-	
	Available activities	-	
	Dependence of locals on tourism	-	
	Natural and cultural tourism potential	-	
<i>Destination visitors</i>	Demand	+	Basterretxea-Iribar et al., 2019; Chan & Lim, 2011; Goh & Law, 2002; Hylleberg, S. & Mizon, G. E., 1989; Kim & Moosa, 2001; Koc & Altinay, 2007; Nunkoo & Smith, 2013; Song & Li, 2008; Song & Witt, 2006; Y. Wang & Pizam, 2011
	Regulation	-	
	Seasonality	+	
	Transport and accommodation capacity	+	
<i>Tourism intensity</i>	Destination visitors	+	Choi & Sirakaya, 2005; Cooper, 2008; Edgell, 2015; Martín, 2011; Simão & Partidário, 2012; Wan & Li, 2013
	Destination carrying capacity	-	
	Visitor management	-	
<i>Demand</i>	Price level	-	(Abubakar et al., 2017; Burger et al., 2001; Cheng et al., 2013; Crouch, 1995; De Vita & Kyaw, 2013; Formica, 2006; Kulendran & King, 1997; Kulendran & Witt, 2003; Law et al., 2004; Nasir et al., 2015; Nelson et al., 2011; Peng et al., 2012; Simpson & Siguaw, 2008; Song & Li, 2008; Song & Witt, 2006)
	Natural and cultural tourism potential	+	
	Reinvestment	+	
	WOM	+	
	Available activities	+	

Exogenous variables are included in the model to test different policies and scenarios using these variables.

The CLD was then converted in the mathematical simulation model in the form of SFD. The interrelations were constructed following the CLD structure, however, not all the variables were replicated in the feedback loops, as it was mentioned in the methodology. The feedback loops and interactions that were replicated are highlighted in Figure 4.

Český Krumlov represents a urban destination with high tourism intensity and negative impacts on the local community. The number of arrivals in the town has been increasing rapidly. Consequently, the intensity of tourism activity has also been rising steeply and constantly. The biggest problems perceived by residents were identified as traffic, rising prices, and overcrowding of the town centre (Valtrová, 2018). High tourism demand and, subsequently, high number of visitors use public infrastructure (such as roads, pavements, relaxing zones, parks, water supply etc.) and offered activities (such as cultural facilities, entertainment, or sport facilities), decreasing their availability to locals, on one hand. On the other hand, tourism activities generate positive economic impact for the town and its derived revenue may be used for reinvestment. Local government works under pressure and tries to solve the problems that cause rising residents' irritation as a result of tourism activities. Therefore, we have chosen this part

of CLD for simulation to show, how the set of policies (such as regulations, or visitor management) can reduce the residents' irritation from tourism in the long-term planning period. The SFD model is shown in Figure 5.

Figure 5. *System Dynamics Model of Residents' Irritation (Stock and Flows Diagram)*

The system dynamic simulation model is the main output of the study. The model enables to run infinite number of simulations and, thus, to test wide range of policies and their combinations. This system dynamic model represents a holistic solution and an effective tool which can be applied in practice in urban destinations. Testing combinations of different policies it is possible to find an optimal solution how to reduce or stabilize the residents' irritation in a long-term period.

As an example, we simulate various scenarios of the possible future development of the Český Krumlov Town as a tourism destination. To find an optimal solution for stabilizing the residents' irritation in the long term it was necessary to combine various policies (to set more parameters of simulation) as it is shown further in the paper. In fact, we would not be able to find the optimal set of measures in correct volume without the complex structure of the model and simulation possibilities.

The Case of Český Krumlov – Simulation Results

To present the functionality of the model and simulation possibilities, we simulated two possible scenarios (Scenario 1 and Scenario 2) of a future tourism development in connection with the policies for reducing residents' irritation in Český Krumlov. We compare the results of these two scenarios with the base situation (Scenario 0), where no policies were presumed.

Scenario o – Base situation

In this scenario, the whole model has been calibrated to reflect the present situation of the destination of Český Krumlov. Demand is higher than both transport and accommodation capacity, destination carrying capacity and capacity of public infrastructure, in this scenario.

We are also leaving reinvestments on the same level leading to reproduction and small growth (2% p.a.) of public infrastructure capacity, available activities, and natural and cultural potential. There is no regulation or management of visitors.

Figure 6. Simulation Results (Scenario o)

As we can see from the Figure 6, if we do nothing, irritation of residents increases together with increasing number of destination visitor days. This leads to growing political pressure as well.

Scenario 1 – Is regulation leading to lower residents' irritation?

One of the obvious policies to deal with the problem of overtourism is better visitor management, i.e. dispersion of visitors over other places within destination or better time management during their visit using different tools such as parking time slots or fees.

Český Krumlov introduced such a solution in June 2019 – online booking of time slots for bus parking and fees for buses. In our simulation model, this was represented by two changes – setting up fees to EUR 2.00 and regulation to 200,000 persondays/month (4,000 buses/month, 133 buses/day).

The simulation results show short-term improvement in the residents' irritation during peaks (Figure 7). But if the demand is steadily rising, one of the outcomes is in price level which could increase more than in the base scenario. It means, higher irritation may be at the end caused by this effect more than by the number of visitors alone. Moreover, destination could have less financial resources. However, there are also some other benefits: lower use of public infrastructure by tourists; higher value of local property; and lower deterioration of natural and cultural potential.

Figure 7. *Simulation Results (Scenario 1 vs. Scenario 0)*

To summarize this case, such a regulation helps to decrease the overall irritation especially in peak times when overcrowding occurs but may not be sufficient to keep resident irritation lower in longer term due to the effect of price level increase and seasonality changes.

Scenario 2 – How to keep the residents' irritation stable?

In the scenario 1, regulation together with a fee was used to influence the irritation of residents. However, these changes were not successful enough in long term. It is thus necessary to use more advanced approach combining visitor management (number of visitors, time and space management of visitors, attracting less obtrusive visitors) with benefits for residents.

One such a combination is in comparison to Scenario 1 related to higher investment of financial resources from tourism into available activities for locals and public infrastructure as well as steady increasing of fee per visitor (transport, parking, accommodation) from EUR 2.00 to 18.00 in 10 years. The results of Scenario 2 simulation are shown in Figure 8.

Figure 8. *Simulation Results (Scenario 2 vs. Scenario 1 vs. Scenario 0)*

Another possibility is related to the structure of visitors, it means attracting less problematic ones, but again that would be solution for a limited time only. And the last option is in making residents more directly dependent on tourism.

Discussion

Managing residents' attitude towards tourism development in tourism destinations has often been discussed in previous research studies (Dyer *et al.*, 2007; Gursoy *et al.*, 2002; Milman, 2004; Ozturk *et al.*, 2015; B. Sharma & Dyer, 2009; Styliadis *et al.*, 2014; Xie *et al.*, 2014; Zhang *et al.*, 2018). However, there is a lack of studies explaining the dynamics of negative attitudes and how to reduce locals' irritation within the process of managing tourism development in urban destinations.

The number of visitors in a tourism destination increases residents' irritation. However, the Doxey's theory of residents' irritation has been widely criticised (Gerritsma & Vork, 2017), we considered this approach, which has been used by some researchers recently (Irandu, 2004; Milman, 2004; Zhang *et al.*, 2018), as a general assumption and the basis for our model. This concept works well in destinations in Butler's (1980) phases of late development, consolidation, stagnation, and slight decline, or rejuvenation. We considered the irritation as the level of annoyance more than the Doxey's (1975) Irrindex stages. We use the Doxey's theory only to validate the relationship between the tourism intensity and resident's irritation in the model. However, the irritation itself was influenced by other factors in our case. The residents' irritation (annoyance) has been proven in the case of Český Krumlov. The level of residents' irritation over a year very strongly correlates with the number of guests in collective accommodation facilities (Pearson correlation coefficient = 0.95, p-value <.0001). These findings supported our decision to deal with the irritation and its dynamics in the simulation model.

Several authors (Jere Jakulin, 2016; Štumpf & Vojtko, 2016; Vojtko & Volfová, 2015) regard residents as only one of the stakeholders or part of the destination environment in the system dynamic models. None of the studies are aimed at managing residents' attitude toward tourism development and the dynamics of irritation of the local community. Therefore, our ambition was to fill the gap using system dynamics for modelling policies for irritation reduction and stabilization in urban tourism destinations. Furthermore, we assume the proposed system dynamic model as a unique tool for DMOs to aid with understanding and dealing with the leverage points, which determine the dynamics of residents' irritation.

Conclusions

The main ambition of this study was to reveal the dynamics of residents' irritation from tourism development in a tourism destination and to find efficient solutions for its reduction.

From the theoretical viewpoint, our research extends the current knowledge to the use of system dynamics modelling for a sustainable tourism development in a destination. We present the complex method for modelling residents' irritation as a part of social sustainability in the tourism destination with respect to the environmental dimension and economic contributions of tourism.

The case study has shown that regulation of the number of visitors helps to decrease the overall irritation especially in peak times when overcrowding occurs but may not be sufficient to keep residents' irritation lower in long-term period.

Theoretical contribution

Based on the literature review, we can state that there was a need for a progressive research approach and analytic tools to effectively manage residents' attitudes towards tourism development over a long-term horizon (Choi & Sirakaya, 2005; Khazaei *et al.*, 2015). Firstly, presented system dynamic simulation model represents the main theoretical contribution of the study. The model enables to run infinite number of simulations and, thus, to test wide range of policies and their combinations. This complex model extends current theory in the field of residents' attitudes in tourism destinations with high tourism intensity suffering from the "Venice Syndrome" (Capocchi *et al.*, 2019). Secondly, this study contributes to the current knowledge of systems theory. To the best of our knowledge, none of the published studies focuses on residents in a tourism destination from the system dynamics point of view.

Managerial implications

The proposed system dynamic model is considered as a unique tool for DMOs to understand and deal with the soft systems and tourism development policies which determine the dynamics of residents' irritation and has a broad practical implication. Using simulations, destination management activities

can be aimed at reducing the residents' irritation with the systematic explanation. The model enables to simulate different combinations of policies, to test their effectiveness and to find the optimal solutions to reduce residents' irritation.

Based on the simulation results, the recommendation for DMOs can be as follows: (1) the regulation of the number of visitors helps to decrease the overall irritation especially in peak times but may not be sufficient to keep resident irritation lower in longer term; (2) to reduce irritation in long-term period, it is necessary to use more advanced approach combining visitor management (number of visitors, time and space management of visitors, attracting less obtrusive visitors) with benefits for residents.

However, there are other ways to reduce the overall irritation of residents. This can include involving residents in tourism industry, because there are significant differences between various groups of residents in their attitudes towards tourism development (Lundberg, 2015). The influx of new inhabitants, who are attracted by the vision of possible economic advantages, generally increases the dependence of the locals on tourism. The question is whether, this is a sustainable way of dealing with residents' irritation because it can increase the tensions between the old residents and new incomers.

The actual irritation from overcrowding also seems to be strongly dependent on the actual number of visitors. This has one important consequence – it might be helpful from this perspective to introduce relief periods for residents to allow their recovery. The proposed model is also useful for simulations of various scenarios in connection with the post-COVID-19 travel behaviour. This crisis of tourism showed enormous and sudden drop of international travelling and likely also the reduction of residents' irritation from overcrowding. However, they may perceive their economic dependence on the travel and tourism industry more than in the past. Finally, a quick recovery of travelling and fast growth of tourists, in combination with a fear of COVID-19 disease, can lead to a rapid increase of residents' irritation, especially those who are not involved in travel and tourism industry. The simulations of the post-COVID-19 scenarios represent a big challenge for the future. These examples outline the necessity of a complex and systemic approach in managing the residents' irritation towards tourism development in destinations. Therefore, we consider our conceptual model as a useful tool for decision-making support and sustainable destination development in the post-COVID-19 era.

Limitations and suggestions for future research

We used data about residents' irritation and attitudes towards tourism only from one year and thus, it was not possible to track residents' irritation over the long period of time. Therefore, we cannot see the detailed changes between years. We consider this as a limitation of our research study. To fully understand the dynamics, long-term tracking would be necessary, which we suggest as an avenue for future research.

The proposed model will be used for simulations in the post-COVID-19 era, where the complex and system approaches will be much appreciated to understand the changing travel and tourism world.

The systems approach and complex system dynamics modelling deserve more attention in the future research, in terms of social, environmental, and economic sustainability in tourism destinations. These methods represent the scientific tools that can provide balanced, optimal results, when one uses them properly. Thus, the main task for future research is to verify and precise the proposed simulation model in other urban destinations. Testing of the model on the set of urban destinations, analyzing the efficiency of different policies and scenarios, comparing them with the reality in the period of time, and developing a more accurate model based on empirical data are the main aim of the future research.

Appendix 1. Initial values, equations and calibration of the simulation model

Type of variable	Name of variable	Unit	Initial value	Equation	Comment
Stock	Tourism financial resources	EUR	0	INTEG (Inflow of TFR-Use of TFR)	Public infrastructure available for locals (13 thousand inhabitants) and visitors (such as roads capacity, water etc.) Index showing relative changes in the value of base price level in the beginning of simulation
Stock	Total economic impact	EUR	0	INTEG (Economic impact)	
Stock	Public infrastructure capacity	personday	500000	INTEG (Improvement of PIC-Deterioration of PIC)	
Stock	Price level	Dmnl.	1	INTEG (Changes in PL)	Taken from the number of accommodated tourists as provided by the Czech Statistical Office + estimate of one-day visitors provided by the Cesky Krumlov municipality Scale between 0 (no potential) and 1 (extremely high potential)
Stock	Destination visitordays 12M	personday	2000000	INTEG (Destination visitordays-DVD out)	
Stock	Standardized demand	personday/year	1250000	INTEG (Changes in SD)	
Stock	Available activities	Dmnl.	0.5	INTEG (Improvement of AA-Deterioration of AA)	Proportion of economic impact as financial resources available (8 %)
Stock	Natural and cultural tourism potential	<0,1>	0.75	INTEG (Improvement of NCTP-Deterioration of NCTP)	
Stock	Transport and accommodation capacity	personday	2000000 / 12	INTEG (Changes in TAC)	
Flow	Inflow of TFR	EUR		Economic impact * 0.08	Exogenous trend is 2% growth of demand per year
Flow	Use of TFR	EUR		Re-investment to PIC + Re-investment to AA + Re-investment to NCTP	
Flow	Economic impact	EUR		Destination visitordays * Revenue per visitor	
Flow	Deterioration of PIC	personday		0.005 * Public infrastructure capacity	Unmet demand * Price level * 0.05 + Exchange rate effects MIN(Regulation, MIN(Seasonal demand, Transport and accommodation capacity))
Flow	Changes in PL	Dmnl.		Unmet demand * Price level * 0.05 + Exchange rate effects	
Flow	Destination visitordays	personday		DELAY FIXED(Destination visitordays, 12, Destination visitordays 12M / 12)	
Flow	DVD out	personday			Exogenous trend is 2% growth of demand per year
Flow	Changes in SD	personday/year		(0.1 / 12) * Standardized demand	

Type of variable	Name of variable	Unit	Initial value	Equation	Comment
Flow	Deterioration of AA	Dmnl.		$0.005 * \text{Available activities}$	
Flow	Improvement of NCTP	Dmnl.		$\text{MIN}(1 - \text{Natural and cultural tourism potential} + \text{Deterioration of NCTP}, 0.006)$	
Flow	Deterioration of NCTP	Dmnl.		$0.005 * \text{Natural and cultural tourism potential} * \text{Tourism intensity}$	
Flow	Changes in TAC	personday		$\text{Exogenous trend is 2\% growth of demand per Year.}$	
Constant	Improvement of AA	Dmnl.		0.0075	
Constant	Improvement of PIC	personday		4000	Increase of capacity through investment + depreciation
Constant	Exchange rate effects	Dmnl.		0	
Constant	Cost per PIC unit	EUR		120	Estimate from Cesky Krumlov budget
Constant	Cost per AA unit	EUR		1200000	
Constant	Irritating behaviour of visitors	Dmnl.		0.7	Scale between 0 (not irritating) and 1 (extremely irritating)
Constant	Regulation	personday		200000	
Constant	Destination carrying capacity	personday		1800000	
Constant	Dependence on tourism	Dmnl.		0.2	Proportion of inhabitants dependent on tourism. Estimate from our primary data collection
Constant	Visitor Management	Dmnl.		0	0 means no management, 1 halves the tourism intensity
Constant	Local need for PIC	personday		$13000 * 30$	13 thousand inhabitants multiplied by number of days in a month.
Constant	Fees	EUR		3	
Constant	Base revenue	EUR/personday		50	
Auxiliary	Irritation of residents	$<0,1>$		$\text{MIN}(1, \text{MAX}(0, 0.2 * \text{MAX}(0, \text{Tourism intensity} - 0.5) + 0.25 * \text{Irritating behaviour of visitors} + 0.25 * \text{Price level} + 0.15 * (1 - \text{PIC availability for locals}) - 0.05 * \text{Natural and cultural tourism potential} - 0.05 * \text{Available activities} + 0.05 * \text{Value of local property} - 0.1 * \text{Dependence on tourism}))$ $\text{WITH LOOKUP}(\text{MODULO}(\text{Time}, 12), ((0,0)-(1,1)), (0,0.06), (1,0.038), (2,0.04), (3,0.05), (4,0.08), (5,0.09), (6,0.11), (7,0.15), (8,0.14), (9,0.1), (10,0.09), (11,0.06)))$	Scale between 0 (no irritation) and 1 (extremely high irritation)
Auxiliary	Seasonality	Dmnl.		$(1,1), (0,0.06), (1,0.038), (2,0.04), (3,0.05), (4,0.08), (5,0.09), (6,0.11), (7,0.15), (8,0.14), (9,0.1), (10,0.09), (11,0.06))$	Calculated from number of overnights within a year
Auxiliary	Unmet demand	Personday		$\text{Unmet demand} * \text{Price level} + \text{Fees} / \text{Base revenue}$	Proportion of demand which is not fulfilled
Auxiliary	Effect of PL on demand	Dmnl.		$\text{WITH LOOKUP}(\text{Price level} + \text{Fees} / \text{Base revenue}, ((0,0)-(10,5)), (0,5), (1,1), (2,0.5), (3,0.2), (4,0.1), (5,0)))$	
Auxiliary	Seasonal demand	personday		$\text{Standardized demand} * \text{Seasonality} * \text{Effect of PL on demand}$	

Type of variable	Name of variable	Unit	Initial value	Equation	Comment
<i>Auxiliary</i>	Re-investment to PIC	EUR		Improvement of PIC * Cost per PIC unit * MAX(o, Public infrastructure capacity - Local need for PIC) / Public infrastructure capacity	
<i>Auxiliary</i>	Re-investment to AA	EUR		Improvement of AA * Cost per AA unit	
<i>Auxiliary</i>	Re-investment to NTCP	EUR		Improvement of NCTP * Marginal cost per NCTP unit	
<i>Auxiliary</i>	Marginal cost per NTCP unit	EUR		WITH LOOKUP (Natural and cultural tourism potential, ((o,o)-(1,200000)),(o,o),(o,2,5000),(o,4,20000),(o,6,50000),(o,8,100000),(1,200000)))	
<i>Auxiliary</i>	Value of local property	Dmnl.		Price level	Index showing relative changes in the value of base local property
<i>Auxiliary</i>	Revenue per visitor	EUR/personday		Base revenue * Price level + Fees	Base is 50 EUR/personday. Estimate from profile of visitors survey.
<i>Auxiliary</i>	PIC availability for locals	Dmnl.		MIN(1, (Public infrastructure capacity - Destination visitor days) / Local need for PIC)	Between 0 and 1 (100% availability). When the availability is limited, irritation rises.
<i>Auxiliary</i>	Tourism intensity	Dmnl.		(Destination visitor days / (Destination carrying capacity / 12)) / (1 + Visitor management)	Tourism intensity higher than 1 means overcrowding
<i>Auxiliary</i>	Welcoming behaviour of residents	Dmnl.		1 - Irritation of residents	
<i>Auxiliary</i>	Political pressure	Dmnl.		MAX(o,1, Irritation of residents - 0,5)	

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