

# A Decade of System Dynamics Modelling for Tourism: Systematic Review

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**Abstract:** Global rapid growth of tourism requires innovative methods of exploration of its complexity. Researchers and stakeholders can benefit from computational modelling approaches, including system dynamics models. A systematic review of system dynamics models in tourism following the PRISMA guideline was undertaken. The review was focused on which tourism-related topics were studied, what were the purpose and the temporal scale of models, what main variables and diagrams were used. Scientific databases were searched to identify contributions from 2010-2019; finally, 46 publications were selected as relevant. Thematically, the papers focused on marine tourism, negative impacts of tourism, sustainable tourism, low-carbon economies, decision making, and policy making, and planning for tourism in a broad sense. From the modelling perspective, stock and flow diagram and causal loop diagrams were presented in most of the papers, while systems archetypes were rarely used. System dynamics models have the potential to support research in the field of tourism. The number of papers grows significantly, and the attention of researches moves from case studies to sustainable tourism, negative impacts of tourism and how to manage them.

**Keywords:** tourism; system dynamics model; systematic review

**JEL Classification:** Z30; Z32; C39

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## 1. Introduction

Tourism was defined as the temporary, short-term movement of people to destinations outside the places where they normally live and work and their activities during the stay at each destination. It includes movements for all purposes (Beaver 2002). Nowadays, tourism is a highly important part of an economy: according (WTTC 2019) the Travel and Tourism sector accounted for 10.4% of global GDP and 319 million jobs, or 10% of total employment in 2018. On the other hand, tourism is accompanied with negative externalities such as overcrowding, a decline of living standards of locals, high demand for goods and services, pollution and devastating of natural resources, and more. Human society and tourism can be understood as a complex system and the process taking place in it. Therefore, it is possible to apply various computational modelling approaches including models of system dynamics.

System dynamics (SD) helps us to understand the nonlinear behaviour of complex systems over time (Forrester 1961, 1969). To achieve this, models are developed using stocks, flows, internal feedback loops, table functions, and time delays. These artefacts are composed of two main types of diagrams: Stock and Flow Diagram (SFD) and Causal Loop Diagram (CLD). Typically, CLP captures cardinal variables of the system and defines relationships between them. A Systems Archetypes is a universal type of CLD, well applicable in most domains. SFD capture the dynamics of systems, it might be used for predicting the future behaviour of the system, evaluating scenarios, testing extreme settings, boundary testing or sensitivity analysis.

## 2. Methodology

A systematic review following the PRISMA guideline. It was managed in order (1) to map the decade of system dynamics modelling in tourism and (2) to identify new research opportunities. Three questions were sought:

1. Which tourism-related topics have already been studied using the system dynamics modelling approach?
2. What were the purpose and the temporal scale of models?
3. What modelling platforms and what system dynamics diagrams were applied?

The search was undertaken using the scientific databases (Scopus, Scinapse, Google Scholar, LENS). The review includes full texts published in English. The search was conducted in September-December 2019. We included articles published within a decade (2010-2019). The selection criteria and data collection strategy focused on two main topics: *system dynamics* and *tourism*. Cross-searching was carried out using search terms *tourism*, *system dynamics model*, *system dynamics approach*, *system thinking*, *stock and flow diagram*, *causal loop diagram*, *system archetype* (few queries are presented in Table 1).

**Table 1.** Search in databases.

Database	Query	Results
Scopus	TITLE-ABS-KEY ( "system dynamics" AND "tourism" ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )	67
Scinapse	"system dynamics" and "tourism"	40
Google Scholar	allintitle: tourism "system dynamics"	37
LENS	( Title: ( tourism "system dynamics" ) OR ( Abstract: ( tourism "system dynamics" ) OR ( Keyword: ( tourism "system dynamics" ) OR Field of Study: ( tourism "system dynamics" ) ) ) ) (Filtering: journal articles)	87

Abstract and keywords of papers were screened to reject papers we identified as not fulfilling our inclusion criteria. Full-text papers were included if they satisfied eligibility criteria as follow: tourism-related theme (e.g. including management of tourism, destination management, development of tourism, negative impacts of tourism, and/or complexity of tourism, tourism case studies) and application of system dynamics modelling (including systems archetypes, stock and flow diagram, causal loop diagram, and/or system dynamics equations).

We used bibliometric networks for meta-analyses. We chose VOSviewer as software for quantitative synthesis. We focused on the change of keywords related to tourism over time. For that, the keywords related to system dynamics were extracted. VOSviewer allowed us to use overlay visualization, which captures the timeline of selected variables. Items for meta-analysis were extracted from Scopus records.

## 3. Results

### *Study selection*

We identified 231 results from scientific databases. After removing duplicates, we get 128 papers, from which 61 papers were passed to the stage of full-text assessment for eligibility (the rest of 15 full-text papers were rejected). Finally, we obtained 46 papers suitable for both qualitative and quantitative synthesis. The whole process is shown in Figure 1.

Studies selected are presented in Table 2 in descending order by date of publication. The majority (70%) of studies were published within the last five years (2015-2019), more than one third (39%) of papers were published 2018-2019.

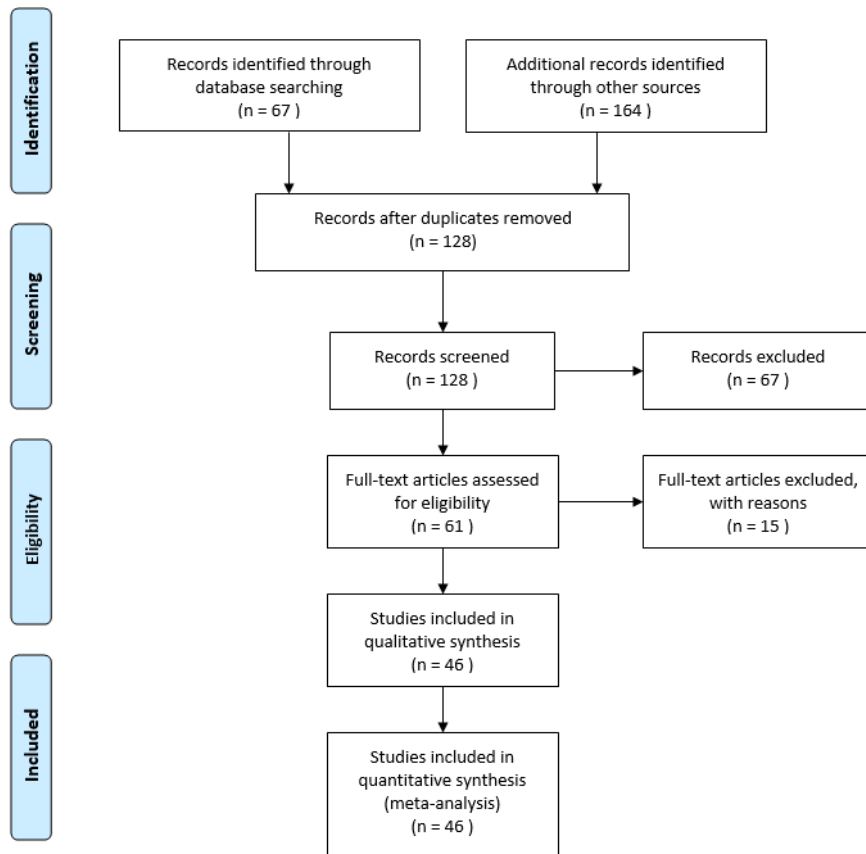


Figure 1. PRISMA flow diagram.

### Results of individual studies

The largest proportion of papers focus on sustainable tourism. Typically, authors tested the impact of different protentional policies on the state of the environment and ecotourism demand, see e.g. (Aliani et al. 2018).

(Zhang et al. 2015) explore sustainable tourism in Tibet under different scenarios up to 2050 through CLD and SFD, outputs of the simulation are employment caused by tourism, the value of tourism enterprise, pollution, and the number of visitors.

(Nguyen and Bosch 2013) identify key variables of sustainability in a touristic area in the Cat Ba Biosphere Reserve Vietnam; for that purpose, authors created CLD and applied systems archetypes such as *fixes that fail* (tourism development), *tragedy of the commons* (carrying capacities in tourism), *shifting the burden* (international aid).

(Xing and Dangerfield 2011) focus on the sustainability of mass tourism within island economies. Authors created complex SFD aimed at transport, number of visitors, water and energy supply, waste, and accommodation capacities. Outputs of the simulation are the prediction of the total number of visitors, the impact of tourism on prices, the requirement of new accommodation capacities for 720 months under different scenarios. (Widhianthini 2017) aim at sustainable planning of touristic villages in Bali in cooperation with local institutions, simulation outputs are the prediction of areas of paddy fields, settlements, green space, and sacred places up to 2030 under several scenarios.

(Nugroho et al. 2019) focus on the sustainability of marine protected areas in the case study of Pieh marine park. Their first SFD captures renewable resources, non-renewable resources, and pollution, while CLD shows relationships between main factors of the marine park (fish population number of visitors, pollution, condition of coral reef). The main SFD connects the main variables of the marine park. The simulation was developed to predict fish and coral populations and pollution up to 2040 under different scenarios.

Similarly, (Vugteveen et al. 2015) study the socioecological system in the Dutch Wadden Sea region through the model of sustainable fisheries and the model of tourism. The touristic sub-model shows variables measuring the number of visitors, their satisfaction, proportions of fauna and flora, investments in tourism, and sustainability.

(Alcalá et al. 2015) focus on the sustainability of groundwater in an agricultural and touristic area, with the case study of Amtoudi Oasis in Morocco. Their CLD captures the hydrological-economic model and water management. The output of the simulation is the prediction of the number of visitors and the local population for the next 100 years.

Few papers discuss tourism in general; for example (Lu et al. 2019) analyse ecological system security in the case study of the coastal tourist city of Dalian in China. CLD shows relationships between variables related to tourism, economics, and the environment. SFD mainly focuses on GPD, the number of visitors, and population size. Outputs of the simulation are the prediction of the number of visitors, income from tourism, and marine pollution up to 2028 under three different scenarios.

Other papers study seaside tourism. (You et al. 2018) focus on landscape changes in coastal areas of South Korea. SFD was used to show changes in areas of a coastal sand dune, coastal grassland, coastal forest in relation to tourism infrastructure up to 2054. The authors created two different scenarios: the first one focuses on the erosion of land and the value of ecosystem services. The second scenario was modified to address the impact of the landscape plan and its impact on ecosystem services.

(Chiu et al. 2019) created a system dynamics model to simulate land use of the Chiku coastal zone in Taiwan. The model focuses on the long-term period, and the main goal of the model was to analyse and to improve regional carbon balance. Outputs of the simulations are the prediction of land use, population, tourism, and carbon dioxide absorption and emissions up to 2065.

(Shen 2019) analyses recreation opportunities of Long Island Marine Stone Forest Park. The model was validated through a data survey. The output of the simulation was the prediction of the number of visitors up to 2025.

Only a minority of papers use system dynamics for decision making. (Tan et al. 2018) created a decision support system based on the system dynamics model of sustainable tourism, with the case study of the coastal zone in Cijing Kaohsiung in Taiwan. Both CLD and SFD show main forces related to tourism and pollution in the coastal zone. Outputs of the simulation are the tourism area, number of visitors, size of local population, state of ecosystem, and economic value index under different scenarios. Outputs of the simulation suppose to improve the decision making of stakeholders.

Negative impacts of tourism were studied by (Phan et al. 2016; Koenigstein et al. 2016; Walsh and Mena 2014). For example (Phan et al. 2016) analysed the conservation status and viability of the critically endangered Cat Ba Langur, CLDs show the conservation status of the monkeys, forest habitats and species population, and the international help.

The impact of ocean warming on the Barents Sea region was described by (Koenigstein et al. 2016): system dynamics model focuses on changes in ocean life and its impact on fisheries, tourism, and recreation, the output of the simulation is a prediction of the amount of the biomass inside an area such as Herring, Seals, and Krill, up to 2075 under different scenarios. Furthermore, the authors predict economic, political, and environmental factors.

Some papers explore waste production caused by tourism. (Estay-Ossandon and Mena-Nieto 2018) studied municipal solid waste generation in touristic islands with an application on a case study of the Balearic Islands. The study predicts the solid waste production by locals and visitors up to 2030 under several scenarios.

(Kapmeier and Gonçalves 2018) explore the waste production through the case study of Maldives. SFD shows economic growth and environmental pollution; the main variables were the number of visitors, amount of waste, and tourism demand and supply. Furthermore, the waste sub-model was processed in detail. Outputs of the simulation are the prediction of tourists per year, revenue per year, and the amount of waste per year up to 2050 under several scenarios.

Table 2. Studies selected

Citation	Domain	Purpose	Results, outputs, variables	Temporal scale	Scenarios	Platform	SD artefacts
1 (Brennan et al. 2019)	Seaside tourism	Increase literacy	Visitors, accommodation	30 Years	No	sd.js	CLD, SFD
2 (Yin et al. 2019)	Planning	Study the safety of overcrowded areas	Identification of feedback loops	Not specified	No	Vensim	CLD
3 (Nugroho et al. 2019)	Sustainable tourism	Improve the effectiveness of sustainability area	Number of visitors, pollution	2003-2040	No	Vensim	CLD, SFD
4 (Chiu et al. 2019)	Seaside tourism	Simulate land use	Land use	2000-2070	Yes	Vensim	CLD
5 (Lu et al. 2019)	Tourism in general	Analyse ecological system security	Number of visitors, income, pollution	2001-2028	Yes	Vensim	CLD, SFD
6 (Shen 2019)	Seaside tourism	Analyse the potential of the destination	Number of visitors	2013-2025	No	Not specified	CLD
7 (Cheng et al. 2019)	Destination management	Find out the possibility of land use	Land use	2011-2025	No	Vensim	SFD
8 (Novani et al. 2019)	Tourism in general	Improvement of tourism	Number of visitors, their satisfaction	2013-2023	Yes	Powersim	CLD
9 (Haraldsson and Ólafsdóttir 2018)	Destination management	Analyse destination and visitors	Identification of feedback loops	Not specified	No	Not specified	CLD
10 (Aliani et al. 2018)	Sustainable tourism	Predicate future of ecotourism	Population, infrastructure	2005-2025	Yes	MapSys	SFD
11 (You et al. 2018)	Seaside tourism	Show change in the landscape	Land use	2014-2054	Yes	Stella	SFD
12 (Tegegne et al. 2018)	Destination management	Show image of Ethiopia	Number of visitors	Not specified	No	Vensim	CLD, SFD
13 (Estay-Ossandon and Mena-Nieto 2018)	Waste production	Show main producers	Waste production	2000-2030	Yes	Vensim	SFD
14 (Kapmeier and Gonçalves 2018)	Waste production	Analysed the waste production	Number of visitors, waste production	1979-2050	Yes	Vensim	SFD
15 (Bempah 2018)	Destination management	Analyse tourism in the national park	Number of visitors, income, land-use	2008-2029	Yes	Powersim	CLD, SFD

16	(Mona 2018)	Tourism in general	Study visitors of Cape Town	Number of visitors	2015-2055	No	Stella	SFD
17	(Sampedro et al. 2018)	Island tourism	Study the food-supply system in Galapagos	Tourism, labor, consumption	2012-2037	Yes	Vensim	SFD
18	(Tan et al. 2018)	Sustainable tourism	Decision support system	Number of visitors, population size	30 years	Yes	Stella	CLD, SFD
19	(Widhianthini 2017)	Sustainable tourism	Sustainable planning	Land use, water use	2009-2030	Yes	Powersim	SFD
20	(Matthew et al. 2017)	Low carbon policy	Analyse the impact of low-carbon law	Electricity use	2005-2050	Yes	Vensim	CLD
21	(Phan et al. 2016)	Negative impacts	Analyse the state of endangers animal	Identification of feedback loops	Not specified	No	Vensim	CLD, archetypes
22	(Koenigstein et al. 2016)	Negative impacts	Analyse the Barents Sea area	Amount of ocean creatures	2015-2075	Yes	Stella	CLD, SFD
23	(Halioui and Schmidt 2016)	Tourism in general	Analysis of tourism sector in Tunisia	Recognition of feedback loops	Not specified	No	Vensim	CLD
24	(Jere Jakulin 2016)	Agritourism	Decision Support System	Number of visitors, level of agritourism	Not specified	No	Powersim	CLD, SFD
25	(Alcalá et al. 2015)	Sustainable tourism	Analyse the state of underground water	Number of visitors, population size,	100 years	Yes	Not specified	CLD
26	(Zhang et al. 2015)	Sustainable tourism	Planning sustainability in Tibet	Number of visitors, employment	2000-2050	Yes	Vensim	CLD, SFD
27	(Vugteveen et al. 2015)	Sustainable tourism	Analyse the Dutch Wadden Sea region	Number of visitors, fauna, flora	Not specified	No	Vensim	CLD, SFD
28	(Li et al. 2015)	Destination management	Analyse the impact of new infrastructure to tourism	Number of visitors, production	2000-2018	Yes	Vensim	CLD, SFD
29	(McGrath* et al. 2015)	Sustainable tourism	Decision Support System	Land use	Not specified	Yes	Powersim	CLD, SFD
30	(Ran 2015)	Sustainable tourism	Minimize the harmful effects of tourism	Number of visitors, water consumption	1990 - 2100	Yes	Stella	SFD
31	(Vojtko and Volfová 2015)	Sustainable tourism	Analyse sustainable regional tourism	Identification of feedback loops	Not specified	No	Vensim	CLD

32 (Provenzano 2015)	Destination management	Analyse tourism in Sicily	Identification of feedback loops	Not specified	No	Powersim	CLD
33 (Walsh and Mena 2014)	Negative impacts	Analyse threats to the national park	Number of visitors, land use,	Not specified	No	Not specified	SFD
34 (Ropret et al. 2014)	Destination management	To improve tourism in Slovenia	Identification of feedback loops	Not specified	No	Other	CLD
35 (Luo et al. 2014)	Low carbon policy	Analyse the impact of decarbonization on tourism	Carbon emission	2013-2025	No	Vensim	CLD, SFD
36 (Liao et al. 2014)	Sustainable tourism	Analyse the impact of sustainability on tourism	Number of visitors, quality of the environment	2000-2100	No	Vensim	CLD, SFD
37 (Hsiao and Hsu 2014)	Agritourism	Forecast need of human recourses	Number of staff	120 months	Yes	Vensim	CLD, SFD
38 (Asasupakit and Thiengburanathum 2014)	Decision making	Decision Support System	Identification of feedback loops	Not specified	No	Vensim	CLD, SFD
39 (Lee and Lin 2014)	Sustainable tourism	Decision Support System	Number of visitors, touristic area	30 years	Yes	Stella	CLD, SFD
40 (Nguyen and Bosch 2013)	Sustainable tourism	Leverage points for sustainability	Recognition of feedback loops	Not specified	No	Vensim	CLD, archetypes
41 (Soufivard et al. 2013)	Destination management	improve cultural heritage sector performance	Number of visitors, quality of services	2012-2020	Yes	Powersim	CLD, SFD
42 (Xing and Dangerfield 2011)	Sustainable tourism	Analyse mass tourism	Visitors, accommodation	720 months	Yes	Vensim	CLD, SFD
43 (Semeniuk et al. 2010)	Destination management	Analyse animal ecology and human behaviour in Stingray	Population size+	25 years	Yes	Stella	CLD, SFD
44 (Jiang et al. 2010)	Destination management	Analyse investment into transportation infrastructure	Accessibility of destination	2008 - 2027	Yes	Vensim	CLD, SFD
45 (Xuke Wang 2010)	Urban tourism	Analyse the urban tourism industry	Feedback loops	Not specified	No	Vensim	CLD, SFD
46 (McGrath 2010)	Decision making	Decision Support System	Impact on transport	Not specified	No	Powersim, Vensim	CLD, SFD

A couple of papers study low carbon policy in destinations. For example, in (Luo et al. 2014) the CLD aims at main factors of decarbonization, economical operation, and development of the destination, SFD focuses on tourism and areas related to environment and socioeconomic variables. The output of the simulation is the prediction of the decarbonated level and attractiveness of the destination.

(Matthew et al. 2017) investigated the impact of new low-carbon laws on islandic touristic area in Azorean island of São Miguel, CLD aims at the consumption and generation of electricity in the closed area. Outputs of the simulation are the prediction of consumption of electricity up to 2045 under several scenarios within the different growth of tourism.

Destination management was studied e.g. by (Tegegne et al. 2018), where the system dynamics model was designed to show the destination image of Ethiopia. Authors provided CLD of visitors, products, market, level of infrastructure, level of service, and wealth distribution.

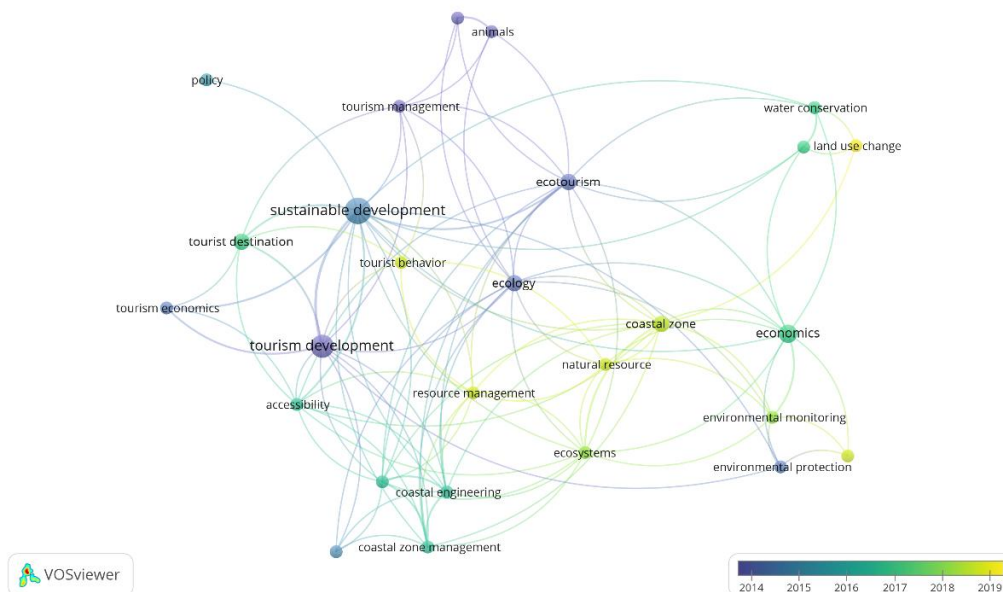
(Li et al. 2015) analyse the impact of new infrastructure. Here authors present a case study of Xidi and Hongcun in China: their CLD aims at the accessibility of destinations and behaviour of visitors, then they created SFD based on the CLD and finally, they specified case studies with two scenarios (competition vs. cooperation of two destinations when constructing road infrastructure). The output of the simulation is the prediction of the probability of the visitor's choice of destination up to 2018 under different scenarios.

(Semeniuk et al. 2010) focus on wildlife tourism. It deals with the population of the stingray and its impact on the number of visitors, with scenarios for the next 25 years under different destination management scenarios.

(Ropret et al. 2014) modelled innovations in Slovenian tourism within the SiPlan model, which aimed at the development of destinations.

### Synthesis of results

We applied a bibliometric method in order to provide an overview of the change of central topics in indexed keywords of selected papers. Terms without relevance to tourism were excluded from the list of keywords. The result of the analysis indicates a change in the main topics over time. Before the decade, papers mainly focused on the positive impact of tourism on economics and how to attract tourists. After that, the focus splits into two main categories: sustainability (sustainable development, ecotourism, environmental protection, and conservation of natural resources) and image of the touristic destination (including investments and land-use). The latest papers aimed at the negative impact of tourism and how to address this issue (e.g., water management, land-use change, environmental monitoring, natural resources, and tourism behaviour), see Fig. 2.



**Figure 2.** The bibliometric network of keywords.



We identified 46 papers addressing the application of system dynamics on tourism between 2010-2019 (Fig. 3). We found the main topics of system dynamics models: seaside tourism, sustainable tourism, low-carbon economies, destination management, decision making, planning, negative impacts of tourism and tourism in general (some papers might belong to several categories) (Fig. 4). The main implementation platforms were Vensim, Powersim and Stella (see Fig. 5).

Typically, a combination of CLD and SFD was used (23 papers, 50%), followed using SFD only (10 papers, 22%) and CLD only (11 papers, cases 24%). Systems archetypes in combination with CLD rarely appeared (2 papers, 4%).

The temporal scale of scenarios varies from 8 to 110 years; most of the models work with the about 30-year horizon (Fig. 6). In 16 papers, the temporal scale was not specified.

The results of the quantitative synthesis indicate the shift in the scope: while early papers were focused on the impact of tourism on economics and tourist attraction, in later papers sustainability and investment in touristic areas were explored. The interest in coastal zones tourism is significant.

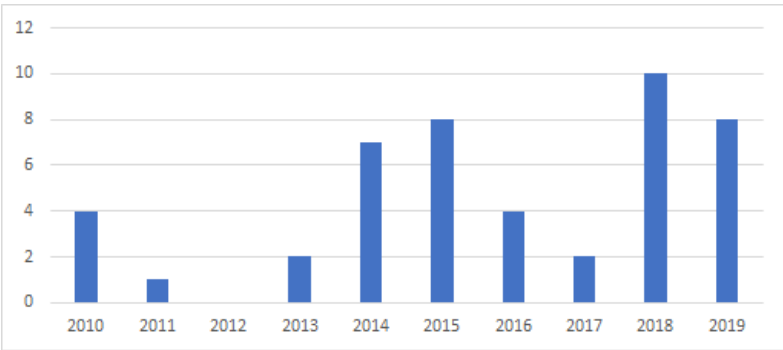


Figure 3. Number of publications per year.

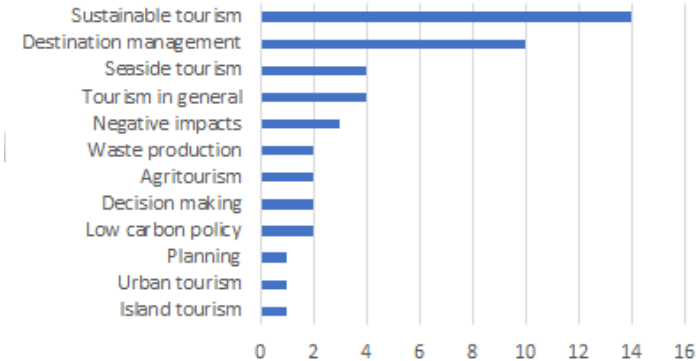


Figure 4. Number of publications per domain.

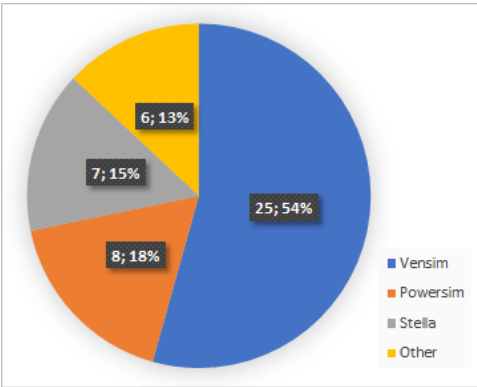


Figure 5. Implementation platforms.

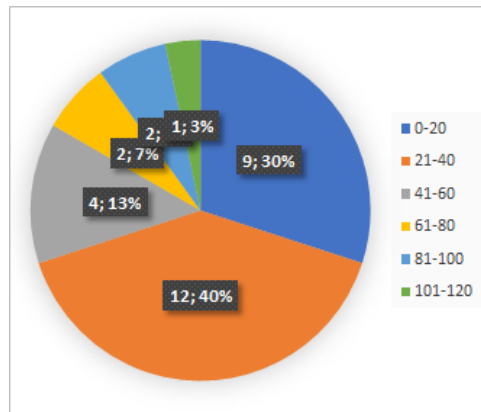


Figure 6. Temporal scale (range of years in simulation).

#### 4. Discussion

System dynamics models and outputs of simulations, in general, might help to monitor the current state of area e.g., capture hidden feedback loops, analysed current strategies and verified their outputs. In the view of future development system dynamics might bring new strategies for dealing with negative externalities or/and bring new visitors, verify the new strategies and draw a prediction of outputs of selected strategies; thus, it may be used for decision making.

Touristic areas might be divided into two groups; the overcrowded areas or areas with negative externalities from tourism; and areas with lack of tourists.

Application of system dynamics on tourism might be useful for the first group, e.g., national parks, populated areas with historical parts, a sports centres in populated areas, areas with endangered species — overall, almost all areas with negative externalities caused by tourism. Tools of system dynamics may capture hidden feedback loops such as unknown reasons for the popularity of the area, negative externalities, the behaviour of tourists. Furthermore, system dynamics may analyse current policies (e.g., law and strategies to low negative externalities from tourism) and predicate future state with the application of current policies. Nextly system dynamics might create new strategies to deal with problems caused by tourism and predicated their impact on a future state. Outputs of system dynamics might be used by e.g., decision management of the area, Council, and curator of area.

The main goal of the second group of touristic is to bring new tourists. For the purpose system dynamics tools might find hidden loops, which cause a lack of tourism, analyse current policies and predicate a future number of tourists. Secondly, system dynamics might create new policies, which can bright new tourists, predict outputs of application of these policies e.g., number of tourists, income to the area, and state of the area. The outputs of system dynamics might be used by Council, and local companies.

#### 5. Conclusions

Our systematic review shows the potential of system dynamics models for decision making and planning in tourism, finding externalities caused by tourism, and predicting positive and negative impacts of tourism. Our further research may lead to the development of general system dynamics models of sustainable tourism in protected areas. Another direction of future research might lead to the application of system dynamics modelling in case studies, namely creating models for future policy makings/decision making in order to change the extent of tourism in certain destinations.

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