GIMA
Geographical Information Management and Applications

Urban tourism:
Developing a modeling framework to explore spatio-temporal patterns of pedestrian tourists in Amsterdam

Julia Ubeda Briones

June, 2018

Universiteit Utrecht
TU Delft
University of Twente.
Wageningen UR

Gemeente Amsterdam

Urban Tourism:

Developing a modeling framework to explore spatio-temporal patterns of pedestrian tourists in Amsterdam

Author: Julia Ubeda Briones (julia.u.b@gmail.com / j.briones@amsterdam.nl)

Student number: 5652286

Supervisor (WUR-GIMA): Dr. ir. Arend Ligtenberg (arend.ligtenberg@wur.nl)

Professor (WUR-GIMA): Prof. Dr. ir. Arnold Bregt (arnold.bregt@wur.nl)

Thesis submitted in partial fulfilment for the Master of Science Degree Programme in Geographical Information Management and Applications (GIMA) - Utrecht University (UU), Delft University of Technology (TUD), Wageningen University (WUR) and University of Twente (ICT)

Research study developed at the Traffic and Public Space department, Amsterdam Municipality - Verkeer en Openbare Ruimte (V&OR), Gemeente Amsterdam.

Amsterdam, June 2018

Preface and acknowledgements

During the past year, I developed an exploratory walkability study for the City of Amsterdam. I realized that one of the most critical factors affecting walkability was the lack of (pedestrian) space in the inner city, mainly because of the compact and medieval nature of its historical city center, but also, because of the amount of people making use of that limited space. Furthermore, and at a more personal level, I sometimes surprised myself avoiding the city center of Amsterdam just because of the crowd of distracted tourists that do not know exactly where to go. In the last couple of years, urban tourism has been put into perspective and it has been criticized sometimes because of the nuisances generated around it, however, who has not been a tourist at some point in their lifetime? I was very interested in exploring what drives tourists' decisions when visiting a city and exploring the role that tourism marketing strategies have on the behavior of tourists.

Despite all the "noise" around the tourism topic, there is still a generalized lack of detailed knowledge about the tourists spatial and temporal distribution. I was curious about this fact too, as I was aware that not all the areas in the city center are targeted by tourists, nor are they used in the same way along the day. At this point is when (computer) simulations came into scene to allow the proper exploration of this theme.

The aforementioned reasons leaded me to select the topic of this research, I am happy that Arend Ligtenberg shared his enthusiasm about the subject as well, therefore, Arend, I would like to first thank you because of your energy and positivism. I appreciate your sharp and efficient supervision. Thanks also for giving me autonomy and freedom to take my own decisions. I would also like to thank Erika for the punctual but valuable reviews.
I am pleased that Stefan Verduin and his curiosity about simulation tools came along my way too, thanks for giving me the opportunity of developing and finalising the thesis within your team at the Gemeente Amsterdam. I would like to thank also Johan Olsthoorn for giving me always a hand and for taking care of the bureaucratic arrangements. Thanks to the people from the Gemeente Amsterdam, V&OR, Amsterdam marketing (Iamsterdam), TU Delft (ALLEGRO programme) and Datalab that collaborated in different ways with this research. Special thanks to Ewald Dijkstra, for his sense of humour, patience, advice and caring.

Thanks, as well to Elke, my mum and Paula for their support, acceptance and their almost daily conversations. To Lucas, Bea and Ana for keeping track of my daily life. To Kees for the last-minute writing review and, especially, I would like to thank Txell, Piotrek, Jaap, Daniela and Wijnand for cheering me up in some other way during these months.

Finally, and particularly, I would like to thank Srirama for his teachings, not only about GAMA, but also about statistics, technology, data visualization, writing, and, in general about life.

I would be satisfied if this work would contribute to show other ways of using simulations in the search of innovative methods to explore pedestrian tourist spatio-temporal patterns.

Summary

The objective of this research is to define and develop a modeling framework, based on theory and available data, on which to formalize and implement a simulation that allows to explore and to reveal spatio-temporal patterns of pedestrian tourists when visiting a city center. The first step is to build a comprehensive theoretical review to identify explanatory factors that influence tourist travelling patterns within an urban destination. The simulation targets to explain what the existing situation is more than predicting the future one. The Gemeente Amsterdam has detailed information about numbers, such as stays in hotels, but it lacks information about the spatial and temporal component of the tourist travelling patterns within the city. This insight would be beneficial to properly develop the tourism phenomenon in the city and to keep the balance between Amsterdam's urban growth and the tourist inflow.

Agent-based models and activity models are both implemented in this research: ABM allow to simulate individual agents that interact with each and the environment and reveal patterns and emergence. Activity-based models are based on behavioral theories about how people participate or not in certain activities in the presence of constraints, in this case, spatio-temporal constraints. The tourist market and the tourist activities are included in the model. The model also integrates the concepts of preference and attractiveness: tourist have preferences for specific activity types and are attracted to the most popular attractions within an activity type. The popularity of each attraction has been quantified from available data and it is referred in the study as the attractiveness score.

The model verification is a phase that tests if the model works as it is designed. In the model validation phase, the outputs should be compared to real-world data, however, the limited real-world data that is available, is used to populate the model, therefore, the validation phase consist of comparing the input data to the model output and analysing the variation between the two.

The main conclusion is that the defined framework is adequate because it allows to reveal spatio-temporal patterns of pedestrian tourists based on the city daily activity patterns. It is also considered adequate because it can be applied to other European cities with similar characteristics: compact city centers. Besides that, most of the data used to populate the model is publicly available and It will be most likely already present for other cities. However, the model should be first re-calibrated. Testing the effect of other parameters is also required. Last, adding some elements would improve the accuracy of the model such as including the distance as a factor when selecting a destination or implementing route-choice.

The model is used to evaluate three "what-if" scenarios, based on some of the Iamsterdam tourism marketing strategies. This exploration task is considered the sensitivity analysis of the model. It reveals dependencies between parameters and it shows the consequences of specific decisions. In the mid-term, the model might contribute to facilitate the modification of tourist attraction systems.

Index

Chapter 1: Introduction

The first chapter focuses on the context, problem statement and scientific relevance of this research. The context justifies why this topic has been selected. The problem statement supports why simulating pedestrian tourist movement within a city is becoming relevant and necessary for managing cities. The objective of this research and the subsequent research questions are formulated based on the previous findings. The structure of this section is subdivided as follows:

1. Context and problem statement
2. Objective and research question
3. Research relevance
4. Research design
5. Case study

1.1 Context and problem statement

Currently, little knowledge exists about the spatial and temporal distribution of tourists in a city. As Ashworth and Page (2011) stated, very little attention has been given to questions about how tourists actually use cities. As Grinberger et al., (2014) identified: the study of tourist's spatio-temporal behavior has been mainly researched on a descriptive level and there is still a scarcity of suitable tools for the advanced analysis of the temporal and spatial data.

McKercher and Lew (2004), Lew and McKercher (2006) and Lau and McKercher (2006) have conducted research about modelling routes and itineraries of tourists within a destination. Some other examples can be found in Cooper et al. (1993) and Pearce (1995), but there is still limited knowledge about why pedestrian tourists select a certain itinerary and what decisions they make when visiting an urban destination. Middleton (2010) highlights the aforementioned issue, stating that there is a lack of appropriate data in order to study and analyse pedestrian behavior. Also, Antonini et al, (2014) assured that data collection for pedestrian dynamics is indeed particularly difficult.

Traveling and especially urban tourism is becoming a popular trend worldwide (Pinkster and Boterman, 2017). The City of Amsterdam (from now on Gemeente Amsterdam to be consequent with the references) made the decision of promoting tourism in the past to overcome the financial crisis, because of its beneficial impact on the economy and employment. Amsterdam itself is a unique attraction with a lot to offer. Not only in art, culture, architecture and monumental canals, but also a wide recreational offer regarding shops and restaurants (Gemeente Amsterdam, 2016a). Tourism marketing policies met their objective and, only in 2016, the city welcomed 17.3 million visitors. The tourism growth rate was 5% from 2008 to 2015. If this trend keeps the same pace, the expected number of visitors by 2025 will be around 23 million (Onderzoek, Informatie en Statistiek, 2016).

The Gemeente Amsterdam acknowledges that some downsides are derived from this situation: increased traffic, overflowing bike jams at the intersections, public nuisance, street litter, noise, people queuing on the sidewalks to enter museums and a reduction in the diversity of activities due to the presence of the same mainstream shops. In general, Amsterdam's tourism is leading to a growing crow in the inner city (Gemeente Amsterdam, 2016 b, 2016c). Furthermore, the city's appeal is also attracting a growing population in terms of inhabitants; the current population is 834.713 inhabitants which grows at a rate of 11,6% since 2008. This will yield into a total number of 950.000 inhabitants by 2025.

Lastly, the Amsterdam mobility paradigm is experiencing a switch in which walking is becoming an emerging mobility trend amongst citizens, especially in the city center due to Amsterdam's compactness. Furthermore, not only inhabitants walk but also 80% of the tourists that visit the city move on foot (Gemeente Amsterdam, 2016b).

The aforementioned facts (increasing tourism and population and more people on foot) lead to a higher pressure on the public space and therefore to a lack of pedestrian space. This lack of space in the inner city is indeed becoming a critical factor that leads to a higher number of conflicts between pedestrians. Tourists and especially residents perceive sometimes that the city center is simply "too busy" (Gemeente Amsterdam, 2016d).

The Gemeente Amsterdam has detailed information about numbers such as stays in hotels or numbers of museums visitors, but it lacks information about the spatial component of the tourist route choices and travelling patterns within the city (van der Drift, 2015). The Gemeente Amsterdam is interested in knowing the density, location and characteristics of tourist's use of the urban infrastructure, (Gemeente Amsterdam, 2016e) in order to properly develop the tourism phenomenon in the city. Pedestrian tourists spatio-temporal travelling patterns should be further explored in order to keep the balance between Amsterdam's urban growth and the tourist inflow, and to highlight in which parts of the city crowds are causing issues.

Feasible approach

Pedestrian modeling is a topic receiving more and more attention in different areas of application (Antonini et al., 2014) that can be studied through computer simulations. Many different pedestrian models have been formulated in literature, using different approaches (Schreckenberg and Sharma, 2002). However, human behavior and consequently pedestrian behavior, are better represented following a complex system approach (Joffre et al., 2015). By definition, in complex systems, it is difficult to predict what the result will be because the interaction between individuals creates organizations and dynamics that cannot be defined, nor foreseen beforehand. (Batty, 2005). Computer simulations offer the potential to study the evolution of these complex behaviors and human interactions adding the spatial component to the equation (Itami and Gimblett, 2001).

Gilbert (2008) explained that there are generally two usual approaches to study social behavior (being the first approach the most common one): 1. collect specific data or surveys, analyse them and build a model based on them or 2. begin from a simple theoretical understanding of a specific social behavior and then "build a model to simulate its dynamics in order to gain a better understanding of its complexity". Batty (2017) stated that "more and more frequently we build models to demonstrate theory. The main reason for beginning with theory is that the conventional wisdom of science begins with theory and then testings theory against observations: data".

The reflections of these two scientists are the key bone of this research; one feasible approach would be building a **model based on theory and assumptions,** that can be translated into mathematical rules so that they can be implemented in a simulation. Therefore, even if there is a lack of real data to populate these models, **the first step is to develop a comprehensive theoretical review to identify explanatory factors that influence tourist travelling patterns within an urban destination.**

Finally, it is worth mentioning that simulations have become less focused towards predicting or forecasting, and more towards understanding the current situation. Batty and Torrens (2005) assured that in complex systems, it is more valuable to observe plausible patterns in the model output than to predict future states. This research is then aligned with the previous statement: **it targets to explain what the existing situation is, more than predicting** the upcoming one.

1.2 Objective and research questions

This section presents the research objective and formulates the required research questions to meet that objective. The findings from the former section have facilitated the objective formulation which, is as follows:

to define and develop a modeling framework, based on theory and available data, on which to formalize and implement a simulation that allows to explore and to reveal spatio-temporal patterns of pedestrian tourists when visiting a city center

The following research questions should be answered to meet the objective. They have been grouped into 4 phases according to the research design phases presented in section 1.3.

RQ. I – PHASE I Theoretical framework

- Which modeling approaches are available to develop a simulation of pedestrian tourists? Which is the most suitable one to meet the research objective and why?
- What theories and constraints exist about the tourist decision making processes when visiting urban destinations?

RQ. II - PHASE II Conceptual model

- What are the key elements that must be included in the model, based on the findings of the theoretical framework and why?
- Which input data is required to populate the model?

- Which model assumptions must be taken to be as accurate as possible given the data availability constraints?

RQ.III - PHASE III Model Implementation

- How can the conceptual model best be translated into mathematical rules to be implemented in the model?

RQ. IV - PHASE IV Analysis of results and testing of the scenarios

- To what extent is it plausible to validate the model taking into account that the available data might not be representative enough for the validation purpose?
- What are the input variables and parameters that are having a major influence in the model and why?
- What is the usefulness of the model when exploring multiple scenarios?

1.3 Research design

Section 1.3 describes how the research is structured. The research design (figure 1.1) has been divided in two main blocks: the **Setup of the project** and the **Modeling exercise**. The research process divided into 5 phases; each phase is related to the specific research question group (RQ) presented in the previous section 1.2. The only phase not related to any RQ is Phase 0 – Kick off since this phase focuses on framing the study and it occurred before redacting the initial research proposal. Figure 1.1 shows the phases flow and the connections and feedback loops between the main activities.

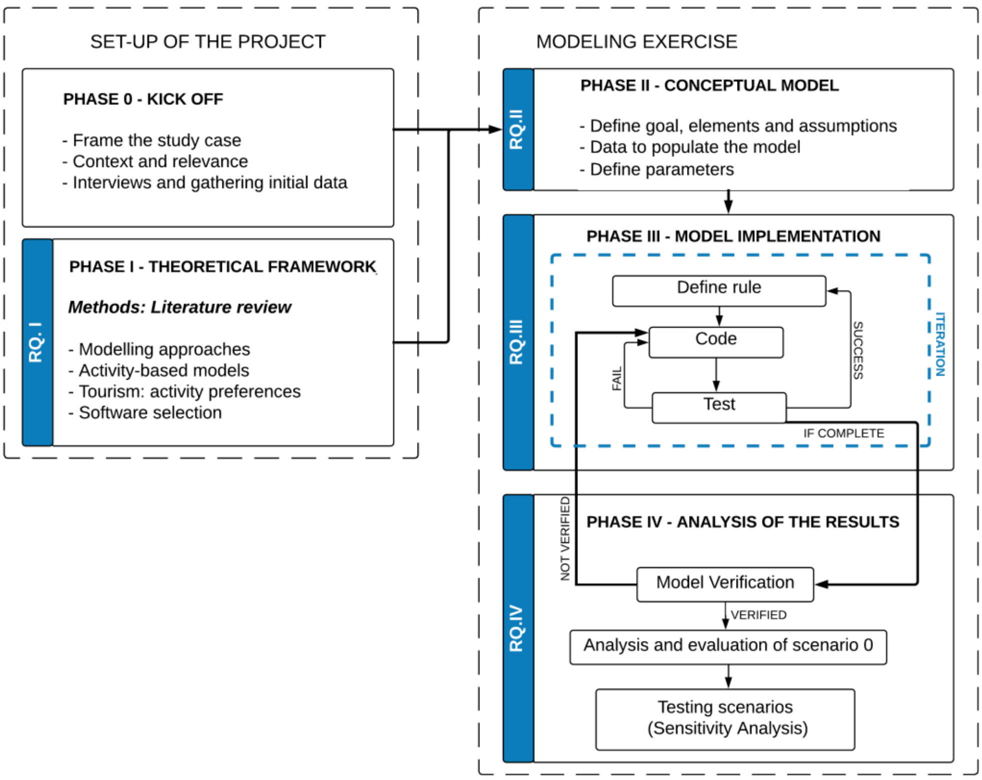


Figure 1.1. Research design and research structure

The closure of this research will comprise of: an elaboration of the results, drawing conclusions and proposing scenarios to be tested. The project will be considered successful if the final delivery is an appropriate modelling framework that could be used and populated with real data in the near future.

1.4 Case Study

A glimpse over section 1.1. already highlights the city of Amsterdam as an adequate case study for this research. Why Amsterdam is a suitable case have been clearly stated in section 1.1. these are: increasing population, increasing tourism numbers and there is an increasing trend towards walking due to the compactness of the city. Moreover, the city center and the canal belt offer a limited amount of space due to its medieval and historic nature. All these facts translate into a higher pressure on the public space. Furthermore, this study is a collaboration with Gemeente Amsterdam – Verkeer en Openbare Ruimte department (Traffic and Public Space department). Therefore, the easy access to data, spatial datasets, and valuable expert knowledge are also important facts that support selecting Amsterdam as a study case.

Amsterdam is the capital of The Netherlands.Located in the province of North Holland, in the west of the country (figure 1.3). With 834.713 inhabitants in the city, 1.351.587 in the urban area and 2.410.960 in the Amsterdam metropolitan area. Amsterdam is one of the five world's most visited tourist destinations (Boniface and Cooper, 2005), even if it does not count famous landmarks such as the Eiffel Tower, London Eye or Colosseum, as other European capitals do. Only in 2016, the city welcomed 17'3 million visitors; 10,6 million were days visitors whereas 6.7 million were overnight visitors (Figure 1.2) (Onderzoek, Informatie en Statistiek, 2016). For hotel guests, in 2008 the total number was 4.526.900, in 2015, 6.826.000 and only until June 2016 the number of hotel guests was already 3.564.000.

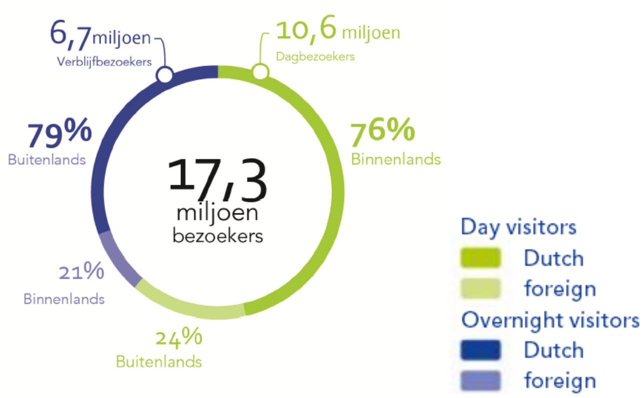


Figure 1.2. Amsterdam Tourism numbers in 2016 – Onderzoek, Informatie en Statistiek via Gemeente Amsterdam

Altogether, Amsterdam constitutes an interesting case to frame this research. The study area will be limited to the city center (figure 1.4). It is the area presenting the higher claims on the public space and it is where tourist highly concentrate because of the high number of activities and attractions. Besides that, two thirds of Amsterdam's overnight accommodations are situated in the inner city, as the heat map of figure 1.4. displays.

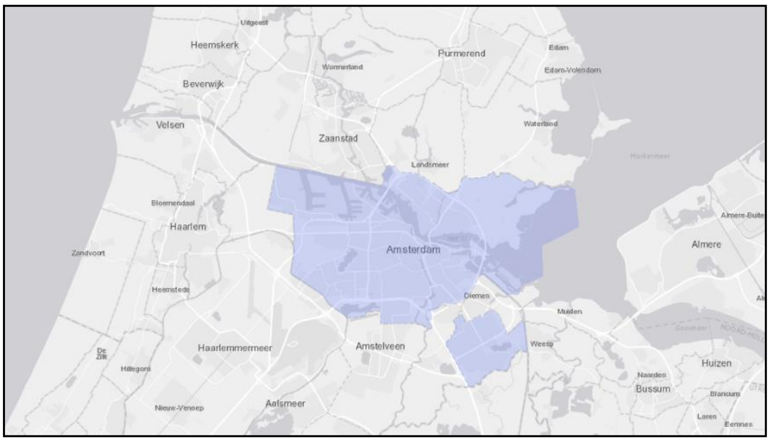


Figure 1.3. Amsterdam city

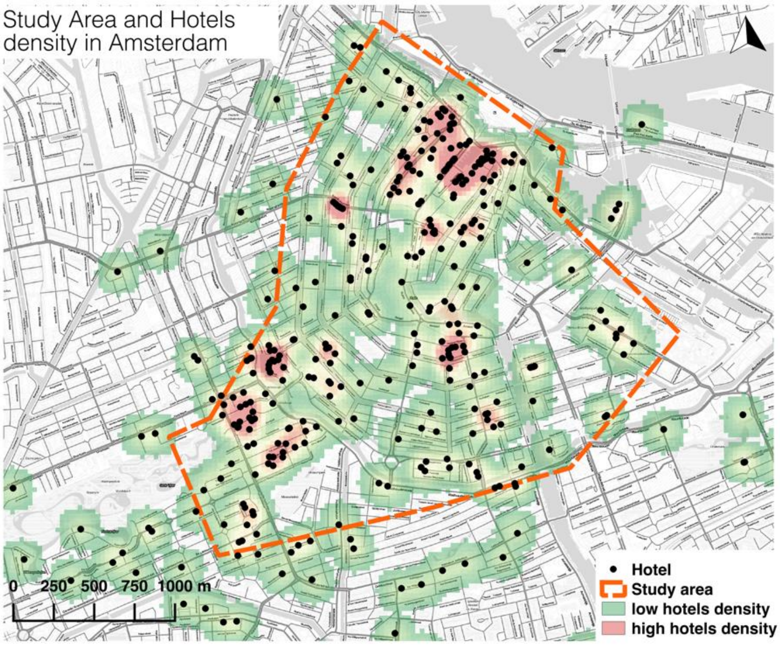


Figure 1.4. Study area and hotels density

1.5 Research relevance

In recent years, computer simulations are being implemented to explore human and pedestrian behavior. Pedestrian movement simulations fall within this field. These simulations are largely based on previously collected data or surveys; the models try to mimic and fit those datasets. However, there is usually a lack of information and real data about tourist itineraries and travelling patterns when visiting an urban destination, which is mainly due to the difficulty of monitoring those. Nevertheless, an emergent way of developing these simulations is to start with a theoretical understanding and simple observations about a topic, and then model it. The output is subsequently analyzed in order to get a better understanding of the dynamics of the current situation, to highlight what influences variables and parameters have on the model, and to depict emergent patterns. This research targets to follow the least widespread approach and this is where its contribution lays: instead of building a model that matches an existing dataset, this study will describe a framework based on theory and assumptions on how to model a pedestrian tourist simulation. Available data, if any, will be used to populate it.

The relevance of the research is not only due to its scientific significance, but it is also due to its possible contribution to the fields of urban planning and design, tourism policy making and the development of tourism marketing strategies. Urban tourism is becoming a popular trend worldwide and it is mainly accused in historic centers of European cities. As stated by (Lau and Mckercher, 2006; Huang and Xiao, 2000) understanding tourist travelling behavior within a city might contribute in the mid-term to facilitate tourism policy design, marketing strategies or development of new tourism products. To conclude this section, this study might ultimately illustrate how the model could prove to be a useful tool to evaluate the consequences of specific decisions, such as spreading out the tourism mass invading the city centers or promoting not so-well-known hotspots in the city. These simulations have been rarely explored with that objective in mind. The exposure of these type of tools to practitioners could be one step closer in bringing science and practice together.

1.6. Reading guide

The theoretical framework of this study is presented in Chapter 2. Chapter 3 encompasses the material and methods of this study; at the beginning of chapter 3, the main findings from the theoretical framework are summarized. It also includes the model assumptions, the used data sources and model description and implementation. Chapter 3 explains how the analysis of the results and the testing of the scenarios is going to be carried out. The model verification and model validation are presented in chapter 4. Chapter 5 includes the evaluation of three "what-if" scenarios, which is considered as the sensitivity analysis of the model. Lastly, chapter 6 summarizes the main findings and elaborates on the discussion and reflection of some critical points of this research.

Chapter 2: Theoretical framework

This chapter is composed by two main research blocks:

2.1. Computer simulations: modeling approaches
The goal of this first block is to research the possibilities that are available and have been already used to study pedestrian dynamics, the summit of this section is to select the most adequate modelling approach to meet the research objective.

2.2 Tourist travel behavior within an urban destination
The second block gathers information about the tourist decision models and travel behavior of tourist within a destination. The goal is to identify key concepts and factors that should be selected to build the model as effectively as possible.
The way the second section is structure might seem not logic, but it follows the thinking process of this research.

Finally, the conclusions from the theoretical framework that are relevant for this study will be compiled at the beginning of chapter 3: Material and Methods

2.1 Computer simulations: Modeling approaches

"A model is a simplification of reality which takes the theoretical abstractions and puts them into a form that we can manipulate. Simulation is often used to characterize this process of implementation." (Batty, 2017)

In order to understand city dynamics, computer simulations are used to build pedestrian models. Chapter 1 already stated that due to the nature of pedestrian models, the complex systems approach is the most adequate method to tackle this research.

There are many models aiming to simulate pedestrian behavior and movement in cities: Borgers and Timmermans (1986), Haklaty et al. (2001), Batty (2003), Bierlare et al. (2003), Borgers and Timmermans (2005), amongst others. Together, they give a decent insight of the modeling methods, processes and dynamics to mimic and understand pedestrian behavior. The target group of this study are pedestrian tourists which obviously fall within the pedestrian group and will share some of the behavior features presented in the former models.

The state of the art of the pedestrian behavioral models is based on the following two main approaches: **microscopic and macroscopic models** (Antonini et a.l, 2004.). A third type between the aforementioned two has to be included in this review: the mesoscopic level. This classification (macro, meso and micro) represents the **different model granularities** based on the aggregation levels of the individual behaviors.
The management of pedestrian flows demand requires the understanding of both; the collective pedestrian flows as well as the individual pedestrian movements in the flow

(Hoogendoorn and Bovy, 2002). Depending on their aims, models can be more focused on one level than the others.

Macroscopic models

These are models that describe pedestrian dynamics with fluid-like properties (Antonini et al., 2004), they represent the flow of individuals, this flow can be characterized by densities or speeds, for instance. Therefore, only a few parameters are needed to describe these models dynamic. Individuals and their interactions are not considered (Duives et al., 2013). They are related to traffic flow modeling.

Mesoscopic models

Mesoscopic modeling represents a group of individuals (in this case pedestrians) sharing common characteristics. They describe pedestrian dynamics, such as route patterns in large environments like cities.

They are considered as the intermediate granularity between microscopic models (all the individuals are simulated) and the macroscopic models (simulate the crowd as a whole flow). The mesoscopic models embody the concept of individual somehow; they include individual entities but only a few details about the interaction between entities with common fields are given. Therefore, the individual behavior and interaction between entities are represented but in an abstract manner.

Microscopic models

These models represent the specific system based on individual behaviors and interactions. They are considered to follow a bottom-up approach: they simulate individual behavior and because of the resulting aggregated phenomena a specific pattern at a higher level might be observed.

These models have been implemented in the study of pedestrian dynamics; they describe the space-time behavior of individual pedestrians (Antonini, et all 2004) and they are normally applied to highly control spatial events like in building evacuation contexts (Bierlaire et al., 2003) or detailed design decisions such as the spatial position of street furniture.

There are several types of microscopic models:

- (Social) Force-based models: pedestrians are individual entities that moved by attractive of repulsive forces.
- Cellular Automata (CA): pedestrians are represented by a state of cells. Rules are applied to this regular grid of cells by means of reaction-diffusion equations which change the state of the cell (Batty, Xie, and Sun, 1999).
- (Multi) Agent-based models (ABM): pedestrians are described as an individual agents (entities) that have their own characteristics and preferences and interact with each other and the environment. Rules are applied to define the agent’s behavior and interactions.

2.1.1 Reflections from the modeling approaches review

The former findings lead to relevant conclusions about the optimal modeling approach to be selected:
Macroscopic or flow modeling has been considered the first approach to be followed in the current research. However, flow modeling has to do with modeling aggregated data, it follows a top-down approach and therefore **does not allow to represent individual behavior**. It also presents some limitations: it is necessary a relatively high amount of flow occurring at a specific moment, like in metro or train stations. It is more convenient for representing street (limit) capacities or in crowd and evacuation modeling.

On the other hand, both, **micro and meso models**, represent dynamics based on individuals' behaviors, singularly modelled. Bretagnolle et al., (2006) stated that the emergent complex systems theory **emphases on "the emergence of properties at a macro-level** as a result of the interactions between individual behavior at a micro-level". Consequently, predicting beforehand what might occur is almost impossible. Microsimulations and meso simulations allow for this needed bottom approach. Agent-based models constitute a special micro simulation case, the reasons why this is the case are exposed in the next paragraph.

Agent-based as a special case of micro simulation

Agent-based models (ABM) are a type of modeling in themselves. Each pedestrian (or tourist) is treated as an agent. This concept has been developed in artificial intelligence (Ferber, 1999) and widely used in traffic simulations. They are categorized within the micro level category because an agent is defined as a single, autonomous entity (Agarwal et al., 2002; Joffre et al., 2015). ABM is a methodology that consist out of components (individuals) that dynamically interact with each other and their environment to achieve their goals (Hall and Virrantaus, 2016; Joffre et al., 2015), because of these interactions, they can give rise to collective behavior (New England Complex Systems Institute, n.d.) or emergence. Complexity increases when there is a number of independent variables that interact with each other and this interaction might lead to unpredictable results, these complex interactions can reveal emergence, and patterns, at a higher level, thus, they can be also categorized as mesoscopic simulations. The understanding of an ABM system is not derived from understanding the behavior of a single agent but by understanding their behavior as a collective (Hall and Virrantaus, 2016).

Most real-world phenomena such as pedestrian dynamics have some degree of chance, so they require **stochastic simulation**. Stochastic simulations use random number generators to model chance and randomness. It is unlikely that two runs of a stochastic simulation give the same results. The tourist decision-making process will include probability to avoid that agents always make the same decision.

2.2 Tourists travel behavior

Even though there are several models targeting to simulate pedestrian behavior, specific research about pedestrian tourist's behavior is also required to complete the study. This section investigates first which model level of detail is required to meet the objective to then explain how tourist move and make decisions when visiting an urban destination. Besides that, this section deepens the knowledge about which parameters might have a primary impact on tourist behavior.

2.2.1 Simulation at the tactical level

It has been already stated that microscopic modeling is related to the highly detailed description of the spatial environment, for instance, obstacles position. However, not all the design-level decisions need such as specific level of detail when modeling (Borgers and Timmermans, 2005). This exploratory research focuses on revealing spatio-temporal patterns and these patterns will be evaluated at a **tactical level.** Tactical level comprises, for instance, the **daily plan decomposed into schedules** and **activities** to be executed, therefore, schedule of activities, choice of activity areas and streets to go through must be defined in order to work at this level (Hoogendoorn and Bovy, 2004).

The behavior at the tactical level is influenced by external factors (built environment) and personal factors (preferences, time-pressure or attitudes of the pedestrian) (Hoogendoorn and Bovy, 2002). For instance, the street network topology and the pedestrian timetable would be required for the decision-making process at this level (Schadschneider, 2008 and Hoogerndoorn and Bovy, 2004). At the tactical level, several pedestrian groups with similar characteristics can be distinguished. ABM allows some of these aggregation techniques at a mesoscopic level keeping the microscopic approach (Antonini et al., 2014), for instance, tourists can be classified in different groups according to activity sets, travel purpose or demographic characteristics. Then, different behaviors are developed based on the external factors (built environment) and personal factors (preferences).

2.2.2 Time-space geography

It is evident that, if the goal of the study is to reveal spatio-temporal patterns, the space-time constraints have to be include in the model. Time-space geography was first presented in 1970 by Torsten Hägerstrand. He established that time and space are the "basic dimensions of analysis of the dynamic processes". Time-space geography or time-geography concept is also applied to the traffic and transport fields; giving too a good framework to analyze human behavior (Millier, 1991) and therefore, pedestrian dynamics. Hägerstrand used the space-time cube or prism to illustrate that an individual describes a certain path in space limited to other imposed contraints (figure 2.1). Figure 2.1 represents the individual accessibility; it shows graphically the reachable area of an individual given the time-space relation constraints (Millier, 1991). Depending on the built environment limitations and the personal characteristics, the individual will select his path within that reachable area.

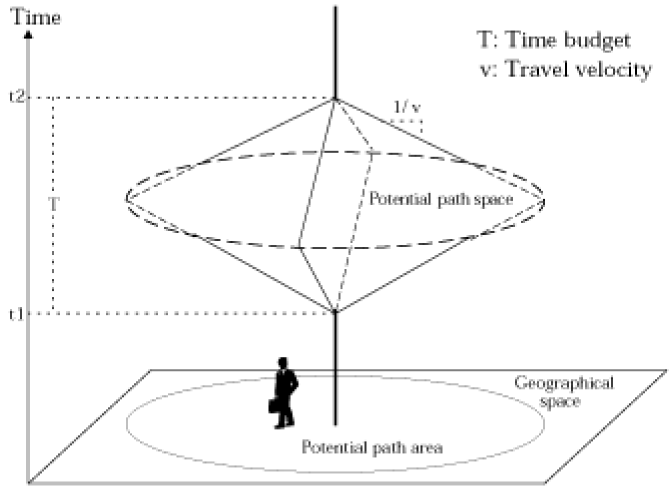


Figure 2.1. Space-time prism (adapted from Hägerstrand)
https://web.utk.edu/~sshaw/Personal%20Homepage/AAG2010-Shaw-Time%20Geography%20Presentation.pdf

Activities can be allocated in the potential path area (figure 2.2). The vertical lines depict time spent performing a specific activity like working or shopping. Inclined lines represent travel time spent in moving from one activity to the next one.

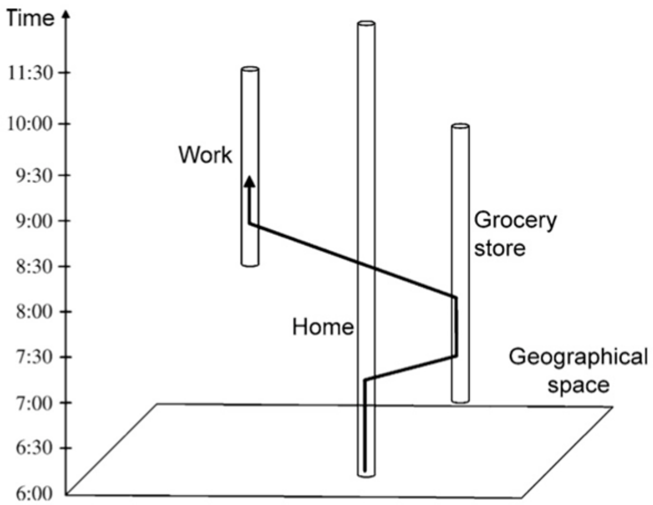


Figure 2.2. A space-time path adapted from Millier (1991)

2.2.3 Tourist movements patterns within a destination

Lau and Mckercher (2006) specified that, at the local level, **tourists travel** within a single destination **from attraction to attraction or shifting from activity to activity.** The spatial relationship between accommodation and attraction will also influence the travel behavior. McKercher and Lau (2008) conceptualized intra-destination and inter-destination movement patterns in a study. In this case, they analyzed a total of 1,273 arrival interviews, trip diaries and end-survey at the four participating hotels in Hong Kong. The data was analysed and visualized using GIS software. 78 viable patterns were reduced into 11 different movement styles, although only the cases from I to VIII are included here, the remaining cases have to do with inter-destination movements patterns.

I. No movement: the tourist stay at the hotel.
II. Unspecified local exploration around the hotel.
III. Local exploration around the hotel with specified stops.
IV. Multiple distant stops: journey trips more than 500 m from the accommodation, visiting more than one attraction
V. Local exploration (wandering within 500 m around the hotel) and a single distant stop to a specified attraction.
VI. Multiple trips: more than one journey per day, returning to the accommodation.
VII. Inter-destination travel – a day trip to a neighbouring destination.
VIII. Multiple day trips including more than one journey out of the accommodation.

Because of the nature of this study (spatio-temporal movement patterns within a city). The movement IV will be considered to be implemented in this model simulation, therefore, tourists will be travelling between destination and destination.

2.2.4 Activity-based models

The **location of activities** in an area and the **time spent performing that activity** seem relevant in order to properly represent the time-space constraints. This is when activity-based models pop up in the literature review. These models are based on behavioral theories about how people participate or not in certain activities in the presence of constraints (Castiglione et al., 2014). Activity-based models can incorporate the constraints induced by time and space. As each individual's time budget is becoming filled, the available time to participate in activities, or to travel amongst them, will be diminished.

This exploratory study aims to simulate spatio-temporal patterns in tourist movement and activity-based models provide a more intuitive, consistent, and behaviorally faithful representation of travelling. Activity-based models work at a disaggregate person-level rather than a more aggregate zone-level, so they are implemented using a **disaggregate microsimulation framework which makes them perfectly compatible with ABM.** By representing the single tourist, these models simulate the travel decisions of individuals that will collectively result in **activity patterns**.

The **choice formation** is important in activity-based modeling systems. The choices to be implemented are **choices such as selecting destinations depending on the time of the day and the time available (constraints)**. The set of destination characteristics will influence the decision-making behavior.

2.2.5 Discrete choice models and destinations attractiveness

Discrete choice theory represents a natural theoretical framework for agent-based modeling and disaggregate complex systems as well (Antonini et al., 2004); the behavior of each agent (tourist) is modeled as a sequence of specific choices related to where to put the next step. The choice set is the group of alternatives considered to be available to the chooser in a given context (Castiglione et al., 2014). Discrete choice is used in this study to select which attractions or "in-between" destination will be visited from a set of possible attractions.

It is assumed that the decision-maker selects the alternative that is perceived to offer the **maximum attractiveness** from a set of alternatives that are mutually exclusive; this set of alternatives is known as the choice set (Castiglione et al., 2014). In discrete choice models, the attraction of each alternative (in this case destination or activity), is a parameter that introduces probability in the model formulation, so the **stochastic nature of the model** is met. The tourist activities with a higher attractiveness score will have then a greater probability of being selected by a specific tourist.

2 .2. 6 Tourist types

The choices regarding activities are the ones reflecting personal desires (Grinberger et al., 2014), therefore, preferences will determine in which types of activities a tourist engage at, and consequently, define the tourist type as well. McKercher (2004) examined the visitors according to classes of attractions. He identified 24 different types: heritage, beach, shopping…He named the types according to activity classes instead of concrete spaces in the city because "each visitor picks and chooses from the many activities available to create a personalized itinerary that suits their interests' "(McKercher, 2004).

Given these facts, it seems appropriate to define tourist according to his personal motivation that will be defined through personal preferences to perform specific activity types: the set of **preferences will be associated to different activity types** (i.e. outdoor activities, visit parks, visit city highlights, shopping activities, cultural activities…)

2. 2. 7 Tourist attractions characteristics

The constraints of time-space relationship will determine in which activities or attractions a tourist is able to engage at. The spatio-temporal patterns will, therefore, be **influenced by the opening and closing times of different attractions.** Spaccapietra et al. (2008) conceptualized the trajectories as having a defined beginning and end time, and the movement along the journey is divided into movement segments by stops, these stops could be conceptualized as well as **the time staying in an attraction or performing an activity.** Therefore, it is also important to determine the average time spent on each attraction type: a tourist might spend only 2 minutes in a shop, but he might spend hours in a museum if he finds it appealing. Lastly, there are specific attractions like restaurants that are more attractive at specific times of the day, i.e. Lunch and dinner times.

The aforementioned concept can be implemented in the modeling exercise following a similar approach to the one presented by Pires and Crooks (2017). The goal of the modeling exercise from these authors studies is completely different to the tourist movement: they model the emergence of riots in Kibera, Nairobi. However, the modeling framework is an agent-based model and they introduced an interesting concept about defining activities characteristics that will influence the agent (in this case, tourist) behavior. This method has been used as inspiration to determine the attractions or activities characteristics. Table 2.1. exemplifies this concept.

Table 2.1. Example of activity characteristics [opening time and staying time] (adapted from Pires and Crooks, 2017)

Activity / attraction type	Opening time	Staying period	Visiting preferred time
Shop	10.00 - 18.00	5-30 minutes	-
Restaurant	11.30 - 22.30	1-2 hours	12.00-15.00 and 19.00 to 21.30
Museum	10.00 - 18.00	1.5-4 hours	-
Park	all day	-	-
…	…	…	…
.	.	.	.

2.2.8 Tourist supply market

Lastly, to conclude the research about tourist behavior in an urban destination, the tourist market of the city has to be identified and described. Van der Knaap (1999) described that two sides conform the tourist realm: the demand side, which is related to the tourist characteristics and the supply side which is associated with **the built environment and the tourist products or attractions.**

In addition, pedestrian movement is influenced by mainly two elements: urban network configuration and the attraction points on that network (Hacklay et al., 2001), in this study the attraction points will be obviously represented by the tourist attractions. The key concepts of urban transportation modeling, which can be also applied to tourist trips, include: 1. trip origin or generation, 2. trip destinations, the supply or stops, **3. the transportation network**, the street networks in this case and **4. the mode or type of transportation** used (Castiglione et al., 2014). The transport mode decision is not considered as part of this study since is selected beforehand: walking.

Trip origins, in the tourism industry context, are normally zones or point with a high concentration of hotels, resorts, motels, dispersed second homes, houses from friends and relatives (Lau and Mckercher (2006), dispersed Airbnb accommodations fit within trip origins definition too. Like regular commuters, the flow of overnight tourists will start from these points in the morning and return to them at the end of the day.

Trip destinations or in-between destinations are the attraction or activity points in the urban network. The land use, specific tourist products and some elements in the built environment, like parks, are considered as a range of attractions or activities that form the touristic supply side (Lau and Mckercher (2006). Van der knap (1999) exposed that depending on the nature of the activity, some attractions take place as **points** (specific locations such as museums) and other activities are embarked on an **area** (shopping area). The zone approach might not be only related to activity areas but also define areas with distinct characteristics like scenery, smells or architecture design Lau and Mckercher (2006). **This differentiation between zonal or discrete destinations might also derive in distinctive movement patterns.**

2.2.9 Walking speeds

Wart Rothuisen performed a study for Gemeente Amsterdam (2016) in which he evaluated pedestrian routes around Museumplein. His assumptions about walking speeds were based on Ministerie Vlaamse Gemeenschap or Flemish minisitry (AWV, Administratie Wegen en Verkeer, 2016) research, they agree on the adult pedestrians walk at an average speed of 0,8 m/s to 1,2 m/s. Gehl and Svarre (2013) measured pedestrian walking speeds in Strøget, the most commercial street in Copenhagen; they registered differences in walking speeds between 1,6 m/s (July) and to 1,17 m/s (in August). Gehl and Svarre distinguished also different types of walkers regarding their speed. Gemeente Amsterdam tracked pedestrian speeds (Toerisme en voetgangers strtagische kennis agenda 2017) and it is agreed that people do not wlak faster than 6 km / h = 1,7 m/s

Transport of London carried out an extensive research regarding pedestrian movement due to the development of the master plan for the Olympic city in 2012; They categorized different pedestrian types according to their walking motives and different locations. Other authors such as Blue and Adler (2001) or Daamen (2004) and exploratory studies from US have been also consulted in order to complete the walking speeds research. Table 3.3. compiles all these findings.

Table 2.2. Summarized walking speeds

Study / Author	**Characteristics**	**Walking Speed (m/s)**
Gehl and Svarre (2013)	Very fast walker	2,08
	Fast walker	1,7
	Medium walker	1,25
	Slow walker	0,69
Ministerie Vlaamse Gemeenschap (2016) used by Gemeente Amsterdam		0,8 - 1,2
Transport of London (2012)	Average in public transport hubs	1,45
	Average in tourist attractions	1,23
	General average	1,36
Daamen (2004)		1,34
Blue and Adler (2001)		0,83 - 1,7
USA walkability studies		0,75 - 1,4

Choi (2013) exposed that recreational walking trips are generally conducted with less purposeful attitude and therefore, at a slower speed than utilitarian trips. Tourists are considered to have recreational purpose more than goal-oriented purpose like going to work. Given this fact, and considering the above gathered walking speeds, this research will set the walking speed in a scale ranging from 0,7 m/s (slow walker according to Gehl and Svarre, 2013) to 1,3 m/s which correspond with a medium speed walker according to Gehl and Svarre (2013) and is more in line with the Transport of London research, Blue and Adler results and the Ministeri Vlaamse Gemeenschap (2016).

2.2.10 About route choice

Going from A to B seems to be a relatively simple task from a routing perspective, but in practice, it is difficult to document and to make sense of all the possible travel routes; some tourists go from A to B using the shortest route or the most direct one, some go indirectly or will make several stops at intermediate points C, D or E (Lau and Mckercher,2006). Recreational and touristic trips have more flexibility than utilitarian trips, for this reason they are not always directed by the shortest distance route (Choi, 2013). Normally, pedestrians follow routes that engage them or comply with their personal motivations or preferences. Borges and Timmermans (2005) assured that the **attractiveness of the street** has a major influence on the route choice behavior. Empirical research has indicated large differences in how different types of pedestrian's value route attributes (Bovy and Stern, 1990; Hill, 1982; Senevarante and Morall, 1986). These factors must be included when calculating the street attractiveness. Some of them has been researched and they are: **Number of activities or supply degree, route directness, total travelled time crowdedness, passed routes, street physical characteristics**…route choice is an extremely factor that will determine movement patters, however, it constitutes another research field in itself, for this reason, it has been decided to leave out of the current study.

Chapter 3: Material and methods

This chapter is organized around the 4 phases presented in the research design of chapter 1 **(see figure 1.1).** Each phase is related to a research question group, so by the end of this chapter, all the major inquiries about the model will be answered.

RQ.I – PHASE I Theoretical framework

3.1. Conclusions from the theoretical framework and key model elements
3.2. Software selection

RQ.II - PHASE II Conceptual model and RQ.III - PHASE III Model Implementation

3.3. Data sources
3.4. Model assumptions
3.5. Model description (ODD protocol)
3.6. Model implementation
3.7. Number of runs and number of agents

RQ.IV - PHASE IV Analysis of results and testing of the scenarios

3.8. Model outputs, model verification and model validation
3.9. Sensitivity Analysis and testing of the scenarios

3.1 Conclusions from the theoretical framework and key model elements

This section comprises the key findings from the theoretical framework and the required elements to build the model as precisely as possible.

- **Agent-based modeling** is the appropriate **framework** to model complex systems such as (tourist) pedestrian behavior. ABM allows modeling of individual behaviors (microscopic modeling) and allows the emergence of patterns at a higher level (mesoscopic modeling).
- (Spatio-temporal) tourist patterns will be evaluated at a **tactical level,** which comprises the schedule of activities, choice of activity areas or activity types. The street network topology and timetables are required.
- **Time-geography** concept is a necessary conceptual framework to describe the tourists' spatio-temporal behavior in terms of space-time constraints. These constraints are not related to choice but to physical limits.
- To determine in which activities a tourist will engage at, based on the space-time constrains, an **activity-based model** is implemented (see figure 3.1.)

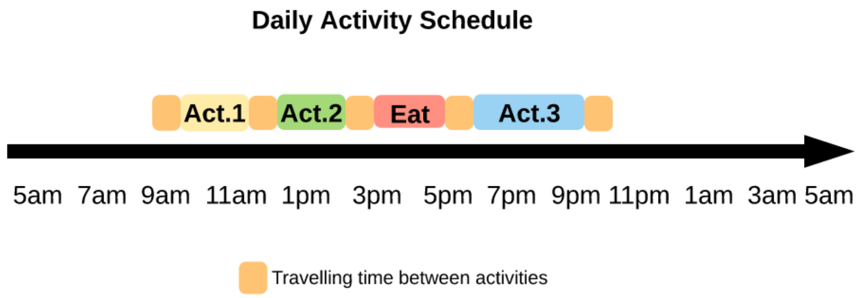


Figure 3.1. Daily activity based-models

- It is required to describe the **tourist supply market** of the city: define activity features such as activity type, average visiting time or opening / closing times. These characteristics will lead to a more realistically model.
- Decisions are influenced by the environment (physical factors) and preferences (personal factors). The tourist behavior will comprise personal **preferences** for activity types.
- A discrete choice model is implemented; tourists will select a destination (point or area) according to time-space constraints and activity type. Once this selection is made, **popular attractions** within the tourist supply market will have a **higher probability of being visited.**
- Stochastic simulation is required since pedestrian dynamics always involve some degree of chance. For this reason, as mentioned in the previous paragraph, the destination decision-making process will include probability in order to avoid that agents always make the same decision.
- Finally, the walking speeds will range from 0.7 to 1.3 m/s.

Thanks to the comprehensive theoretical framework it is possible to identify the **key model elements** that must be selected in order to build the model as effectively as possible. These key elements are:

- Delimit tourist's time availability to explore the city
- Determine the tourist's model entry points: location and time
- Define the different activity types and the preferences for each of them
- Define and describe tourist activity characteristics: location, opening and closing times, time spent in each location…
- Define popularity or attractiveness of each tourist destination or attraction
- Establish tourist walking speeds (already defined in the Theoretical Framework)

3.2 Software selection

The selected software to build the agent model is GAMA (version 1.7.0). **The programming language is GAML,** a high-level *agent-oriented* language dedicated to the definition of *agent-based* simulations (http://gama-platform.org). GAML is based on *object-oriented* languages like Java or C++ but it is more intuitive than those for a nonexperienced programmer. This language combines a number of programming paradigms such as imperative programming and functional programming. Finally, GAML extends the object-oriented programming approach including other concepts such as agent's skills.

Positive points of GAMA are that it is a well-supported online, free and open source, regularly updated, it runs on Mac OSX, Windows and Linux and it has a broad documentation, manuals, tutorials and model examples. Despite these benefits, it is not a very popular and widespread modelling tool, unlike a modelling tool such as (for example) NetLogo.

GAMA is a modelling platform that permits the environment representation with geographical vector data (line, point, and polygon) to **build** spatially explicit agent simulations (Taillandier et al., 2012). Therefore, GAMA is particularly interesting for this model, because of these spatial "agentification" capabilities: GIS-based data can be connected to populate the model.

The last remarkable advantages of using GAMA are its interface that allows for inspecting the agents during the simulation, the variety of displays, the possibility to play with multiple representations of the model while it is running and the diversity of outputs files, including shape files.

3.3 Data sources

The model key elements have been identified in section 3.1. With these in mind, the purpose of this phase is to gather adequate data to define those key elements. The selected software, GAMA, allows to connect GIS-based data to populate the model. The spatial data needed are basically the entry points of the tourists in the model and the tourist attractions. However, not only spatial data but also other data formats are required to properly populate and design the model.

This section enumerates the used data sources and the datasets that are available; the links and specifications about each of them are included in *Appendix I – data sources*. This section is structured as followings:

3.3.1 Quantitative data
3.3.2 Qualitative data
3.3.3 Spatial datasets

3.3.1. Quantitative data

This section elaborates mainly on the surveys from Amsterdam Marketing. Other datasets are included such as the Onderzoek, Informatie en Statistiek datets (OIS) and the results of van der Drift (2015) research.

Surveys: Bezoekersonderzoek Metropool Amsterdam 2016 (BOMA, 2016)

Besides hard-data, it is basic to get an insight about the Amsterdam tourism landscape and about what tourists do when visiting the city. Amsterdam marketing conducted 12.000 face-to-face interviews to compose *the large scale Amsterdam Metropolitan Area Visitors Survey*. These surveys were conducted from January 2015 to December 2015 (published in 2016). The most relevant results are commented here, although reading of full report is recommended (link included in *Appendix I – data sources*).

Visitor types:

Amsterdam Marketing distinguishes **4 visitor profiles**. 80% of the visitors of the city fall within one of these profiles.

1) City trippers
2) Dutch day visitors
3) Cost visitors
4) Conference attendees

City trippers are overnight tourist that visit Amsterdam and come from another country. This is the only group matching the target group of this research. 63% of international visitors choose a hotel for their accommodation, so they remain the most used form of accommodation. The international visitors spend, on average, **8.46 hours visiting the city.**

The reasons for visiting Amsterdam:

The most frequently named reasons for visiting the city are culture and history (49%) and museums (37%). The atmosphere (27%), the reputation as a capital city (19%), a desire to check it off the bucket list (16%) and personal recommendations (13%). Overnight visitors primarily come to Amsterdam for the culture landscape: 82% of them visit one or more museums in Amsterdam.

Activities:

Next to walking around town, visiting a museum is the most frequent activity (79%) amongst all visitors in Amsterdam. The most popular attractions are the Heineken Experience, the canal cruises (both 14%), Artis Royal Zoo (10%), the I Amsterdam letters (9%) and the Sex Museum (8%). Visitors seem to take part in fewer nightlife activities than in 2011. For example, the portion of visitors who visited a café or pub has decreased by 10%. Table 3.1. shows the tourists distribution amongst different activity groups. What is clear from the distribution is that all tourists engage in different activity types.

Table 3.1. Distribution of tourists per activity group (BOMA, 2016)

Activity	% of tourists engaging in the activity
Walking through the city	88
Visit a museum	79
Eating out	66
Shooping	50
Visiting an attraction	49
visit a café or pub	48
Traditional architecture	38
Sitting on a terrace	36
Having snacks or finger food	35
Visit a park	32
Visit a market	32
Canal cruise	28

The surveys give a good overview about the tourist landscape in Amsterdam, however, other quantitative data is required to characterize the Amsterdam tourist supply market, such as: how many visitors visit each attractions or number of hotel stays. The consulted datasets are showed in table 3.2. (see *Appendix I – data sources* for details)

Table 3.2. Used Dataset

Dataset	Source	Description
Several Onderzoek, Informatie en Statistiek (OIS) datasets	OIS	Datasets that contains numbers of museum visitors, theaters and concert halls
Top 50 Nederlandse dagsttracties and kerncijfers	NBTC Holland marketing	It contains number of visitors of other attractions not included in the OIS datasets
Kerncijfers (2017)	Iamsterdam (Amsterdam marketing	This dataset gives an overview of total number of tourists, nights of staying, hotels numbers…
Amsterdamse Thermometer van de Bereikbaarheid	Gemeente, 2016e	This dataset includes a counting campaign in the main shopping streets of the city.
Number of Flickr pictures of international tourists in Amsterdam visiting Amsterdam	Van der Drift (2015) research	13-hotspots or popular sightseeing were identified and also the temporal distribution of the number of pictures. These results will be used as a proxy to define some of the model parameters

3.3.2. Qualitative data

In order to complete the Amsterdam tourist supply market, an indicative and qualitative study is carried out. According to the surveys (BOMA, 2016), 80% of the tourists visiting Amsterdam for the first time browse online what the possibilities are. In this research an indicative exploration is, therefore, based on online browsing of 5 websites using Google as the searching engine. A list is developed containing all the activities and attractions mentioned in these 5 websites. Then, it is counted how many times (if any) an attraction is recommended in the other browsed websites. It is specified if the attraction is shown in the main page of if "a second click" is required. Results of this exploration are found in *Appendix II* – Indicative and qualitive study.

3.3.3. Spatial datasets

Lastly, the spatial datasets are required to introduce the spatial component in the model and to recreate the environment. Some of these datasets are fulfilled with the descriptive attributes of the quantitative datasets from the OIS and NTBC such as the number of visitors or the opening times of each activity.

Stad vol data. Theme: Toerisme en cultuur

Stad vol data is a data portal maintained by Gemeente Amsterdam. The data is published from different parties: Amsterdam marketing, Amsterdam museums, cultural company Noord-hollland, Gemeente Amsterdam (economy, monuments and archeology, OIS, city archive). The downloaded csv files which include the geographical component) are:

- Attracties
- Hotels
- Musea en galleries
- Eten en drinken
- Theaters

Funktiekaart

It is the non-residential land use map published by Gemeente Amsterdam. The land uses retrieved from this dataset are:

- Shops with an open front
- Pubs and Cafes
- Churches
- Leisure and cultural activities

UNESCO architecture quality

Map published by Gemeente Amsterdam, it is used to delimit the Canal Belt

Markets

Downloaded from Gemeente Amsterdam website – maps.amsterdaml.nl

Street network

NWB2016 - Gemeente Amsterdam website - maps.amsterdaml.nl

Main green Infrastructure

Gemeente Amsterdam website - maps.amsterdaml.nl

3.4 Model assumptions

Although the previous section (3.3. Data Sources) is critical to get an insight of the tourist market and to select the tourist destinations, still many assumptions are decided. They are based on the data itself, proxies or educated guesses. The reasons that support each assumption are presented as well.

The model assumptions are:

- *The modelled target group is first-time overnight international tourists during the first day of their visit, therefore, it is a 24-hours simulation (stating at 6.00) –* section 3.4.1.
- *The entry model points will be the hotels that fall within the study area. The number of tourists staying in each hotel will be proportional to their number of beds* section 3.4.2
- *There are not differentiated tourist groups. The way the tourists are differentiated is by the preference (introduced as probability) of visiting different activity types.* section 3.4.3
- *Six activity types (out of the twelve addressed in BOMA) are selected to be included in the model.* section 3.4.3
- *Tourist will not repeat destinations that have been already visited along his / her daily journey. She / he will only visit one destination from the café-pub activity type.* section 3.4.4
- *The most popular destinations will have a greater probability of being visited* section 3.4.5
- *The staying time in each destination is randomly assigned from a minimum and a maximum value (defined by the modeler) and these times depend on the activity type group. The opening and closing times are determined from data.* section 3.4.6
- *The time tourist leaves the hotel and the time they spend on the city follows a gauss distribution defined by its mean and its standard deviation.* section 3.4.7
- *The route to and from the hotel and between two consecutive destinations is calculated based on the shortest-distance on the street network. The travelling distances (and so travelling times) are calculated based on Euclidean distances.* section 3.4.8

3.4.1 Elemental simulation characteristics

The target group is first-time overnight international tourists during the first day of their visit, therefore, it is a 24-hours simulation (stating at 6.00)

This assumption has been decided due to the following reasons:

- The number about the attractions and activity types addressed in BOMA (2016) are referred to the City Trippers group who are international tourists overnighting in the city.
- International tourists are selected because van der Drift (2015) research targeted this group and it is an interesting dataset to be used.
- First time tourists on their first days are selected so that it can be assumed that they would target the most popular destinations in the city.

3.4.2 Entry points

The entry model points will be the hotels that fall within the study area. The number of tourists staying in each hotel will be proportional to their number of beds.

The following reasons support this assumption:

- Data and spatial data about hotels is available.
- Airbnb dataset is also available, although it has not been used due its temporality (not all the locations are permanently rented) and due to the low number of guests compared to the hotels.
- The main train stations of the city are excluded as well as entry points since only overnight tourists are included.
- Tram or bus stops are also excluded since it is assumed tourist move on foot due to the Amsterdam city center compactness. Tourists staying outside of the city center are not modeled; they have been eluded to avoid adding *not-that-crucial* complexity to the model.

3.4.3 Tourist types

There are not differentiated tourist groups. The way the tourists are differentiated is by the preference (introduces as probability) of visiting different activity types

This assumption is, without a doubt, the most critical one; normally the goal of ABM is to simulate groups with different characteristics and see how these interact and may affect (or not) the model output.

The reason for this decision is to match the results of the BOMA surveys. Table 3.1 shows how tourists are distributed amongst different activity types; it is evident that all tourists engage in different types during their visit. Furthermore, no data about specific preferences is available, it is mentioned the "reason why visiting Amsterdam" but many of the answers were as vague as "check it off the bucket list". Therefore, it has been decided to simulate one single group from which the individuals engage in different activity types according to a specific probability. The probability is based on the BOMA percentages of tourists that engage in an activity type. This is how the **preferences** are introduced in the model.

Moreover, a drawback of the BOMA report is that only it only publishes, for instance, one statement is that "32% of the people visiting Amsterdam are between 21 and 30 years old" and the other is "33% of the visitors travel with their partner". However, it is not specified how many visitors are between 21 and 30-year-old AND travel with their partner. Therefore, it is difficult to establish tourist's groups from this data without introducing too many assumptions.

3.4.4. Activity types

Six activity types (out of twelve addressed in BOMA) are selected to be included in the model

The reason why the number of activity types is reduced in the model is explained here:

- Some activities involve another transport mode like canal cruises, therefore this type has been excluded.
- An overlap exists between certain activity types such as visiting a museum and visiting an attraction. Both are considered as "cultural activities" in the model.
- The activity "visit a park" has been included in "walking through the city". This is due to the qualitative indicative research: visiting a park is included also in walking.
- Activities such as having a snack or sitting on a terrace are not considered relevant for this research, although visiting a pub and a café has been included as another activity type.
- The traditional architecture activity has been excluded because it is vague, and it is challenging to make the spatial link to it.
- Lastly, a new activity type is introduced: sightseeing. The probability of "sightseeing" is considered as the same as "walking through the city" since sightseeing are embedded in the public space. This specific type is included because van der Drift (2015) dataset presented rich information about this activity type and because sightseeing is mentioned several times in the indicative research.

Table 3.3 collects the six activity types included in the model. It also shows the percentage of tourists that engage in those activity types according to BOMA surveys. The probability of engaging in an activity type are **not compound events** (a tourist cannot engage at the same time in 2 activities), therefore, they must sum up to 1. Because of the way BOMA results are expressed, the sum of probabilities exceeds 1, which is the maximum allowed probability. Consequently, these probabilities are re-calculated: each value is divided by the sum of all the probabilities (3.85), this ratio calculation is considered the last assumption regarding the activity types (table 3.3, column 4);

Table 3.3. Model activity types and probabilities re-calculated from BOMA (2016)

	Model Activities	**% of tourist engaging in the activity (BOMA, 2016)**	**Probability of tourist engaging in the activity**	**Probability Ratio (probability / total)**	**% (to be compared with the model output)**
1	Walking through the city	88	0,88	0,23	22,86
2	Sightseeing	88	0,88	0,23	22,86
3	Cultural activities	79	0,79	0,21	20,52
4	Shopping	50	0,5	0,13	12,99
5	Visit a market	32	0,32	0,08	8,31
6	Café of pub visit	48	0,48	0,12	12,47
		Total	3,85		

3.4.5. Visited destinations

Tourist will not repeat destinations that have been already visited along his / her daily journey. She / he will only visit one destination from the café-pub activity type.

These assumptions are just modeler guesses.

3.4.6. Popularity of each destination – attractiveness scores

The most popular destinations will have a greater probability of being visited

This assumption requires to **quantify the popularity of each attraction**. *Appendix III (Quantification of the attractiveness scores)* illustrates in detail how the quantification has been made for each activity type. *Appendix IV (Final destinations included and their characteristics)* includes the final table with all the destinations to be included in the model.

The popularity of each destination is scored with a probability that must range from 0 to 1. This probability is called the attractiveness score from hereinafter. Therefore, whatever data source is used to quantify the popularity of the attraction, the values must be standardized from 0 to 1 (see *Appendix III* for details). This means that, for instance, the most popular attraction within the cultural activity type will have a score of 1, the second attraction might have a score of 0.97, the third 0.93 and so forth. Nevertheless, the number of available destinations will vary along the simulation (some destinations might be already close at night or some destinations might have been already visited) therefore, the probabilities should be recalculated in each simulation step; a new probability for every destination will be calculated automatically in GAMA. This probability will depend on the destinations that are available in each simulation step (new probability **= probability / sum of the available destination probabilities**).

1. **Walking activity type**

The walking areas included in the model are selected based on the indicative online research. The attractiveness of these is also based on the indicative online research the number of times they appeared in the browsed websites is counted (see *Appendix II* for the number of counts). For instance, the Canal Belt is recommended in all the 5 browsed websites (nr of counts = 5), so the Canal Belts gets the highest attractiveness score within the walking activity type (=1). Vondelpark is recommended 4 times out of 5, thus its attractiveness score is 0.8. (See *Appendix III*).

2. **Sightseeing activity type**

The attractiveness of the destinations within the sightseeing activity type group have been quantified based on van der Drift (2015) research. 13 hotspots are depicted in the city based on the number of pictures taken from them in one day. The number of pictures has been standardized from 0 to 1 to obtain the probabilities. See *Appendix III* to check the data source and the calculated attractiveness scores.

3. Cultural activities type

The attractiveness score of each cultural activity is quantified based on the yearly number of visits of each attraction during the year 2016. These values have been also standardized from 0 to 1. Only museums and attractions with more than 60.000 yearly visitors have been selected to be included in the model.

4. Shopping activity type

The quantification of the popularity of the shopping streets is based on a proxy. The **proxy is the number of retail shops per meter of street.**

The retails and open front shops are selected from the Funktiekaart layer (non-residential land use map), the map containing the selected shops is intersected then with the buffered street network so that the number of intersected shops can be counted. Then, this number is split by the street length. The process is illustrated in *Appendix III*. From the value shops/m the attractiveness score is standardized from 0 to 1 for each shopping street.

5. Visit a market activity type

The markets have been quantified based on indicative online research. The procedure is the same as the one used to quantify the walking areas: the number of times a specific market is recommended in each of the 5 browsed websites is counted.

6. Visit a pub or café activity type

The cafes and pubs are selected from the Funktiekaart (non-residential land use map) because is the only map that categorized the Restaurants in different classes such as snacks, cafes or pubs. 565 cafes and pubs are selected. No popularity quantification is made for this activity type, because all of them have the same probability of being selected. The map that displays the selected cafes is included in *Appendix III*.

3.4.7. Other destination characteristics: opening times and staying times

The staying time in each destination is randomly assigned from a minimum and a maximum value (defined by the modeler) and they depend on the activity type group. The opening and closing times are determined from available data.

The opening and closing times of the destinations are collected from Google, the Amsterdam Marketing datasets (data.amsterdaml.nl) and from the museums and attractions websites. Walking and sightseeing activity types are supposed to be open all day since they are located in public space (except the Beijnhof, which closes at 17:00).

The staying times in each destination is the only absolute guess from the modeler. Google popular times were used to determine how much time people would spend in some locations, but it was difficult to determine. In order to be more realistic, it is decided to establish a minimum and a maximum time depending on the activity type; in general, a tourist would spend more time visiting a museum than visiting a sightseeing. Then, the staying time on each visited destination will be randomly assigned between these min and max values. Table 3.4 shows these Maximum and minimum values.

Table 3.4. Maximum and minimum staying times – defined per activity type

Activity / destination type	**Input data**	
	Min. staying time (minutes)	Max. staying time (minutes)
Walking area	30	45
Shop	30	150
Dinner-pub	45	90
Market	10	45
Cultural activity	60	180
Sightseeing	0	10

3.4.8 Time of leaving the hotel and time budget parameters

The time tourists leave the hotel and the time they spend on the city follows a Gauss distribution defined by its mean and standard deviation.

The average and standard deviation are estimated from the results of van der Drift (2015) analysis. The number of Flickr pictures is used as a proxy to estimate at what time starts and for how long the tourist activity takes place in the city. Several temporal distributions were extracted from the collection of tourist photos. van der Drift (2015), extracted the unique number of tourists per hour of the week from the timestamps of tourist photos. If one user takes many photos within one interval, it still counts as one. The temporal distribution is shown in table 3.5.

Table 3.5 Temporal distribution of Fickt pictures of international tourists (van der Drift, 2015)

Hours	**Monday**	**Tuesday**	**Wed**	**Thursday**	**Friday**	**Saturday**	**Sunday**
12:00 AM	85	78	83	83	69	108	119
1:00 AM	52	58	50	49	68	70	92
2:00 AM	46	47	57	51	53	54	75
3:00 AM	43	52	54	46	61	61	55
4:00 AM	39	49	53	56	55	71	57
5:00 AM	61	58	69	48	55	70	70
6:00 AM	68	62	55	58	60	86	73
7:00 AM	78	76	62	76	104	98	90
8:00 AM	119	131	104	113	123	145	114
9:00 AM	182	156	146	143	185	237	209
10:00 AM	232	212	215	199	248	322	269
11:00 AM	284	228	244	259	293	398	363
12:00 PM	287	256	251	251	322	476	412
1:00 PM	288	260	311	278	368	453	407
2:00 PM	281	268	274	285	332	458	400
3:00 PM	255	255	273	291	320	462	397
4:00 PM	251	259	245	274	313	435	336
5:00 PM	226	226	217	244	264	379	284
6:00 PM	195	192	212	216	263	319	236
7:00 PM	180	211	178	205	210	260	196
8:00 PM	186	162	143	187	214	268	183
9:00 PM	140	140	134	163	173	193	173
10:00 PM	117	131	139	157	140	175	140
11:00 PM	87	100	117	109	120	140	97

The number of pictures from table 3.5 are plotted in figure 3.2, this data is used as an approximation to establish what time tourists leave the hotel and how much time they spend outside. The hourly difference between the number of pictures is plotted in *Appendix V- Time of leaving the hotel and time budget*.

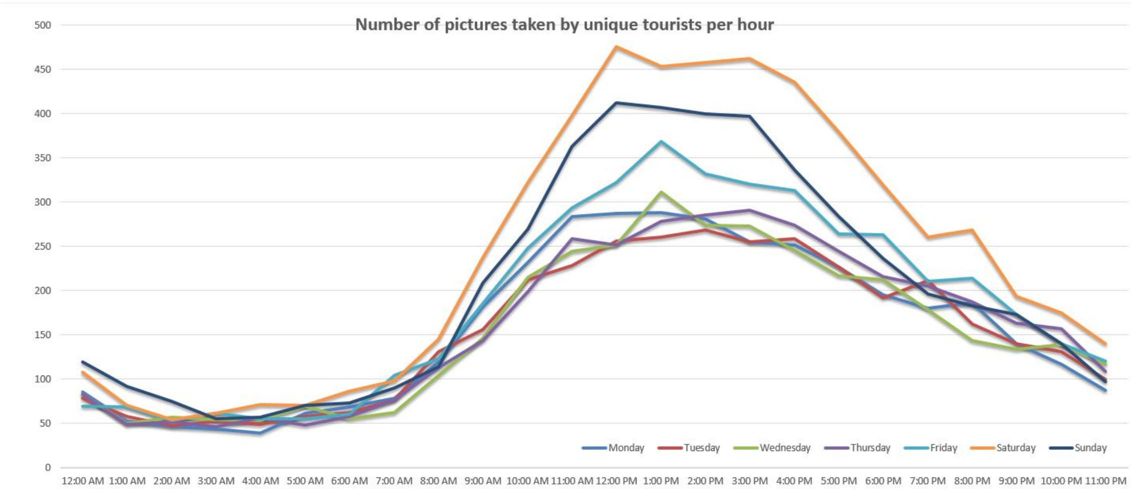


Figure 3.2. Number of pictures hourly distribution by day of the week – made from van der Drift (2015) dataset

Time of leaving the hotel (truncated Gauss distribution)

The hourly difference in the number of pictures taken per day is plotted in Appendix V, these charts are based on van der Drift (2015) results (table 3.5). The average time of leaving the hotel is established at 8:30 based on these charts. Looking at them, the number of pictures is steadily increasing until 11:00, therefore, the standard deviation is considered as two hours and a half. However, this Gauss distribution must be truncated at the left side, otherwise, some tourists would be set to leave the hotel even before the simulation starts at 6:00. Also, if tourists leave the hotel, for instance, at 7:00, most of the attractions will be closed so tourists would go only to the open activities: walking areas and sightseeing activities. For these reasons, the gauss distribution to the left is truncated so that tourist will not leave the hotel before 8:00.

Time budget (Gauss distribution)

The number of daily hours in which the activity of international tourists is high is determined from the charts of Appendix V as well, based on van der Drift (2015) results (table 3.5). The activity is considered high when the number of pictures taken is higher than the average of that specific day. The number of hours in which the activity is high varies between eleven and fourteen, depending on the day of the week, therefore, an average of twelve hours and half is considered. From BOMA 2016 surveys, the average time that tourists spend on the public space is 8 hours and a half. The difference between these two values is 4 hours so this will be considered the standard deviation of the gauss distribution.

3.4.9 Route choice and travelling distances

The route to and from the hotel and between two consecutive destinations is calculated based on the shortest-distance on the street network. The travelling distances (and so travelling times) are calculated based on Euclidean distances.

The first approach when designing this research was to include different factors that might affect route choice (such as directness, number of activities or street busyness). However, knowing what the tourist do is crucial to determine where they go, and it took up the available time for this research. Because of that reason, unfortunately, the route choice has been left to the simplest approach: shortest route.

3.5. Model description

The ODD protocol (Overview, Design concepts, and Details), initially developed by Grimm et al. (2006, 2010) is used to describe the model. This protocol aims to standardize the published descriptions of Agent-based models and it has significantly improved transparency and replicability of these models (Lee et al, 2015). Table 3.6 shows the basic elements of the protocol that should be described (Grim, et al 2010). Numbering all the elements when using the protocol is optional, therefore some categories will be grouped or skipped in order to better describe the current model. The overview section is presented in the main report block because it helps with the understanding of the results. However, due to its extension, the design concepts and details are described in *Appendix VI- ODD protocol*.

Table 3.6. ODD protocol elements (Grim, et al 2010)

Overview	Purpose Entities, state variables and scales Process overview and scheduling
Design concepts	Basic principles Emergence Adaptation Objectives Learning Prediction Sensing Interaction Stochasticity Collectives Observation
Details	Initialization Input data Sub-models

Overview

Purpose

The purpose of the simulation is to build a destination choice model that characterizes the Amsterdam tourist market landscape, so that spatio-temporal patterns of tourist on foot are revealed.

The model aims to simulate what first time international tourist overnighting in Amsterdam *do* on the first day of their visit; *doing* comprises what destinations they visit, what type and for how long. The simulation models how the destination selection is made.
It is a 24 hours simulation starting at 6:00, the time step (cycle) is 1 minute.

Entities, state variables and scales

The entities, agents or species (equivalent term used in GAMA) of the model are:

- Tourist
- Destination
- Street
- Hotel

The destination, street and hotel entities configure **the environment** of the model. They are uploaded in the model as shape files.

The **initial attributes** of each entity are defined on the shape files before these are uploaded. The **initial parameters** are values assigned at the initialization of the model and do not change along the simulation. **The dynamic parameters** are the variables that change their value along the simulation. The dynamic variables are the outputs of the model. The way stochasticity is introduced in the model is through the initial variable values which will differ between each model run. The initial variables and static and dynamic attributes of each entity are specified from table 3.7. to table 3.10.

Table 3.7. Tourist specie

Tourist	Initial paremeters	Time budget Time of leaving the hotel Speed Name Hotel (id)
	Dynamic parameters	Staying time in each destination Visited destinations (name and type) Passed streets (id)

Table 3.8. Hotel specie

Hotel	Initial attributes	Name id Number of beds Location
	Initial parameters	nr of tourists (based on the nr of beds)

Table 3.9. Street specie

Street	Initial attributes	id Name Geometry
	Dynamic parameters	Number of passes

Table 3.10. Destination specie

Destination	Initial attributes	Name Type Location Geometry Opening time Closing time Minimum staying time Maximum staying time Initial attractiveness score
	Dynamic parameters	Number of visits

The relation between the entities is very simple and it is presented in figure 3.3

Table 3.11 presents and briefly defines the model basic parameters. Most of the parameters have been presented in the section 3.4 Modeler assumptions. The parameters quantification is explained also in section 3.4. and in *Appendixes III, IV and V*.

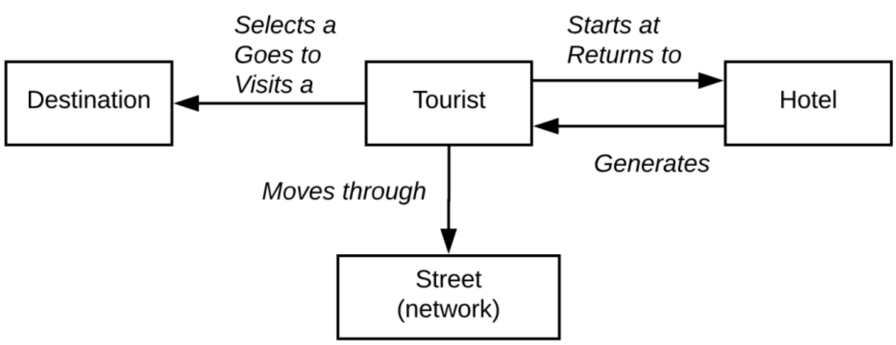


Figure 3.3. Basic relation between model entities

Table 3.11. Model initial and dynamic parameters

Parameter	**Entity to which it belongs**	**Definition**	**Explanation in section…**
Time budget	Tourist	Time each tourist has to explore the city	Chapter 3 - section 3.4.7. / Appendix V
Time of leaving the hotel	Tourist	Time of the day each tourist leaves his / her hotel	Chapter 3 - section 3.4.7. / Appendix V
Speed	Tourist	Walking speed of each tourist	Chapter 2 - section 2.2.10
Staying time in each destination	Tourist	Time that each tourist spends on each destination. The staying time is randomly assigned between a min. and a max. values which depends on the activity type	Chapter 3 - section 3.4.6
Activity type	Destination	Categories in which the tourist market activities have been split. Each destination belongs to one of the activity types. There are 6 categories: Walking, sightseeing, cultural, shopping, visit a market, visit a pub or cafe	Chapter 3 - section 3.4.3
Act. type preference	Destination	Probability of a tourist selecting a specific activity type	Chapter 3 - section 3.4.3
Opening time	Destination	Time of the day the destinations open	Chapter 3 - section 3.4.6 / Appendix IV
Closing time	Destination	Time of the day the destinations close	Chapter 3 - section 3.4.6 / Appendix IV
Min. staying time	Destination	Assumed minimum time a tourist spends on a destination. This value depends on the activity type	Chapter 3 - section 3.4.6 / Appendix IV
Max. staying time	Destination	Assumed maximum time a tourist spends on a destination. This value depends on the activity type	Chapter 3 - section 3.4.6 / Appendix IV
Attractiveness score	Destination	Probability of a tourist selecting a single destination once the activity type has been selected	Chapter 3 - section 3.4.4 / Appendix III
Output parameters	Entity to which it belongs	Definition	
Passed streets	Tourist	The streets id each tourist has passed during the day	
Number of passes	Street	The number of times each streets is passed	
Visited destinations	Tourist	The destinations (name and type) each tourist has visited during the day	
Number of visits	Destination	The number of times each destination is visited	

Process overview and scheduling

The main model process is shown in figure 3.4. This scheme shows the key steps of the simulation. All the parameters presented in the figure 3.4 have been explained in table 3.11. Only the "cycle" term is new to the reader; it is used to express the simulation current time.

The agent will be travelling from activity to activity or from destination to destination during his daily journey. Therefore the first step is to leave the hotel, at the specific time (variable: **time of leaving the hotel**). Then, the agent must select a destination to go to.

The space-time constraints are included here in the way that, primarily, the agent calculates the **travelling times** from his current location to the destinations. Secondly, the agent estimates the time to spend in each of those destinations (the **staying time** of a cultural activity is higher than, for instance, the staying time in a market). Thirdly, the agent must check if the **destination would be still open** by that time (considering the travelling times and the staying time); if yes, those destinations are added to the **feasible destinations** list. The next step is to select an activity type from the feasible destinations list, the **activity type** is selected based on the BOMA surveys probabilities (table 3.3). Ultimately, and once the type is selected, the agent selects the target destination to be visited based on the **attractiveness score**. The higher the attractiveness score, the higher the probability of being finally selected. The last step is to go to the chosen destination. A time counter will initialize as soon as the agent gets into the destination, when this counter equalizes the tourist staying time in that specific destination. It is time to go; the tourist will check then the time left to explore the city **(time budget).** If there is still time, he will pick-up another destination to visit, so the process starts again (excluding the just visited destination so that he does not repeat locations). If the time budget is over, the **agent goes back to hotel** where he finalizes his daily journey.

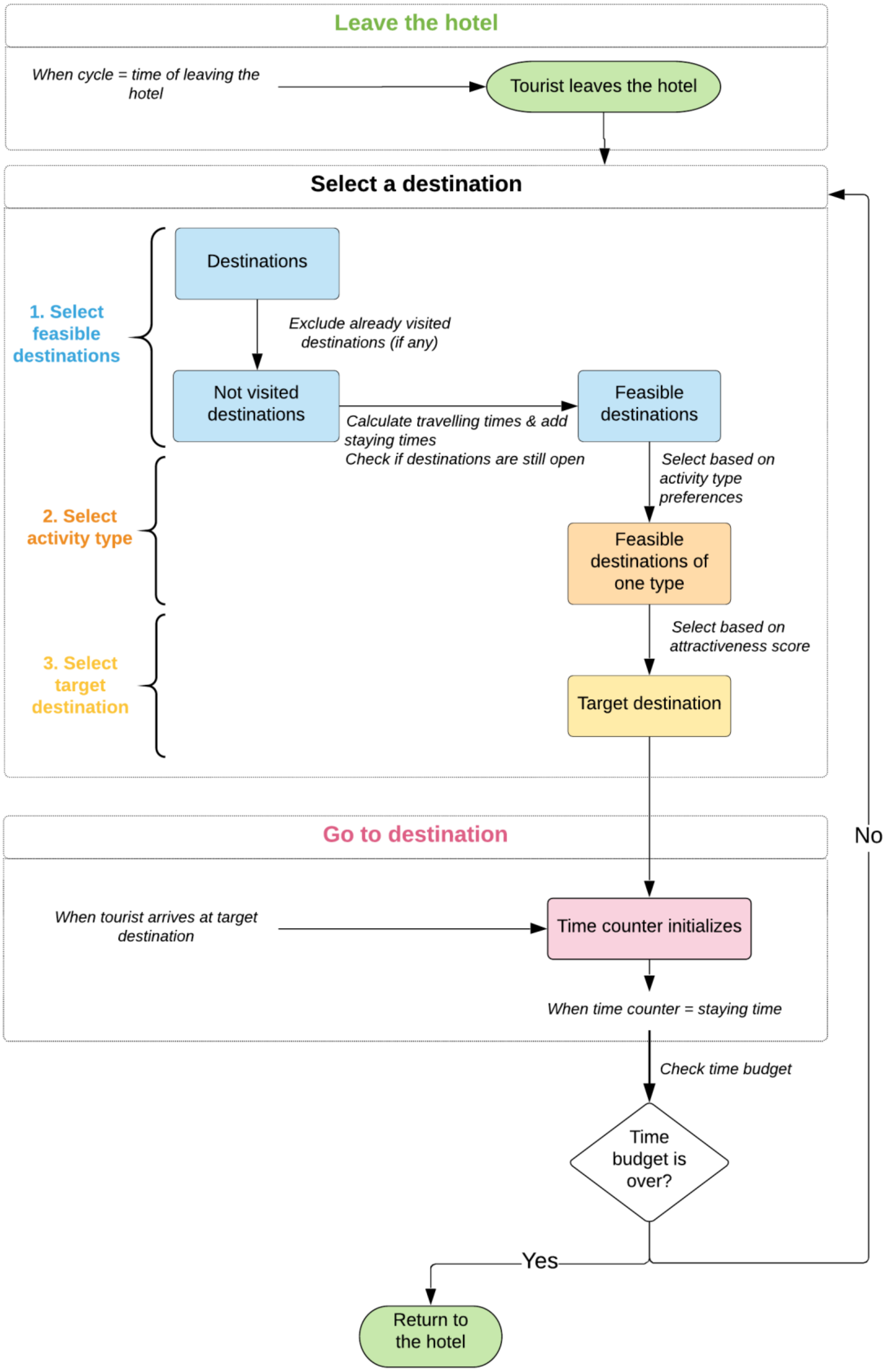


Figure 3.4. Main simulation process

3.6 Model implementation

The codification of the model is developed in small, independent units of code. These pieces are developed independently and then they are tested and debugged. Once one piece of code passes the required tests and meets the expectation, the next piece of code is added. Sometimes, adding the new piece involves changing or adapting the previous one so that no new bugs are introduced. Consequently, the building of the model follows an iterative process in which complexity (new elements or new rules) is added in each iteration until the model is completely developed.
A GAMA model has the following structure:

I. Definition of the **model global characteristics**, attributes or rules:

- Upload shapefiles to populate the model
- Create variables to control and check the model process like boolean variables
- Define global variables such as the probabilities of selecting a specific activity:

```
float mus_prob <- 0.205;
float shop_prob <- 0.130;
float walk_prob <- 0.228;
float dinnerpub_prob <- 0.125;
float sightseeing_prob <- 0.229;
float market_prob <- 0.083;
```

- Create the species (agents) in the initialization section

II. **Definition of the species**, term used in GAMA to depict agents or entities. They are the streets, hotels, destination and tourist in the model

- Definition of their attributes and parameters
- Definition of their behavior or skills – the process overview defined in figure 3.4 describes the behavior of the 'tourist" specie.
- Definition of their aspect to be shown in the display

III. Definition of the experiment

- Input parameters
- Output: includes the monitoring of the preferred variables and the display that can be set as maps, as files, as graphs…

The value of some variables changes along the simulation runs, for instance, the number of visits of a destination keeps increasing along the day, therefore, the output files are obtained along the simulation, so that the evolution in time can be exanimated.

3.7 Number of runs and number of agents

3.7.1. Number of runs

Agent based modelling is based on stochastic processes. Therefore, they require a sufficient number of samples (runs) to achieve the variance stability (Lee et al, 2015). Each parameter setting (scenario) should be run multiple times as well to achieve this statistical stability, so that scenarios can be compared with the initial situation. Otherwise, the modeler cannot assure whether the differences are due to the parameter modification or to the model stochastic nature. The question is what the minimum required number of runs are to reach this stability:

A model variable is selected to evaluate the variance of the model: the **number of visits** of the three most popular tourist destinations. Each of them belongs to a different activity type group. These are:

- Dam square – sightseeing activity
- De Wallen (Red light district)- walking activity
- Rijksmuseum – cultural activity

The model will be run multiple times and the value of this variable (number of visits) will be evaluated. The accuracy of the descriptive statistics will be considered adequate enough when the mean and the variance of the variable reaches stability due to the increasing number of runs. This is a necessary step, because otherwise, the statistics would be simply too uncertain to be reliable. Assessing variance stability requires a metric to properly measure the variable variance: this is the coefficient of variation (Cv) which is the ratio of the standard deviation of a sample (σ) to its mean (μ) (Lee et al, 2015).

$$Cv = \frac{\sigma}{\mu}$$

In general, the coefficient of variation of 2 runs will be higher than the one of 5 runs, and the Cv of 5 runs will be higher than the one of 20 or 100 runs. Lorscheid et al.'s (2012) employs the Cv and a fixed epsilon (E) which is assumed to be the limit of the Cv. When the difference between two consecutive Cv1 and Cv2 falls below the fixed E value, it is considered that the number of runs that produce Cv1 is the adequate minimum number of runs. As Lee et al (2015) exemplifies it: a model is run multiple times (i.e. 10, 50, 100 and 500). The Cv of the different sets of runs is: 0.42, 0.28, 0.21, 0.21. If E is set as 0.01, the minimum number of required runs to reach stability in this model is 100 when the difference between the Cv 's is lower than 0.01.

Lorscheid et al (2012) method is implemented in the current study, E is set as 0.01. The model is run 5, 10, 15 and 20 times. Table 3.12 shows the Coefficient variation of the variable number of visits for the three selected destinations. The model should have been run much more times (i.e. 50 or 100 times). Unfortunately, due to the time constraints this was not possible. However, the Cv's obtained are considered low and the differences between them are below E, showcasing low variable variance. Therefore, 10 runs is considered as an adequate number

Table 3.12. Coefficient of variation of the variable "number of visits"

Number of runs (500 agents	Coefficient of variation - Variable: number of visits		
	Dam Square	Rijksmuseum	De Wallen
5	0,04	0,12	0,02
10	0,04	0,10	0,04
15	0,04	0,10	0,04
20	0,04	0,10	0,04

3.7.2. Number of agents

There are 300 hotels that fall within the limits of the study area, the first assumption is to be considered that they are at their full capacity. This generated a total of 32.000 agents (tourists). However, the run time of this model was more than 15 hours. Large and complex ABM with high run times disallow the production of large number of runs, and, indeed, in this case, the model has to be run 10 times for the initial scenario and, at least, 10 runs more for each scenario which makes a total of 40 runs. The model had to be scaled-down due to the time constraints; it was then run with 3200 agents; the running time was around 5 hours. This amount of time is still considered high due to the time limits and the required number of runs. At this point, it was decided to run the model with 500 agents and compare the results with the 3200 agents model (the shapefile outputs were blocked in the second situation, otherwise the running time was very high for the 10 runs). The variable to be compared is % of visitors of the 3 destinations picked-up before: Dam square, Rijksmuseum and De Wallen (Table 3.13); the magnitude is the same for the two models (500 vs 3200 agents). Therefore, it was decided to run the model with only 500 agents so that time there were no more constraints.

Table 3.13 Percentage of visitors of three destinations (500 and 3200 agents)

Destination	% of visitors	
	500 agents	3200 agents
Dam Square	50,87	50,49
Rijksmuseum	12,46	12,57
De Wallen	50,69	49,54

The results of the number of visits, the percentages, σ, μ and Cv of the 3 selected destinations is included in Appendix VII - Number of runs and number of agents.

3.8 Model outputs, model verification and model validation

3.8.1. Model outputs

The increase amounts of data and complex dynamics of ABM foment the complexity of the outputs. Nevertheless, ABM output data analysis is as significant as developing the

ABM itself (Lee et al., 2015), and adequate output analysis and representation are needed for developing a proper communication with the stakeholders or people that are interested in this topic. For these reasons, effort is placed on thinking how the model outputs should be. A high volume of outputs is generated, and it is important to be able to characterize them statistically. Moreover, trends should be obtained from the outputs to enhance the analysis of the results.

ABM has the potential to produce data on aggregated and agent-level at the end of the simulation. However, in this case, it is also crucial to obtain output data over time and space so that spatio-temporal dynamics can be evaluated. Spatial maps generated may capture the model emergence and represent the temporal outcomes, such as evolving agent characteristics or measure model variables, such as counts.

GAMA allows for diversity of outputs files formats. Comma separated values (.csv) and shape files (.shp) are selected for this model. The results can then be analysed per run or per the 10 runs average. The global model verification and validation is made using the 10 run results.

The following output files are generated in each run, and for each scenario:

- Comma separated values files:
  - Initial variables –obtained after the initialization phase
  - Individual results – obtained at the end of the simulation
  - Visited destinations - obtained at the end of the simulation

CSV files are useful to analyse the initial variable distributions and the results at the end of the simulation. They are necessary to build up charts such as pie or bar charts and histograms that allow the model verification and the comparison with the input data.

- Shape files – generated every 30 minutes

  - Passed streets – obtained every 30 minutes
  - Visited destinations – obtained every 30 minutes

Shape files are necessary to follow the evolution along time and to understand the model dynamics spatially. They are generated every 30 minutes (thus, 48 shape files for each variable [passed streets and visited destinations], 96 in total are generated in each run).

Griffith et al. (2010) used Getis-Ord Gi* "hotspot" analysis to identify statistically significant spatial clustering of high/low values. Heat maps will be generated from the visited destinations shape files. They will display the number of visits of the tourist destinations. Shape files are handled with QGIS software: heat maps are made using the *heat map function* in the software, which calculates the number of visits density using the kernel function (quartic shape) with a search radius of 90 m. The output is a raster file with a cell size of 6x6 meter. The number of passes of each street is represented following a quantile classification, in which each class contains an equal number of features.

3.8.2. Model verification and model validation

The **model verification** is a crucial phase in ABM. It confirms that the implemented model works as it is designed (Pizzitutti et al, 2014). The verification phase comprises the evaluation of the running model and the (statistical) verification of the outputs. The **model validation** consists of the assurance that, not only the model works, but also that it is a good model for what it aims to represent (Gilbert, 2008) and it can be indeed used to inform about a specific phenomenon. The validation phase normally consists of monitoring that the model results are sufficiently close to data from the real world (Pizzitutti et al, 2014).

Generally, systematic model validation requires suitable, accurate data and in sufficient quantity (Troitzsch, 2004) which makes ABM validation a challenging matter. Depending on the model level there are different approaches to validate the models (Boero and Squazonni, 2005). Some ABM aim to formalize a theory, they do not model any empirical case. In this case, the model can be only validated at a very abstract level; the first validation step is to assess whether the model generates the expected patterns at a macro level.

A more specific group of models are the **middle range models**, which aim to describe a particular phenomenon but in a general way, so it could be applied to other cases (Gilbert, 2008). The current model is considered as a middle-range model: the dynamics of the model and its output distributions should be similar to the dynamic of the real world or reveal the same "statistical signatures" (Moss, 2002).

According to Klügl (2008), there are three phases in validation assessments for agent-based models:

- Animation assessment: assessing the overall simulated system, this is considered as the running model assessment.
- Immersive assessment: assessing the behavior of one agent active in the model and check how the agent responds along the simulation
- Output assessment: Evaluating the outcomes. Part of the output assessment belongs to the verification phase. For instance, check the output distribution of known parameters and the other part belongs to the validation phase; assess to what extent the model represents the real-world phenomenon.

Klügl (2008) verification and validation phases have been adapted to the current study, other researchers' suggestions have been also implemented.

The verification of the current model includes:

1. The verification of the small pieces of code while the model was being built (testing first only a few rules with few elements and few agents)
2. The **verification of the running model**: the model visualization in GAMA is crucial in this phase. Some visual aspects are added to the displays so that the model visualization is relatively accurate. This phase comprises checking the times of

leaving the hotels, that tourist do not get stuck at destinations, that only open destinations were visited and so forth. – section 4.1.1.

3. **Verification at the individual level**: Only one agent (tourist) is followed to check that indeed he behaved in the adequate manner, and also the outputs at the individual level are checked: time of leaving the hotel, time budget, number of visited destinations along the daily journey… – section 4.1.2
4. **Verification at the global level**: it is also important to test the parameter values for the known scenarios (Gilbert, 2008). If the output of the parameters is known (at least with some degree of certainty), it is useful to test that the model reproduces this behavior. In this case, the initial variables distribution (speed, time budget, time of leaving the hotel) are checked the maximum staying time in each destination should be within the limits, the time budget must be higher than the sum of the time spent in each destination and higher than the time spent traveling between them. Lastly, the number of visited destinations along a daily journey has to "make sense". It cannot be too high or too low according to the time availability. – section 4.1.3

The validation of the current model comprises:

5. Comparing the model output distributions with the input distributions to evaluate how "good" the model represents the travelling behavior of tourists when visiting an urban destination. The variance between output and input (if any) should be explained and justified, otherwise, it might depict a bug in the code or an incoherence in the model (section 4.2.)

   As it was mentioned above, the current model is considered a middle-range model. A quantitative match is, therefore, not expected but the output should be qualitative similar to phenomenon observed in the world. For instance, in this case, the yearly number of visitors of the cultural activities is available. The model output gives the number of visitors of each cultural activity. These numbers are not the same quantitatively but, qualitatively, they should keep the same proportion as in the real world (comparing % for instance).

A more comprehensive validation test would be to assess what happens when some model parameters are modified. This is known as the sensitivity analysis which will be explained in section 3.9 and presented in chapter 5. If parameters are changed, the patterns at a higher level might change as well and these changes should be interpreted.

3.9 Sensitivity analysis and testing of the scenarios

To complete the model validation some parameters should be modified and see how the model reacts to these changes, this is known as the sensitivity analysis (Gilbert, 2008). **The way the sensitivity analysis is carried out in this study is throughout the exploration of three "what-if" scenarios**. The goal of testing the scenarios is not to predict the future of a specific situation but to analyse how the model reacts under specific changes. For this reason, the sensitivity analysis is considered in the study.

A sensitivity analysis and testing different scenarios are required in this study due to these reasons:

- To deepen the understanding of the model stochastic process
- To evaluate the effect that changes in the input parameter have over the model
- To demonstrate (or not) how the model might be a useful tool to be used in the policy making process
- To evaluate the consequences of specific decisions or specific situations

Sensitivity analysis (SA) focuses on identifying parameters that most impact the model's output. If the output of the model does not show a significant effect when the value is changed, it means that the model is stable and not sensitive to that value. Modified values that have no effect on the model can be excluded of the calibration process. On the other hand, values that have an effect on the model should be re-consider for calibration in order to assure the model represents what is supposed to. The **calibration process** is the process of adjusting the value of some variables to change the response of the model so that it becomes more adequate (Pizzitutti, et al 2014). A proper model calibration is not carried out in the current study. Nevertheless, after performing the sensitivity analysis (chapter 5), there is a clear picture of which variables have an effect on the model and how their values should be modified. These results could be used for future research steps.

The changeable parameters in the model are quite many and they are related somehow to the assumptions made by the modeler:

- Number of runs
- Number of agents
- Time of leaving the hotel
- Time budget
- Walking speeds
- Preference of engaging in a specific activity type
- Attractiveness scores of the single destinations
- Staying time in each activity (minimum and maximum values)
- Opening and closing times of the activities
- Location of specific destinations

This is an extensive list that should be restricted; the amount of outputs and time to analyze the effect would be simply excessive given the available time for this study.

The number of runs and number of agents are excluded from the list; a modest sensitivity analysis is already made using these two variables (see section 3.7). The variance of a selected variable (number of visits) is analyzed and, it has been proven that the model is stable regarding number of agents and number of runs.

Some notions about the relation between variables are known a priori and it is decided that it is more interesting to change the parameters that have a relation between each other; changing the initial variables (time budget, time of leaving the hotel and speed) will definitely have an impact on the model; however, the value of these variables does not depend on any other parameter. For this reason, the final list of changeable parameters is reduced to:

1. Preferences for an activity type
2. Attractiveness scores of single destinations
3. Staying time in each destination
4. Opening and closing times of destinations
5. Location

The **final selection of parameters and**, therefore, **the scenarios to be tested**, is made after the analysis of the initial scenario so that there is a better understanding of the model. It should be noted that the side goal of this study is to highlight the potential of the model to be used in the (tourists) policy making process, therefore, Amsterdam marketing considerations have been consulted in order to select which scenarios would be more interesting to analyze.

The marketing strategies behind Iamsterdam work towards a higher spatial spread of the tourists in the city. Also, Stad in Balans (Gemeente Amsterdam) seeks to promote alternative tourist's destinations and to develop new recreational places or stimulate temporally events like festivals during the summer season. For instance, some locations that are not well known are being promoted such as NDSM, Westergasfabrik, De Hallen, or shopping streets such as Haarlemmerdijk. Lastly, other regulations are related to spreading the crowds outside of peak hours, thus managing the opening and closing times of museums and cruises. Considering the previous facts, table 3.14 shows which relevant scenarios are finally designed.

Based on the previous findings, only three out of the five previous parameters are selected:

1. Preferences for an activity type
2. Opening and closing times of destinations
3. Location

Preferences for an activity type affects the staying time parameter. The attractiveness score is related to opening and closing times, and the location affect the general spatiotemporal patterns which in its turn so it affects the output variables.

Table 3.14. Proposed scenarios

Scenario		Parameter (modified)	Parameter type
1	Winter-summer scenario	Preference for different activity types	Preferential
2	Pop-up Bloemenmarkt	Location of the Bloemenmarkt	Spatial
3	Museum eve	Closing times of a specific museum	Temporal

Chapter 4 - Verification and validation of the model. Spatio-temporal patterns evaluation

Chapter 3 explains which model outputs are obtained and how to carry out the model verification and model validation (section 3.8).

The objective of the verification of the model is to confirm that the implemented model works as it is designed. The model validation objective is to assure the model is a good model for what it aims to represent, the validation of the model consists normally of monitoring that the results are sufficiently close to real-world data. The model validation requires suitable and accurate data which was not available in this case. For this reason, the validation phase of this research consists of contrasting the real-world data used to populate the model (input data) with the model outputs and analyse the variance between the two, although, definitely, the proper validation of these models should be carried out using other data than the one used to populate the model. A limited proper validation is carried out for the shopping activity type (in section 4.2.): a *Locatus* dataset containing number of passes of some shopping streets was available.

The model outputs collect data on a macro (global) level, for example the number of times each street is passed, and at an agent level, for example, collecting the number of destinations each single tourist visit. The model is analyzed at these 2 levels: the individual and the global. At **the individual level**, the initial variables (time of leaving the hotel, speed and time budget) are statically verified. The relation between other variables is also evaluated to assure the model performs as it is expected. At **the global level**, the model outputs and the input data are compared; a high variance might depict incoherencies or inaccuracies in the model, therefore, the variance between these two should be reasoned and justified. Section 4.3. presents the largescale **spatio-temporal patterns**. This chapter is subdivided in 4 sections, the last section (4.4) summarizes the main findings.

4.1 Model verification
- 4.1.1 Verification of the running model
- 4.1.2 Verification at the individual level

4.2 Verification at the global level and model validation
4.3 Spatio-temporal patterns evaluation
4.4 Results Conclusions

This chapter also illustrates the variety of analysis that could be further explored using the outputs of the model. The verification and the exploration of the model is necessary to be able to “play” with it in further stages: in the next chapter, the model is used to generate 3 “what-if” scenarios modifying some of the parameters values.

4.1 Model verification

4.1.1 Verification of the running model

The most straight forward verification is made while the model was built. The model-building process has been iterative where complexity was added in each iteration. The first trials included only a few agents, a few entry points and a few destinations. Once the desired outcome was reached, more elements or more rules were added in the following iteration. This process has been detailed already in the previous chapter (chapter 3 section 3.6).

Once the model is completely built, it starts the verification phase of the running model. GAMA visualization options are used to support visual verification; the destinations color intensity is set up to increase with the number of visitors and specific destinations are colored differently according to their opening and closing times. This is a way of checking that indeed the model reacts properly. The number of passes of each street is displayed while the simulation is running, this time the thickness of the street line increases with each tourist pass. It can be clearly visualized the most passed streets are the ones connecting the most visited destinations. See figure 4.1.

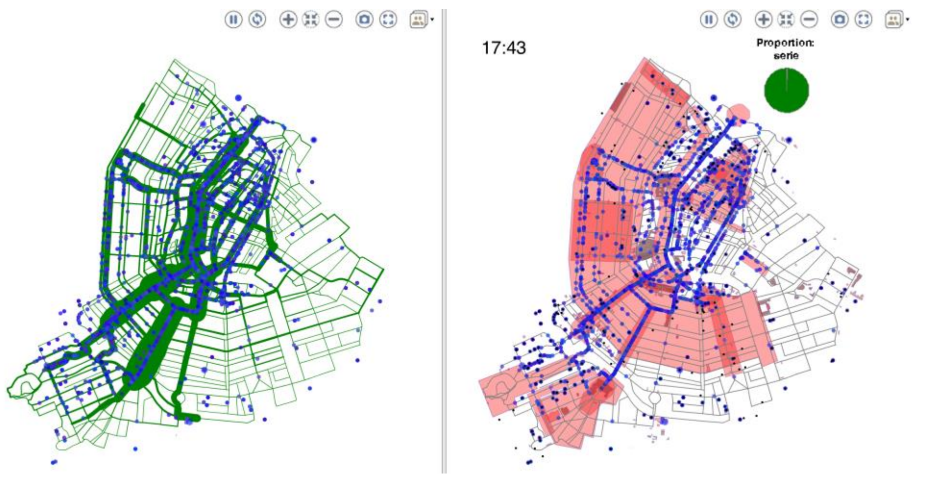


Figure 4.1. Screenshot of the running model. Left: thickness of the streets varying with the number of passes of each street. Right: color intensity of the destinations increasing with the number of visits per destination.

The running model shows already very realistic patterns about the functioning of the city. Figure 4.2. highlights the differences in the temporal distribution. At 11.00 (figure 4.2 – left) some tourists are still clustered at their hotels, so hotels are the hotspots at this time. At 17.00 (figure 5.2 - center) most of the tourists run along the main corridors and shopping streets that connect the hotspots in the city such as Westerkerk, the Flower Market or Museumplein. The most passed streets at this time (17:00) are Spiegelstraat, Leidsestraat, Raadhuisstraat or Rokin. Around 21.00, the pattern changes; now tourists do not run along the main streets but gathered arund the city night-hubs or visiting the remaining open destinations: Leidseplein, Rembrandtplein and De Wallen (Red-light district) (figure 4.2 –

right). The green chart on the upper right corner of figure 4.2. is used to check agents have left the hotels.

Figure 4.2. Running model. Model destinations (Red = open destinations, color intensity increasing with the number of visits. Grey = closed destinations) and agents (blue dots)

4.1.2 Verification at the individual level

The individual results evaluation is aside of the research scope. Nevertheless, they constitute a crucial part of the verification phase. The results obtained at this level reveal also potential further research since they allow, for instance, to track and map individual tourist routes, this issue will be explained at the end of 4.1.2 section. The results have to "make sense" at an individual level in terms of, for instance, number of visited destinations during the daily journey given the available time (time budget).

The initial variables distribution must match the input agent's parameters such as speed, time budget and time of leaving the hotel. Figures 4.3 and 4.4. show the time of leaving the hotel and time budget distribution of only the first 5 runs for the sake of visualization, although the results from the 10 runs are utilized: **the average time tourists leave the hotel in the morning is 9:45. The time budget is 9 hours and 40 minutes. Lastly the average walking speed is 1 m/s.**

Figure 4.3. Time of leaving the hotel variable distribution (5 first runs)

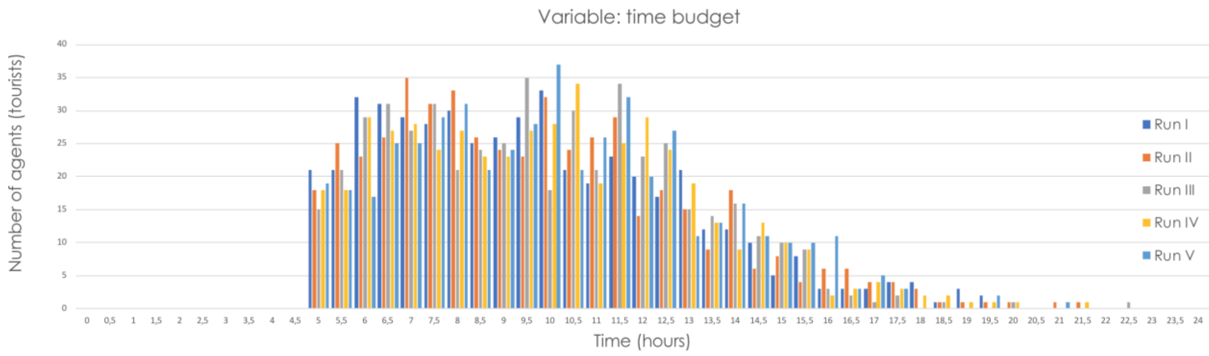


Figure 4.4. Time budget variable distribution (5 first runs)

The results of the 10 runs are combined to establish the average number of visited destinations per tourist in one day. **The average daily number of visited destinations per tourist is 8**, varying between a minimum of 1 or 2 visited destination up to 20 (figure 4.5).

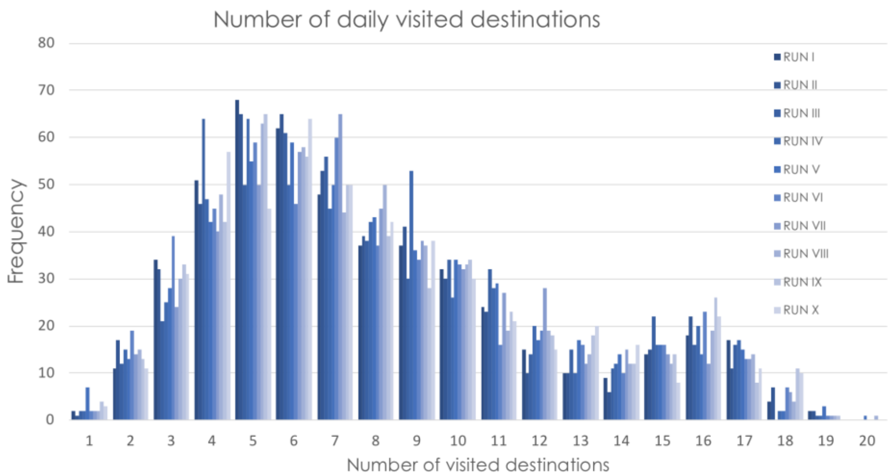


Figure 4.5 Number of daily visited destinations (10 runs)

The number of daily visited destinations can be categorized per activity type (figure 4.6). 50 random tourists have been selected for the sake of the chart visualization. It can be observed in how many different activity types a single tourist engages at. The most visited activity type is sightseeing and walking activities. This graph helps to verify that **indeed, tourists only visit one single destinations form the pub-cafes** activity type as it was set in the conceptual model.

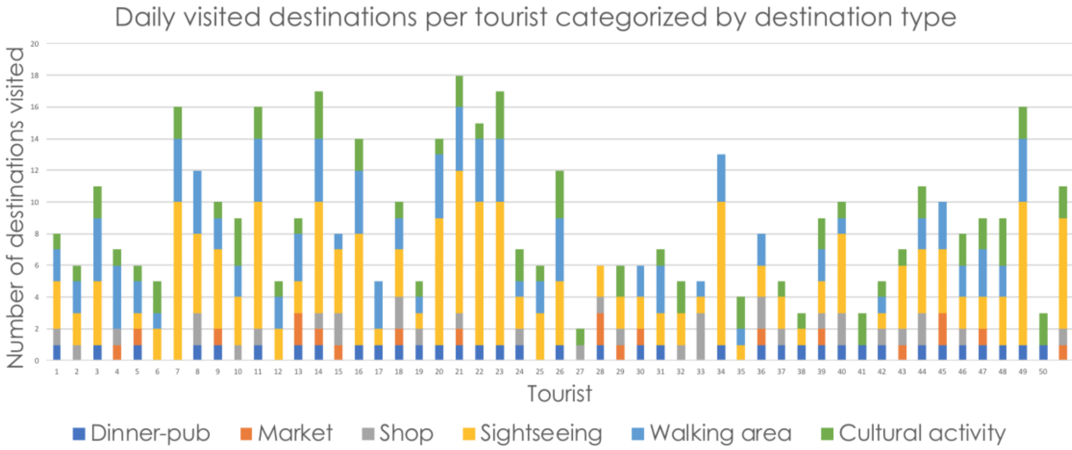


Figure 4.6. Number of daily visited destinations categorized per type (50 tourists)

Another interesting way of verifying the model is comparing the initial variable *time budget* with *total staying time* which is the sum of the time spent on each destination by each tourist along his journey. The time budget indicates the time each tourist has to explore the city since he goes out of the hotel until he goes back at the end of the journey. **The time budget must be always higher than the *total staying time* in each destination**. Figure 4.7. supports that the model performs as it is expected. The comparison of these two variables also provides a meaningful insight about how tourists spend their time; the difference between the time budget and the total staying time is the time tourists spend travelling between destinations and going back to the hotel. **On average, tourists spend around 6 hours visiting destinations and around 3 hours travelling between them**. It is clear that most of the time is spent visiting destinations and not travelling between them. This is due to how the model has been set; as soon as the staying time in one specific destination is over, tourists select the next target destination and go there.

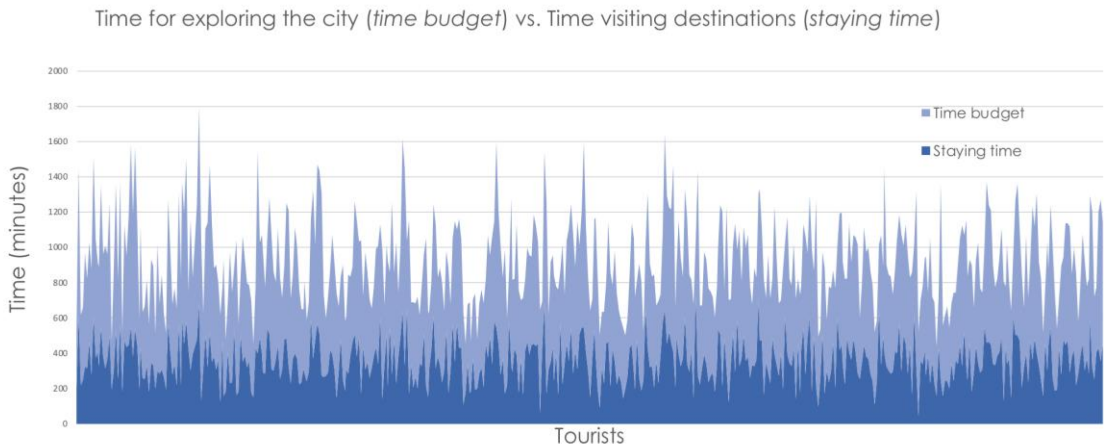


Figure 4.7. Time budget vs. staying time

Time budget and total staying time are related through the number of daily visited destinations; in general, the higher the time budget of a tourist, the more destinations he will be visited and, therefore, the higher will be the total staying time. There are some minor details to be further investigated: the staying time is assigned depending on the activity type, sightseeing activities have a lower staying time than cultural activities, therefore, one tourist might visit only two cultural activities whereas other tourist, with the same time budget, might visit five sightseeing destination. This fact will be further discussed in chapter 5.

To further illustrate the type of results that are obtained at the individual level, a "random" tourist is picked up (tourist x). The time budget of tourist_x is 13 hours, meaning that tourist_x spent 3 hours and 15 minutes travelling from and to the hotel and travelling between destinations. Tourist_x visited a total of 8 destinations in his/her daily journey, this tourist visited 2 museums, 2 walking areas, 1 shopping street, 2 sightseeing and 1 dinner-pub. No markets have been visited in his/her daily route. Most of the time was spent visiting the two cultural activities, although the balance between activity types is well distributed. Tourist_x results are shown in tables 4.1. and 4.2. Table 4.1. illustrates all the destinations visited by this tourist and table 4.2 the time spent by activity type.

Table 4.1. Visited destinations (n=8) and staying time of one single tourist (Xx in his daily journey

Name	**Type**	**Time spent in each destination (min)**
1. Anne Frank huis	Cultural Activity	160
2. Central Station	Sightseeing	4
3. Dam square	Sightseeing	8
4. De Wallen	Walking Area	33
5. Kalverstraat	Shop	112
6. Museumcafe	Dinner-Pub	76
7. Museumplein	Walking Area	31
10. Sexmuseum-Venustempel	Cultural activity	161
Total time spent visiting destinations (min)		**585**

Table 4.2. Time spent per destination type of one single tourist (x)

Activity / destination time	**Staying time spent in each type (min)**
Cultural Activity	321
Dinner-Pub	76
Shop	112
Sightseeing	12
Walking Area	64

The main conclusion from the evaluation at the individual level is that there are many ways to verify the model using the variety of output. The type of analysis presented above can be extended for all the tourists and, therefore, tourist typologies might be established (how many tourists engage at mainly cultural activities, how many do mainly shopping and so forth). Besides, it would be interesting to follow the daily track of each tourist and map it. These results can be analyzed and check when how distance would play a role in selecting the following destination.

4.2 Verification at the global level and model validation

The verification of the model is carried out at the three different stages: 1. Verification of the running model, 2. Verification at the individual level. 3. Verification at the global level. The validation of the model which consist of contrasting the input (real-world) data and the model output, can be only carried out at the global level because of the aggregated nature of the data used to populate the model. Section 4.2

The evaluation at the global level provides what this research is aiming for: revealing spatio-temporal patterns of tourists in an urban destination. The outputs are analyzed to get an understanding of the model performance, so they are compared to the input data. The variance between output and input is reasoned and justified, this is considered the model validation process. What it is expected is that the destinations with higher attractiveness scores should be the most visited ones or the probability of engaging at a specific destination type should match the input data from BOMA surveys. Largescale patterns are also displayed and evaluated such as the number of times each street has been passed and the number of visits of each destination. The results of the 10 runs are used.

The initial variables statistical signatures (average and standard deviation) are compared to the input data (table 4.3). It should be noted that the model average values of the variable "time of leaving the hotel" and "time budget" differ from the input ones. This is due to the left truncation of these variable distributions not to get negative "time budget" values or "time of leaving the hotel" before 7:30 am (explained in section 3.4.7.). It should be remarked that the simulation starts at 6 am, therefore, the value of the variable "time of leaving the hotel" has to be added to 6 am to get the "real" time tourists leave their hotels.

Table 4.3 Comparison between input and model output (10 runs) of the initial variables

<table>
<tr><th></th><th colspan="3">Input data</th><th colspan="2">Model output (10 runs)</th></tr>
<tr><th>Variable</th><th>Distribution</th><th>Av.</th><th>SD</th><th>Av.</th><th>SD</th></tr>
<tr><td>Time of leaving the hotel (min)</td><td>Gauss distribution (truncated left side in 120)</td><td>150</td><td>120</td><td>228,17</td><td>77,70</td></tr>
<tr><td>Time budget (min)</td><td>Gauss distribution (truncated left side in 270)</td><td>510</td><td>240</td><td>580,96</td><td>189,56</td></tr>
<tr><td rowspan="2">Speed (m/s)</td><td rowspan="2">Random (min, max)</td><td>Min</td><td>Max</td><td rowspan="2">1,00</td><td rowspan="2">0,18</td></tr>
<tr><td>0,7</td><td>1,3</td></tr>
</table>

AV media; SD Standar deviation

Table 4.4 Collects the number of visits that each activity type gets (per run), the results they prove that the model output is stable in terms of activity type distribution. These results are plotted in figure 4.8 and compared to the input data in figure 4.9.

Table 4.4. Number of visits that each destination type has been visited (10 runs)

Destination or activity type	RUN I	RUN II	RUN III	RUN IV	RUN V	RUN VI	RUN VII	RUN VIII	RUN IX	RUN X	Av.
cultural activity	643	663	633	660	674	689	641	662	677	703	664,5
dinner-pub	313	307	320	315	305	316	325	314	313	314	314,2
market	232	240	233	265	245	248	244	226	254	241	242,8
shop	308	296	318	322	336	297	325	317	276	286	308,1
sightseeing	1433	1413	1461	1456	1491	1441	1447	1430	1488	1450	1451
walking area	995	978	1053	1035	1006	999	1098	1028	1065	1023	1028

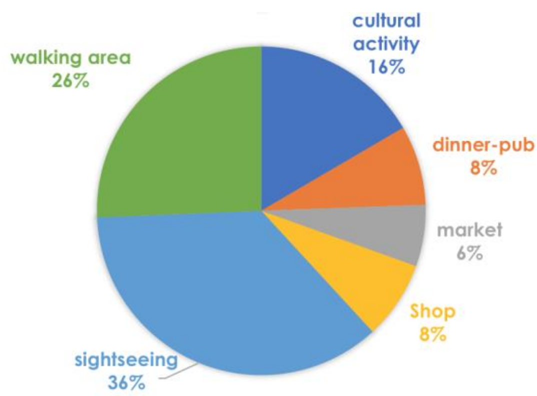


Figure 4.8. Distribution of % of visits per activity type

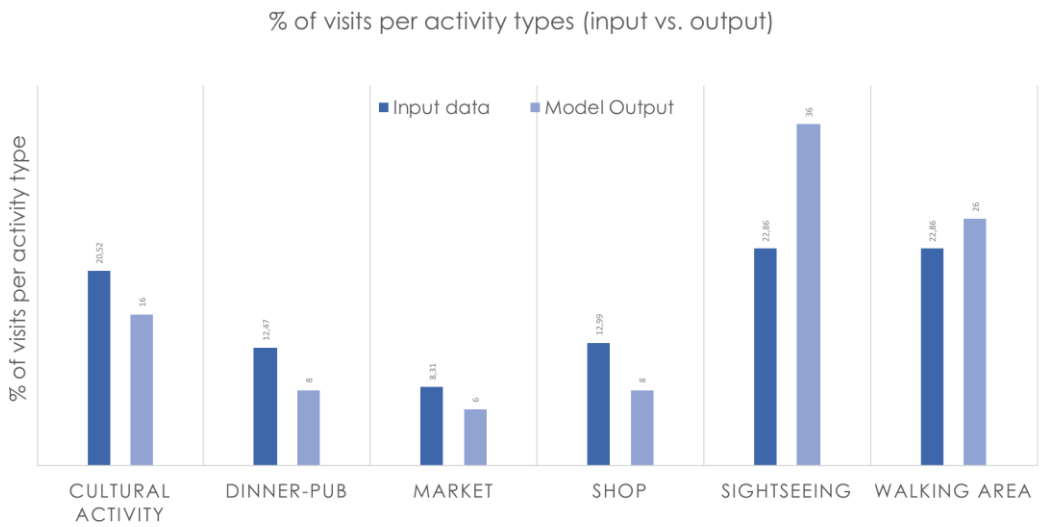


Figure 4.9. % of visits per activity type (input vs. output)

The walking (26%) and sightseeing (36%) activities are the most visited ones (see figure 4.6) as it occurred in the input data. The highest percentages difference between input and output occurs in the sightseeing type. This difference might be due to the sightseen activity closing times; the activities that belong to the sightseeing type are open all day, consequently, when a tourist has to select the next destination at late hours, the probability of selecting a sightseeing will increase because they are among the few open ones.

Another interesting parameter to be evaluated is the maximum staying time on each destination. The maximum value of this variable is fixed, and it depends on the activity type. Table 4.5 compiles the tourist average maximum staying time per run and per activity type. It proves that the model provides stable results for each of the runs. The results are compared with the input data: It is a worthy way of checking if what is the variation that exists between input data and model results (table 4.6).

Table 4.5. Maximum staying times (min)per destination type (10 runs)

Destination type	**RUN I**	**RUN II**	**RUN III**	**RUN IV**	**RUN V**	**RUN VI**	**RUN VII**	**RUN VIII**	**RUN IX**	**RUN X**
Walking area	40,3	40,4	40,0	40,3	40,2	40,1	40,5	40,2	40,5	40,4
Shop	93,7	93,7	99,2	93,7	92,4	93,6	91,7	93,9	93,3	97,9
Dinner-pub	69,4	72,3	69,4	69,4	70,9	69,3	70,1	69,9	70,8	69,3
Market	28,4	28,9	28,2	28,4	29,2	29,9	29,1	28,9	29,8	28,7
Cultural activity	131	131	129	131	132	129	129	129	131	129
Sightseeing	7,1	7,1	7,2	7,1	7,4	7,4	7,3	7,2	7,5	7,5

Table 4.6. Maximum staying times per destination types (10 runs) compared to the input data

Activity / destination type	**Input data**		**Model Output**	**Difference (minutes)**
	Min. staying time (minutes)	Max. staying time (minutes)	Max. staying time (minutes)	
Walking area	30	45	40,3	4,7
Shop	30	150	94,3	55,7
Dinner-pub	45	90	70,1	49,9
Market	10	45	29,0	16,0
Cultural activity	60	180	130,4	49,6
Sightseeing	0	10	7,3	2,7

Table 4.6 displays the maximum staying times split by activity type and they are compared to the input data. There is a high difference with the pre-defined maximum staying time (Input data column) except for the walking and sightseeing activities. This is a flaw related to how the maximum staying times are extracted from the model output but the model assignation is correct.

The following series of charts (figure 4.10 to figure 4.15) are built to see if the percentage of visits of each destination a clear correlation with the attractiveness score has (as mentioned in section 3.4.6a the attractiveness score represents the quantified popularity of each destination).

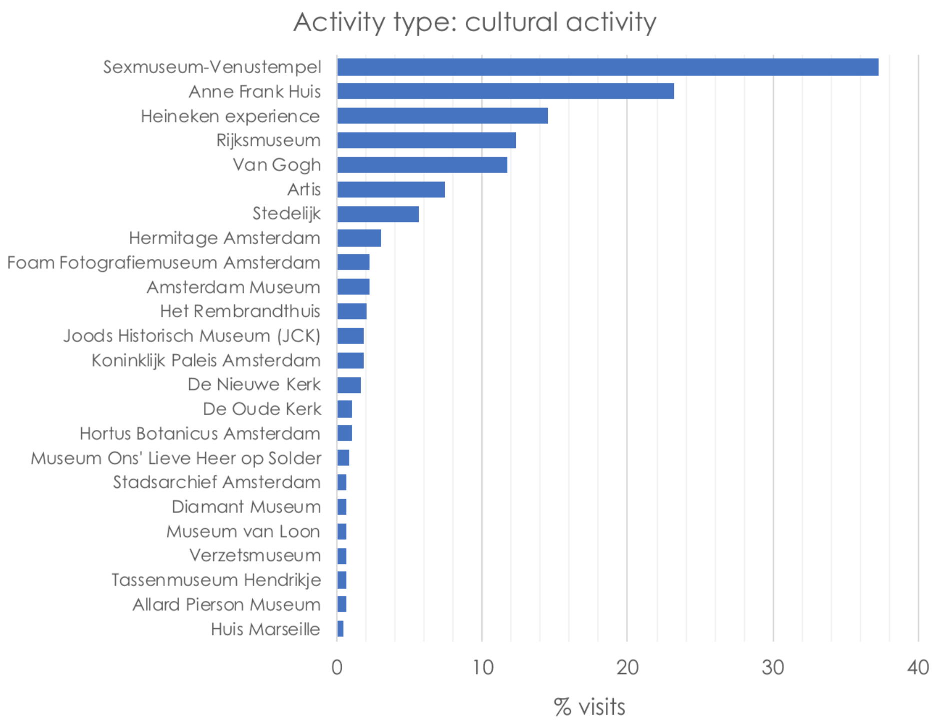


Figure 4.10. % of tourists that visit a specific activity within the cultural type

The top-3 cultural activities according to the model output are 1. Sexmuseum (visited by 37% of the tourists) 2. Anne Frank huis (visited by the 23 %) and 3. The Heineken experience (visited by the 15%). It is interesting to compare the model results displayed with the attractiveness scores input values (attractiveness score tables of each activity type are in Appendix III). According to attractiveness scores (input data), the top-3 cultural activities are Rijksmuseum, Van Gogh and Artis.

It is very likely that the difference is due to the closing times of the cultural activities. Rijksmuseum, Artis and Van Gogh close at 17:00 whereas the Sexmuseum closes at 23.30. Also, Anne Frank Huis and Heineken experience close later, at 20:00 and 19:00 respectively. Therefore, an emergent relation is here addressed: the **relation between the attractiveness scores and the closing times of the destinations.** This relation will be further explored in the next chapter.

Figure 4.11 displays similar results as the previous one but for the **market activity type**. In this case, the results fit better the input data (the market attractiveness score table is in *Appendix III*). The Bloemenmarkt is the most popular market and indeed, the model output "% of visits" supports this fact. The Bloemenmarkt attractiveness score (0.6) is 3 times higher than the ones of the other 3 markets (0.2), and the Bloemenmarkt % of visits is also 3 times higher when compared with Spuimarkt and Noordermarkt, however, it is only 2 times higher when compared with Waterlooplein: this is because Waterloopein closes one hour and half later than the other, so it gets more visits during this time.

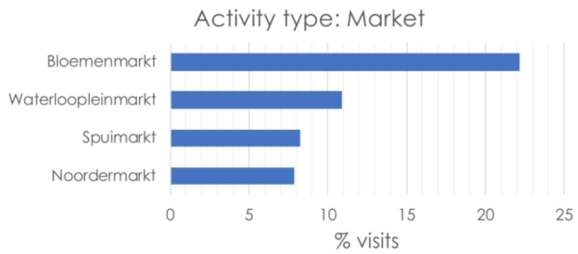


Figure 4.11 % of tourists that visit a specific activity within the markets type

Figure 4.12 displays the % of visitors of the shopping activity type; the model output completely matches the attractiveness scores input data (appendix III), only Utrechtsestraat gets a higher % visits than PC Hoofstraat and Van Baerlestraat in the model, whereas the attractiveness score is slightly lower, nevertheless it is a minor difference. The output matches the input data because the closing time of all the shops is the same so now the attractiveness score is the only variable determining the number of visits.

Figure 4.12 % Tourists that visit a specific activity within the shop type

The interesting is that Locatus (Gemeente Amsterdam, 2016b) delivered some data to Gemeente Amsterdam about the number of visitors passing the main shopping streets in Amsterdam (figure 4.13). Nieuwendijk is the 4th visited destination in the model output whereas is the 2nd most visited in the Locatus dataset, this data represents the total number of passings on a Saturday during peak hours and inhabitants and visitors and not only international tourists are counted; that explains why the match with the model is not perfect. However, it does depict an evident correlation between the attractiveness of a shopping street and the shops/m which is the proxy used to quantify the popularity of the shopping streets in this research. Kalverstraat or Leidsestraat are among the top-3 in the input data, model output and Locatus dataset.

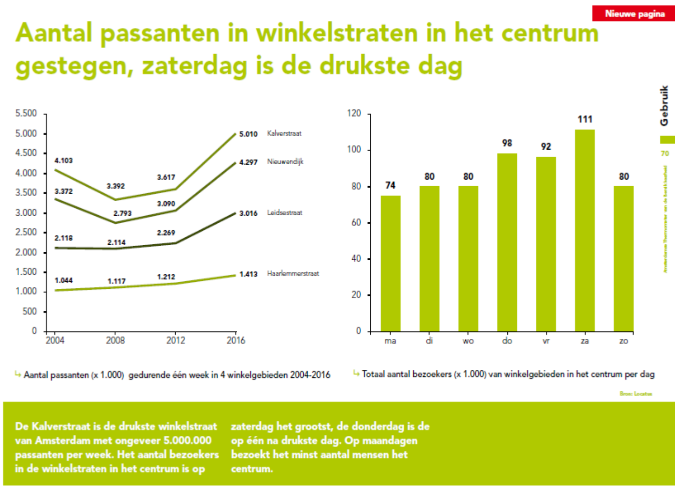


Figure 4.13 Number of visitors passing the main Amsterdam shopping streets
Source Gemeente Amsterdam, 2016,

Figure 4.14 displays the % of visits of the **sightseeing activity type**. The match between the model output and the input attractiveness scores is almost flawless; the top-5 visited sightseeing match. There are minor differences between the number of visitors of Nieuwmarkt and Central station but that's due the probabilistic nature of the model. The only exception is The Begijnhof, it closes at 17:00, so this is the reason why it receives fewer visitors than other sightseeing destinations with lower attractiveness scores. Once again, the relation between the closing times and the attractiveness scores have a role in the % of visits.

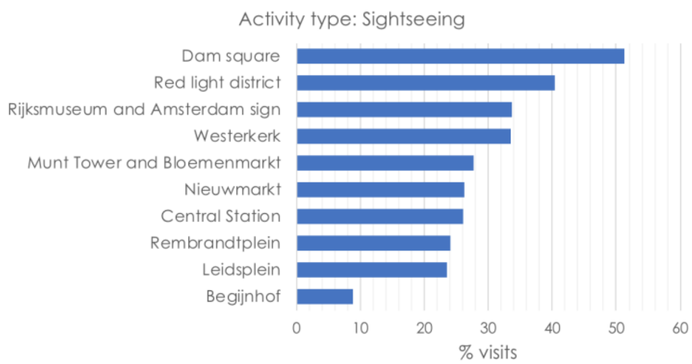


Figure 4.14 % Tourists that visit a specific activity within the sightseeing type

Lastly, the **walking activity type** results are displayed in figure 4.15: the % of visits follow the attractiveness scores input distribution. These areas do not have a closing time, so, despite the probabilistic nature of the model, the output keeps the relation between the attractiveness scores and the % of visitors. For instance, the relation between the Canal Belt and Vondelpark attractiveness scores is 1.25, the relation between their % of visitors is 1.15.

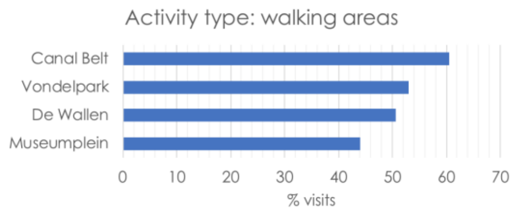


Figure 4.15. % Tourists that visit a specific activity within the sightseeing type

The **dinner-pub activity type** is not plotted because the attractiveness of all the cafes and pubs is the same. In the simulation it is set that tourists visit at most one destination within the dinner-pub activity group, this is verified in figure 4.6.

After this phase, it can be concluded that the model which provides stable results according to what it is set in the model design phase. There are some differences between the input and model output, however, these reasons why they exist are explained. These differences highlight variables that should be further explored.

4.3. Spatio-temporal patterns analysis

The last section of chapter 5 comprises the **spatio-temporal model outputs**. The previous verification and validation phases are decisive to better understand and to reveal these spatio-temporal patterns. Two different spatial outputs (shape files) are obtained: **1. Number of times each street is passed and 2. Number of visitors of each destination**. These files are obtained every 30 minutes during the simulation, so the temporal component is tracked.

Figure 4.16 shows the accumulated number of times a street is passed. The selected day hours are 11:30, 14:00, 18:30 and at the end of the simulation. The maps are quite self-explanatory. At 11:30, there is already activity on the streets and the main streets (Spiegelgracht and Leidsestraat) which connect the main attraction points: Museumplein and Dam Square, also Rokin street begins to be highlighted. At this time, the location of the hotels plays an important role on the passed streets. At 14:00 (figure 4.16 up-right), a higher activity is revealed, other highlighted streets are Vijzelstraat and Keizersgracht that connect the Bloemenmarket and Rembrandtplein with other hubs like Museumplein. At 18:30 some other "hidden" streets are highlighted like Stadhouderskade where the Heineken Experience is located. At the end of the simulation some clear patterns of the highly passed streets is observed. Lastly, table 4.7 shows the top-13 passed streets.

Table 4.7. Top-13 passed streets at the end of the simulation

1	Koningsplein	6	Nieuwe Spiegelstraat	11	Vijzelstraat
2	Spiegelgracht	7	Rokin	12	Dam
3	Weteringschans	8	Heiligeweg	13	Museumstraat
4	Museumbrug	9	Muntplein		
5	Leidsestraat	10	Leidseplein		

The results of the number of times a street is passed are restricted in the way that tourists select the shortest route between destinations and the same streets can be passed multiple times by the same tourist. The patterns are realistic for the city of Amsterdam based on general knowledge and these outputs accentuate which areas are highly used by tourists and which ones fall out of the tourist pursue.

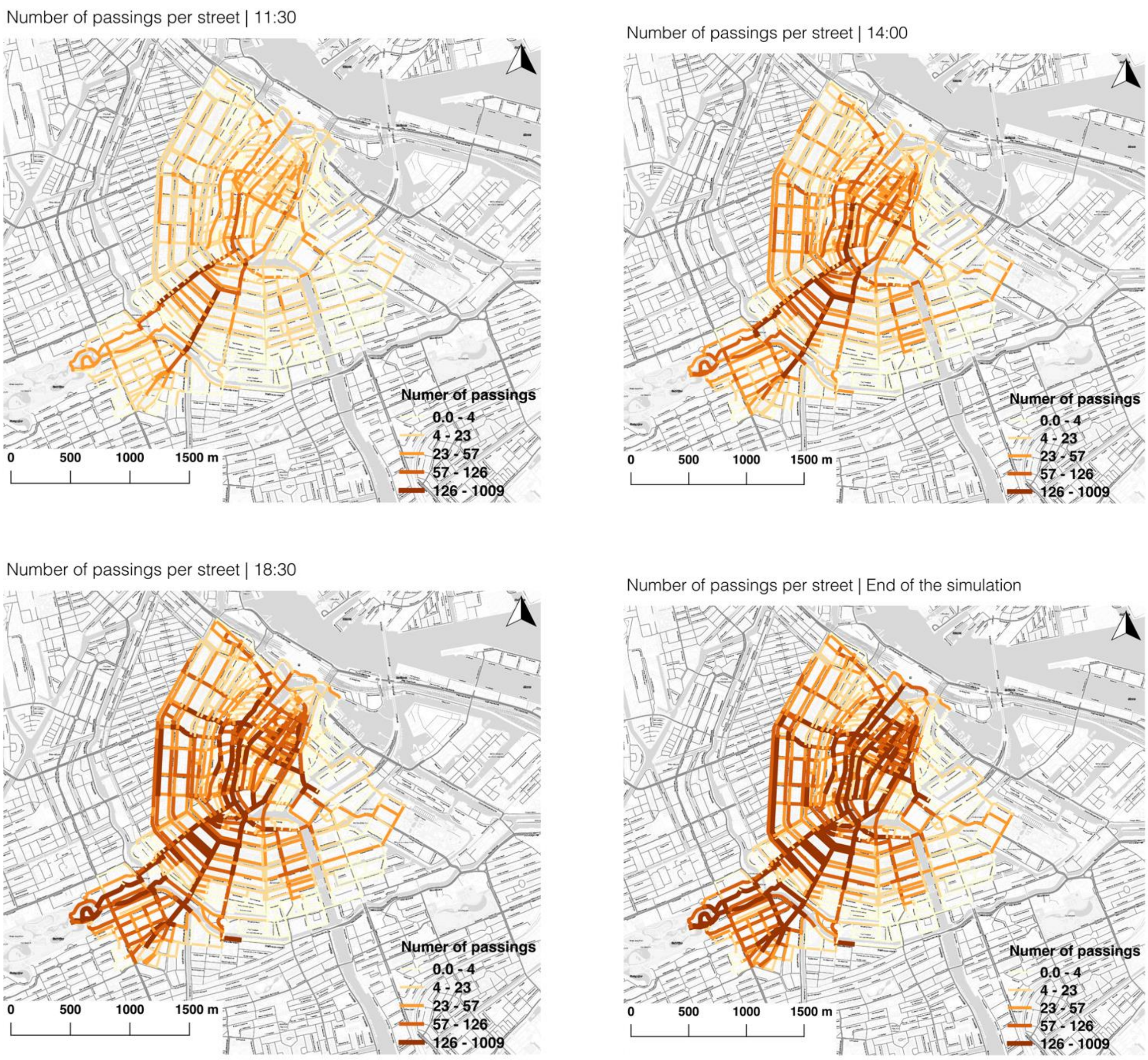


Figure 4.16. Accumulated number of times a street is passed along the day

The spatial component of the number of visits of each destination is plotted in figure 4.17 Its accumulated value along time is also displayed. The visualization allows to see which specific city spots are active and at what times. The destinations are represented by polygons, this geometry imposition is due to the need of detecting when the tourist is inside a destination in the model. However, this is not the best visualization; most of the destinations overlap, especially the walking areas because they are more extensive than other destinations. As it is explained in chapter 3 (section 3.8.1) it is decided to show the data based on the centroids of those polygons and then calculate a heat map. The only drawback of this visualization technique is that is not accurate enough for big or elongated polygons such as the Canal Belt or the shopping streets. For instance, shopping streets are better represented by its actual shape instead of through heat maps. An alternative visualization is proposed is figure 4.18.

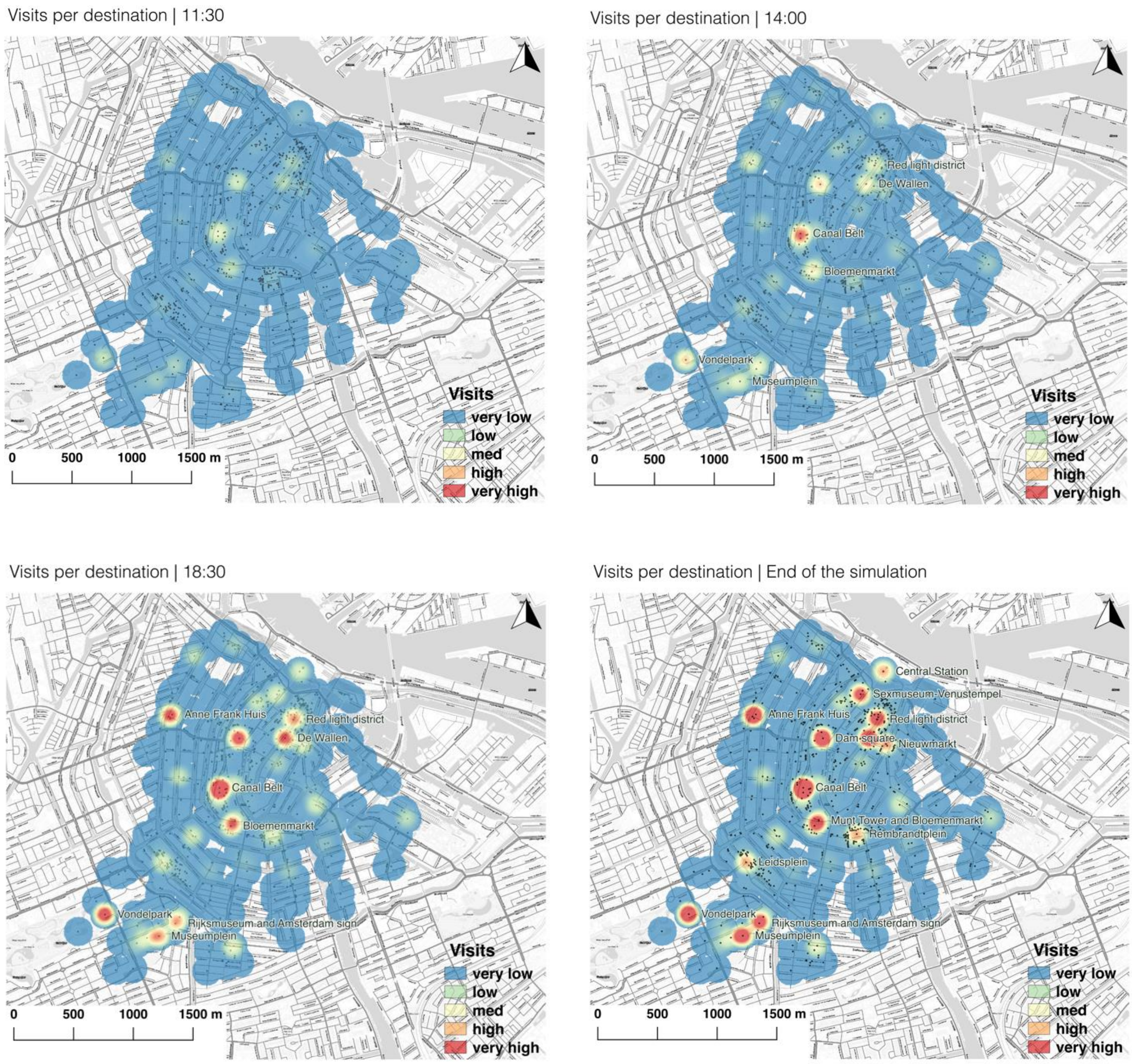


Figure 4.17. Accumulated number of visits per destination along the day

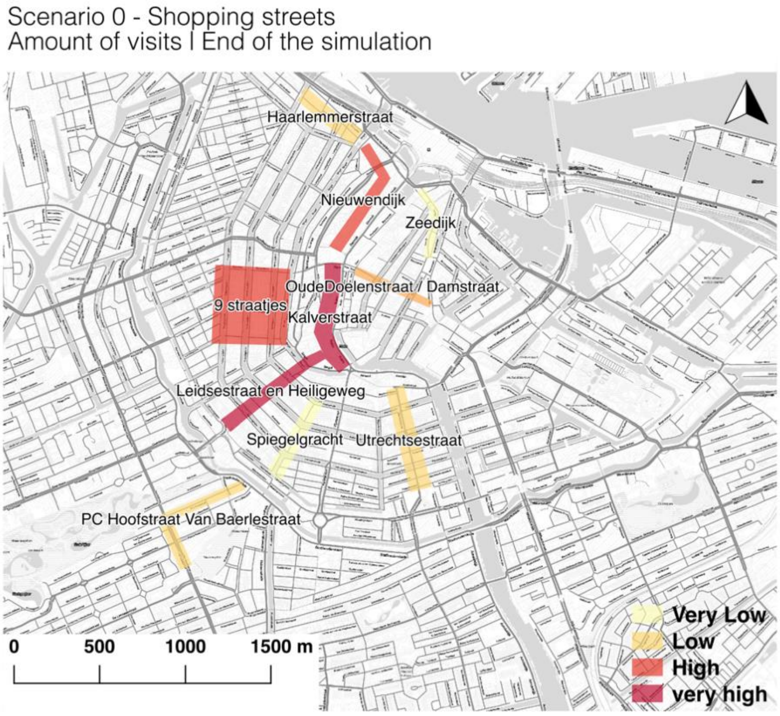


Figure 4.18. Alternative visualization of the number of visits – shopping streets

Figure 4.17 shows a similar pattern that the one revealed in the street network maps: there is a lower activity early in the morning that keeps increasing along the day. At 14:00 only a few destinations have been highly visited, mainly the walking areas, some sightseeing spots and some cultural activities. The heat maps also expose what figures 4.10 to 4.15 already revealed; the closing times of certain activities have an impact on the model. The heat maps make this fact clearer: The Sexmuseum is the top-1 model "cultural activity" even if it is the 6th according to the attractiveness score (the input data). Nonetheless, the Sexmuseum starts only to be highlighted after 18:00 just because most of the other cultural activities are closed by that time. The Sexmuseum number of visits is higher just because it is open in the 18:00 to 23:30 time frame. (18:00 to 23:30).

Last, table 4.8. shows **the top-15 visited destinations**. The preferred activity types are walking, sightseeing and slightly cultural activities which matches the input data.

Table 4.8. Model output - top-15 visited destinations

Name		Activity type	Number of visitors (10 runs)	% of tourists that visited that destination (10 runs)
1	Canal Belt	Walking Area	300	60
2	Vondelpark	Walking Area	263	53
3	Dam square	Sightseeing	254	51
4	De Wallen	Walking Area	251	51
5	Museumplein	Walking Area	218	44
6	Red light district	Sightseeing	200	40
7	Sexmuseum-Venustempel	Cultural Activity	185	37
8	Rijksmuseum and Amsterdam sign	Sightseeing	167	34
9	Westerkerk	Sightseeing	166	33
10	Munt Tower	sightseeing	137	28
11	Nieuwmarkt	sightseeing	130	26
12	Central Station	sightseeing	129	26
13	Rembrandtplein	sightseeing	119	24
14	Leidsplein	sightseeing	117	24
15	Anne Frank Huis	cultural activity	115	23

4.4 Results conclusions

The verification of the model is successful. The model provides the expected response according to how it was designed. In general, it also matches the input data used to populate the model. The existing variations have been clarified and they are explained in this section. Some of the findings will be further explored in chapter 5 and discussed in chapter 6.

- The initial variables time budget and time of leaving the hotel do not match exactly the input data because their probability distribution has been truncated on the left side. The distributions were truncated to avoid getting time budget negative values or to avoid tourist leaving the hotel too early in the morning when all the destinations are still close. Conversely, this modification causes that the average of both variables is skewed and higher than the estimated as the input data. The average the of time of leaving the hotel and the time budget variables is 78 minutes and 70 minutes higher in the model output than in the input, respectively. Nevertheless, these variables follow a Gauss distribution therefore, many tourists get lower values than these averages. The plotted output distribution (figure 4.3 and 4.4.) confirm the output distribution are acceptable.
- The time budget determines how many daily destinations will be visited, the number of visited destinations depends too on the staying time on each destination. The

staying times (min and max) are an assumption of the model but they could be an interesting parameter to play with.

- The preferences for each activity type match the input data with the exception of the sightseeing activity type. This is due to the sightseeing activities are open 24h thus they can be visited at any time of the simulation when other activities are closed, and therefore, they get more visits. The same occurs with the walking activity types, however, sightseeing activities have a lower average staying time (maximum 8 minutes) so tourists might visit many more sightseeing destinations than walking areas given the same time. This results in the sightseeing activity type getting 12% more visits than the expected from the input data.
- The number of visitors of each activity are correlated to the probabilities assigned by the attractiveness scores, however, the late closing times of some destinations have a high influence on the number of visits. The Sexmuseum (closing at 23:30) is the most visited cultural attraction but it is the sixth on the ranking according to the attractiveness scores. On the other hand, The Rijskmuseum is the 4th visited cultural activity in the model output despite being the nr.1 in the attractiveness scores ranking. The same occurs for the Begijnhof (sightseeing activity), it is the only sightseeing activity closing at 17:00, so it gets the fewest number of visits, despite not being the last attraction in the ranking.
- The number of shops / m of street is used as a proxy to determine the attractiveness scores of the shopping streets. A dataset from *Locatus* is used to modestly validate the output of the shopping activity type destinations. There is a positive correlation between the model output and the data for validation: this assures that the proxy street/m provides a good indication of the attractiveness of a shopping street.
- The spatial visualization of the number of visits of each destination should be reconsidered if all the destinations are to be displayed on the same map. For small destinations, like museums, pubs or markets, the heat map (raster) representation works very well and it is highly intuitive. This representation is based on the centroids of the polygons. However, the heat maps distortion the results for bigger or elongated polygons, such as the polygons representing the walking areas and shopping streets, because only the centroid is highlighted, consequently, it might be better to keep the current polygon shape. The drawback in this case is that not all the destinations can be visualized on the same map because they overlap.

Chapter 5 – Sensitivity analysis and scenarios evaluation

Chapter 4 elaborated on verifying and validating the model and evaluating the spatio-temporal patterns. After the successful verification of the model, this illustrates how the model is used to generate 3 "what-if" scenarios. In each scenario, one parameter (spatial, temporal or preferential) is altered to analyze how the modification of some parameters affects the system and how they are related to each other. Each scenario is run 10 times so that it can be compared to the initial scenario (scenario 0 from hereinafter). The scenarios evaluation is an important exploration task that is considered as the **model sensitivity analysis**. Only the parameters that show to have a considerable effect, should be considered for the calibration of the model, therefore, the sensitivity analysis is always performed before the model calibration. The theoretical explanation of the sensitivity analysis and the scenarios is presented in section 3.9, only the results have been included in this chapter. Table 5.1. summarizes the 3 scenarios to be evaluated.

Table 5.1. "what-if" scenarios

Scenario		(modified) Parameter	Parameter type
1	Winter-summer scenario	Preference for different activity types	Preferential
2	Pop-up Bloemenmarkt	Location of the Bloemenmarkt	Spatial
3	Museum eve	Closing times of a specific museum	Temporal

5.1. Scenario 1: Winter – Summer

Scenario 1 tests what would happen if tourists had a higher preference for other activity type such as outdoors activities, fact that might occur during the warmest months of the year. The outdoor activity types are walking, sightseeing and visiting markets. The first two groups already have a very high probability (preference) of being chosen (22,9%), therefore, it is considered that markets now are drawing the attention. The probability of selecting a market will be switched by the probability of visiting an indoor activity such as the cultural activity (figure 5.1). Changing the probabilities is selected directly in the GAMA software when the model is uploaded.

Figure 5.1. Scenario 1: switching the probabilities of being selected (indoor vs. outdoor activity types)

The first chart is shown in figure 5.2. Both charts show the distribution of visits per activity type; this is the most straightforward comparison to evaluate the changes between

scenario 0 and **scenario 1.** Figure 5.3. shows the comparison between both scenarios. As it is observed, the **percentage of visits** of the cultural activities is significantly reduced (from 16% in scenario 0 to 7% in scenario 1) and the markets % of visits has increased from 6% in scenario 0 to 15% in scenario 1. The other activity types get almost exactly the same percentage of visits.

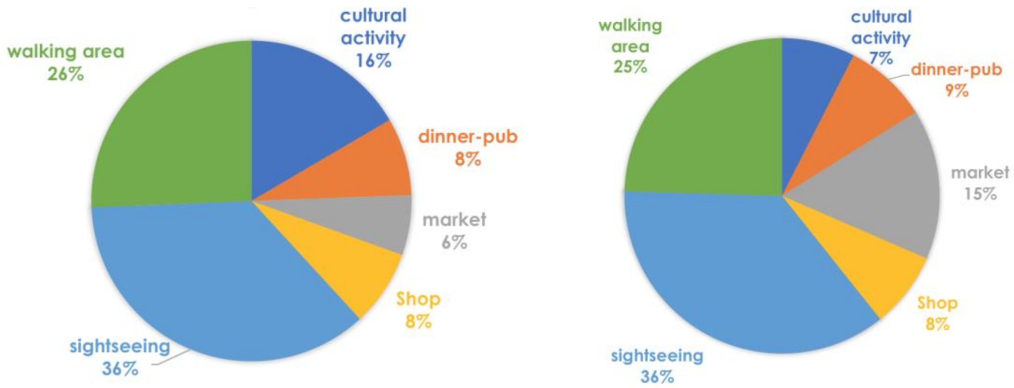


Figure 5.2. Distribution of the percentage of visits per activity type – scenario 0 (left) and scenario 1 (right)

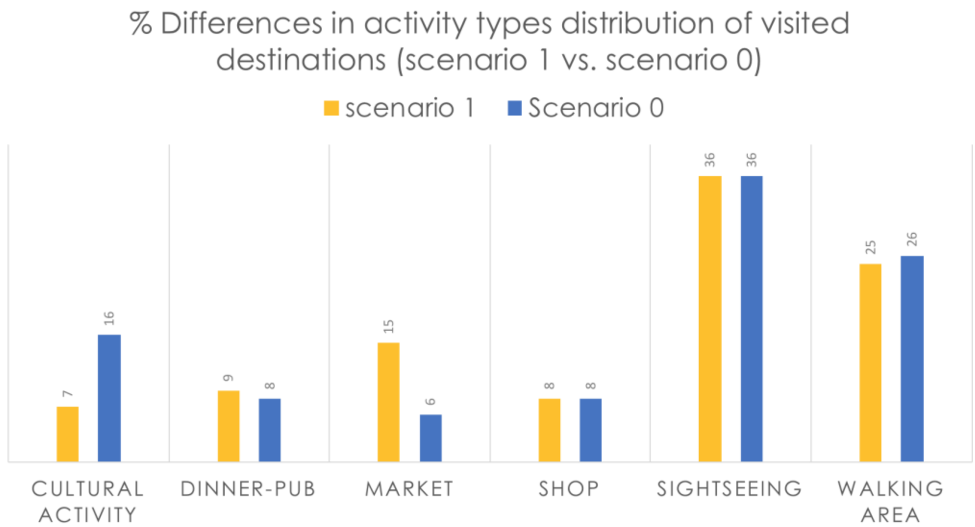


Figure 5.3. Percentages of visits per activity type - scenario 0 and scenario 1

Figure 5.4 and figure 5.5. show, respectively, the **percentage of visitors** of destination within the cultural activity and market types.

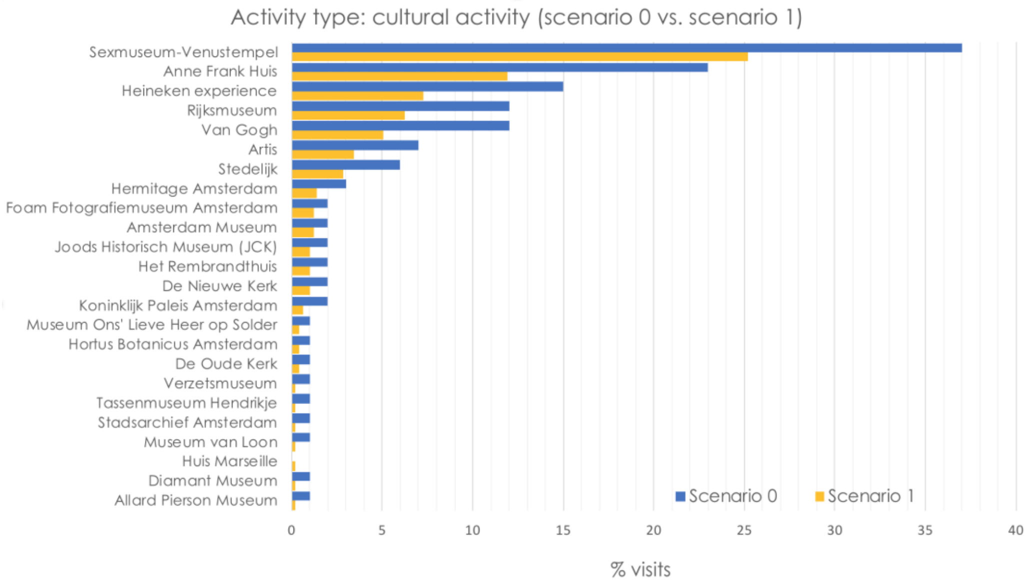


Figure 5.4. Percentage of visits of each cultural activity – scenario 0 and scenario 1

Figure 5.4 shows the scenario 1 percentage of visits decreases for each cultural activity. Anne Frank Huis and Sexmuseum show a decrease around 10%-11%, the percentage of visitors of Rijkmuseum, Van Gogh and Heineken experience decreases in 5-7%. The least popular destinations get half of the visits, from 2% in scenario 0 to 1% in scenario 1. The closing times still influence the number of visits as it occurred in the initial scenario: even if the Sexmuseum is not the most popular activity according to the input data, it gets the higher number of visits because of its late closing time at 23:30.

The change in visiting the markets is shown in figure 5.5, the increase in each single activity is bigger than in the cultural activities. For instance, the percentage of tourists that visit Noordermarkt increases in 19% and 32% in Bloemenmarkt. This variation is due to the number of destinations within each group; there are only 4 markets whereas there are 24 cultural activities, the number of destinations among to spread the same number of visits is lower, thus the markets percentage of visits is higher.

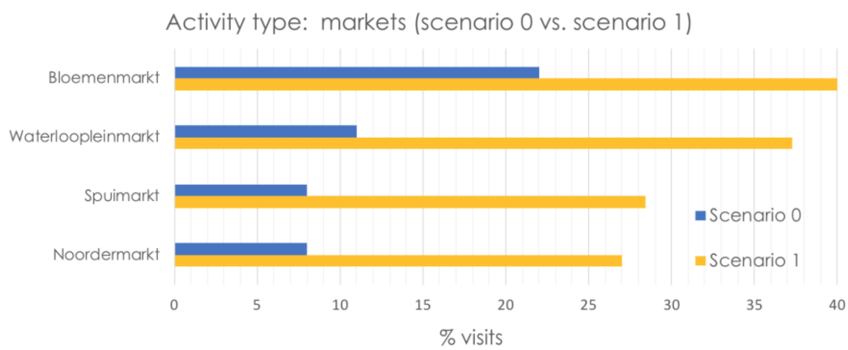


Figure 5.5. Percentage of visits of each market – scenario 0 and scenario 1

Besides that, the distribution amongst other activity types (shop, sightseeing and walking) is plotted in figures 5.6 to 5.8. This is necessary to check whether the results are stable and whether the other activity types are not affected when changing the preferences between cultural activities and markets.

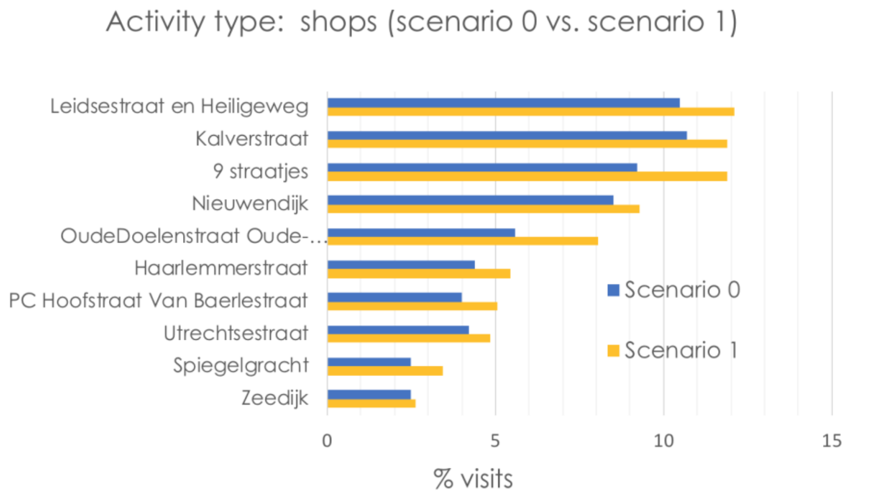


Figure 5.6. Percentage of visits of each shopping street – scenario 0 and scenario 1

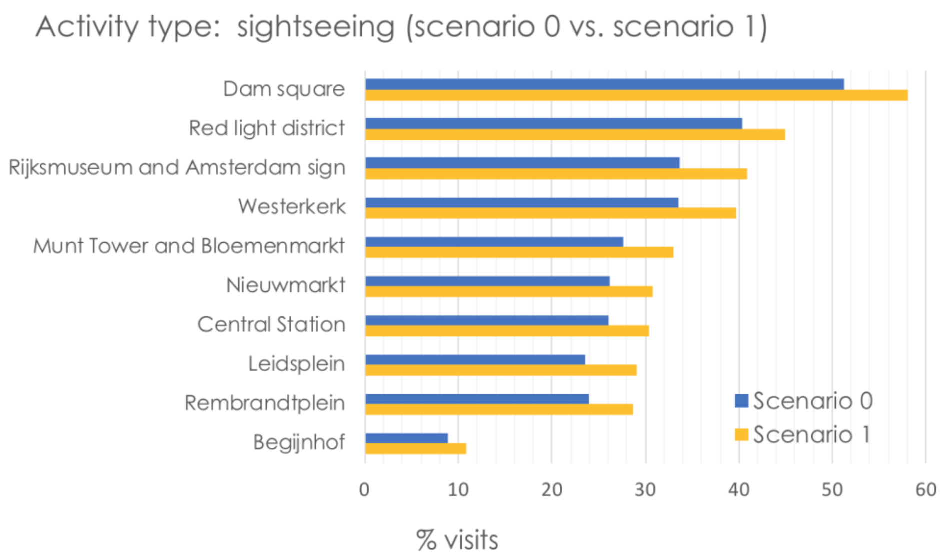


Figure 5.7. Percentage of visits of each sightseeing – scenario 0 and scenario 1

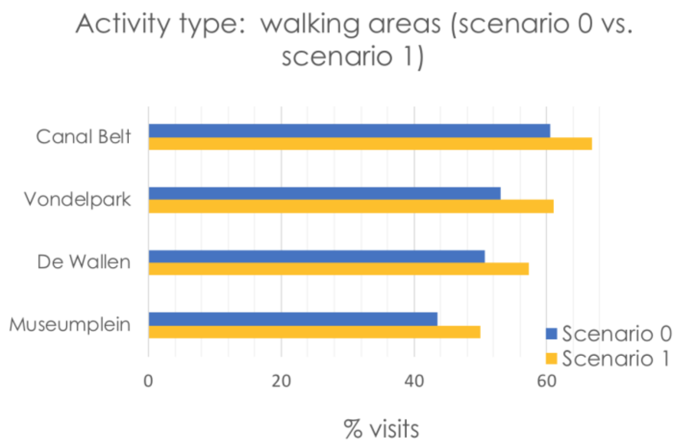


Figure 5.8. Percentage of visits of each walking area – scenario 0 and scenario 1

Figures 5.6 to 5.8 reveal unexpected, although interesting, results: all the destinations that belong to the walking, sightseeing and shopping types get a higher number of visitors in scenario 1, even if the preference for those activity types has not been changed. The sum of the total number visits of each destination is calculated: in scenario 0 is 4068, and 4752 in scenario 1. The number of agents (tourists) is the same for both scenarios. Therefore, the difference in the number of visits (4068 vs. 4752) can be only due to tourists visit more destinations in scenario 1 than in scenario 0 (see table 5.2).

It is reasonable to think that the number of daily visited destinations by a single tourist depends on the time budget; if tourists have more time to visit the city, they will obviously visit more destinations. Table 5.2 collects the values of the time budget, the number of visited destination and the average staying time in each destination of both scenarios. Table 5.2 and figure 5.13 (at the end of this section) clearly highlight that the staying time in each destination has a direct correlation with the number of visited destinations, whereas the relation between the time budget and the number of visited destinations, is stochastic.

Table 5.2. Time budget, number of visited destinations and staying time values. Scenario 0 vs. scenario 1

	Scenario 0	**Scenario 1**
Time budget (min)	581	576
Nr. of daily visited destinations by a tourist	8.1	9.5
Average staying time in each destination (min)	362	309

In scenario 0, tourists have an average time budget of 581 min and the average number of visited destinations is 8.1. In scenario 1, they have less time to spend in the city, 566 min, and each tourist visits (on average) 9.5 destinations. At this point, the staying time on each destination solves the dilemma: the total staying time in each destination is 362 minutes in scenario 0 whereas in scenario 1, it is 309 min. This means that tourists of scenario 0 spend almost 1 hour more in their journey staying at the destinations, and in scenario 1, they visit more destinations because they spend less time on each of them.

The fact that the 10 runs of the scenario 1 get (on average) a lower staying time is not arbitrary: the staying time is randomly assigned between a minimum and a maximum value that depend on the **activity type**. For markets, the staying time varies between 15 and 30 minutes, whereas for cultural activities this time varies between 1 and 2 hours. In scenario 1, there is a higher preference for markets, tourists spend less time in these activities, so, they have more time to visit other destinations.

The previous analysis clearly exemplifies the relation between activity types preferences and staying times, but this preferential change has also some implication in the spatial distribution: the number of visits of the remaining activity types (walking, shops and sightseeing) also increases. The number of visits of each destination is displayed in figure 5.9. For instance, the maps clearly show that Leidseplein and Rembrandtplein get more visits in scenario 1 even though they do not belong to the market nor the cultural activity type.

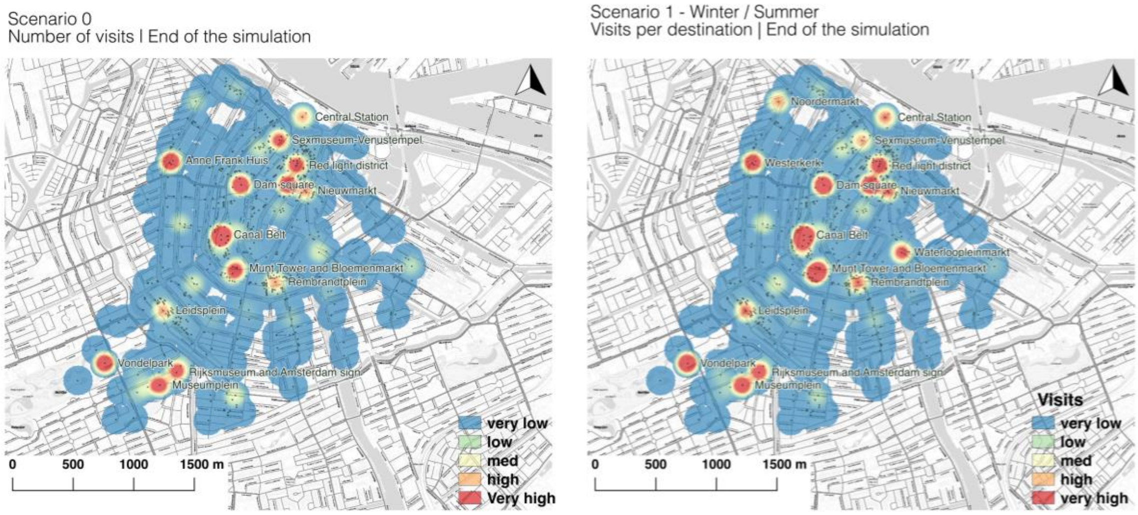


Figure 5.9. Visits per destination - scenario 0 and scenario 1

Figure 5.10 shows the scenario 0 and scenario 1 heatmaps, only the destinations that belong to the markets and cultural activities types are included. The markets Noordermakrt and Waterloplein are highlighted in heat map (figure 5.11 right). The markets show a higher increase in the number of visits because of the abovementioned reason: there are only 4 markets to select from whereas there are 24 cultural activities.

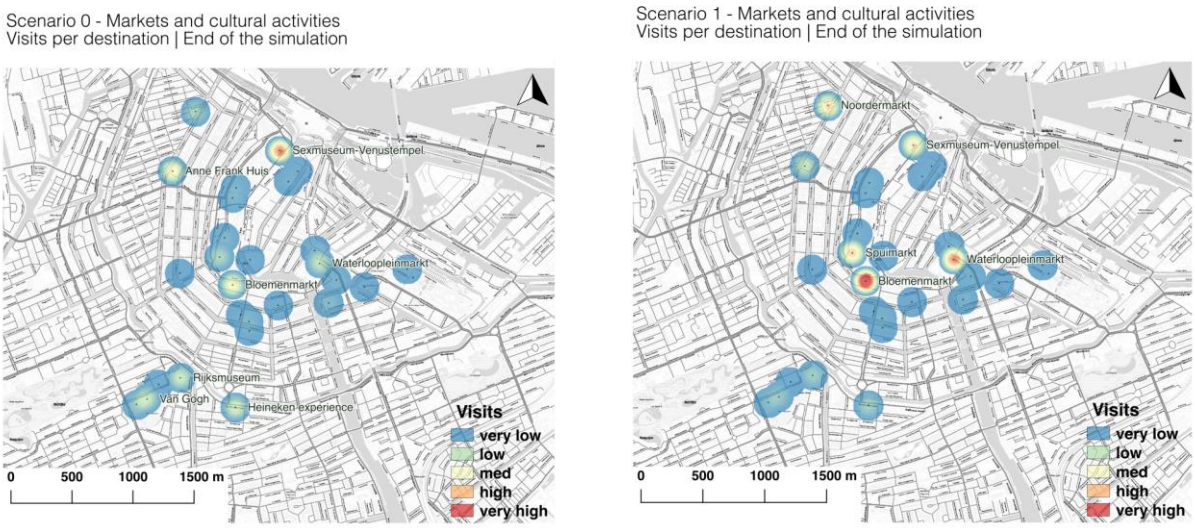


Figure 5.10. Visits in the markets and cultural activities types. scenario 0 and scenario 1

Figure 5.11 shows the % of total number of visits, the top 15 destinations are included in the chart. In scenario 1, some markets such as Bloemenmarkt and Waterloopleinmarkt, are shown up, destinations that do not belong to the top-15 in scenario 0.

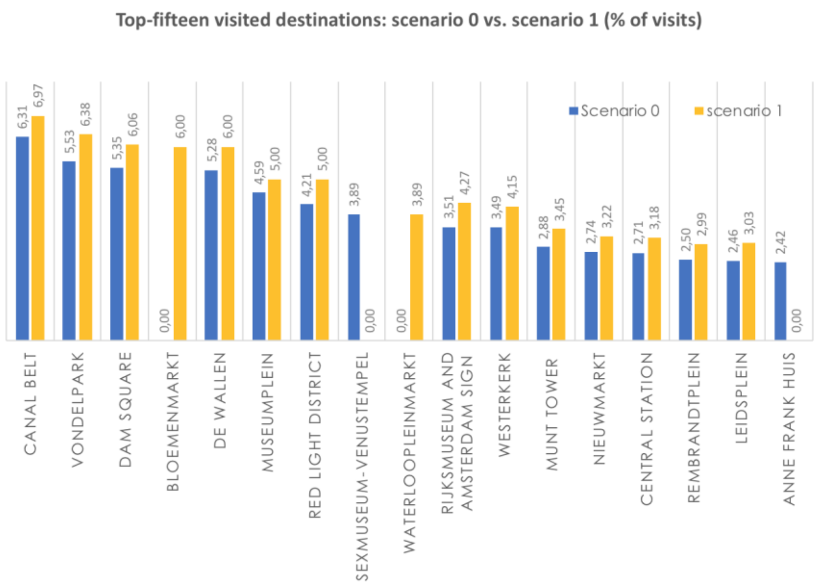


Figure 5.11. Top-15 destinations % of visits. Scenario 0 vs. scenario 1

The **spatio-temporal patterns** are altered since each tourist prefers now other activity types located in other areas of the city. Figure 5.12 shows the number of times each street is passed at the end of the simulation.

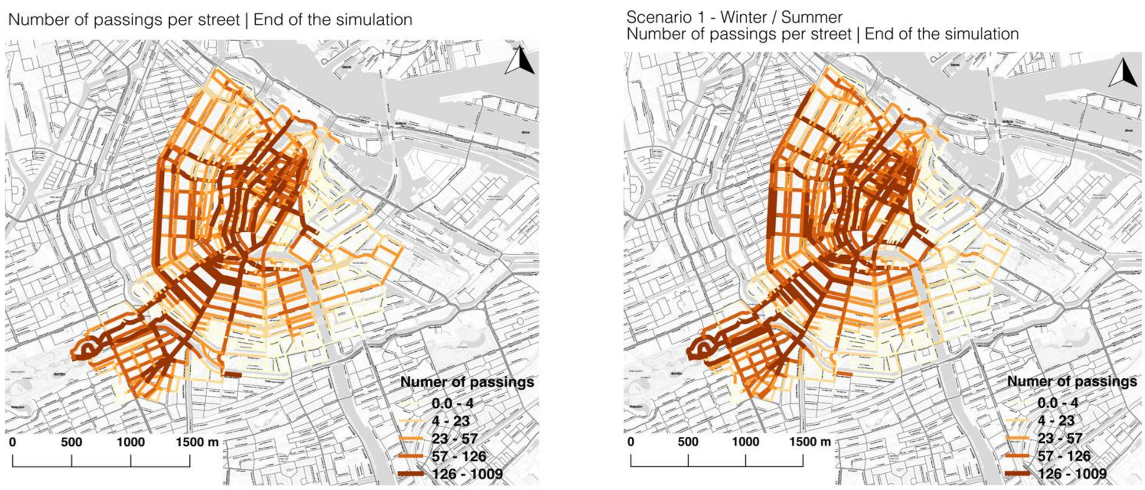


Figure 5.12. Number of passes of each street. Scenario 0 and scenario 1

The streets that connect the markets with the city center are highly passed in scenario 1, this occurs in Prinsenstraat and Herenstraat for example, which are the streets leading to the Noordermarkt. The opposite occurs in other streets such as Plantage Middenlaan and Muiderstraat which are the streets connecting with Artis, a cultural activity located at the east of the city. Stadhouderskade is where the Heineken experience is located, it also shows a decrease in the number of passes. Although there are some remarkable changes in the number of passes, the top-13 passed streets remains the same as in scenario 0 (table 5.3), this is expected since other activity types such a walking areas or sightseeing are still the most popular ones.

Table 5.3. Top-13 passed streets. Scenario 0 vs. scenario 1

Scenario 0		**Scenario 1**	
Street		**Street**	
1	Koningsplein	1	Koningsplein
2	Leidsestraat	2	Spiegelgracht
3	Spiegelgracht	3	Weteringschans
4	Museumbrug	4	Museumbrug
5	Weteringschans	5	Leidsestraat
6	Nieuwe Spiegelstraat	6	Nieuwe Spiegelstraat
7	Heiligeweg	7	Rokin
8	Leidseplein	8	Heiligeweg
9	Rokin	9	Muntplein
10	Muntplein	10	Leidseplein
11	DOELENSLUIS 0220	11	Vijzelstraat
12	Vijzelstraat	12	Dam
13	Nieuwe Doelenstraat	13	Museumstraat

It is crucial to reflect over the results of the comparison between scenario 0 and 1. It is important to analyze how a preferential change in the activity type affects the spatio-temporal patterns. But also, it is important to depict the emergence of the model in terms of the relation between its parameters. The chart of figure 5.13 plots the time budget, number of visited destinations and the sum of the staying time on each activity at the end of the day. The higher the staying time, the fewer the visited destinations. The staying time depend on the activity type. Therefore, when changing the preference for markets, it becomes evident that this preference is an important parameter affecting the global model outputs. It is expected that the time budget had also a direct influence on the number of visited destinations, however, figure 5.13 proves that time budget might increase or decrease in each run and it does not affect the final number of visited destinations, whereas the staying time shows a positive correlation with the number of visited destinations in all the runs.

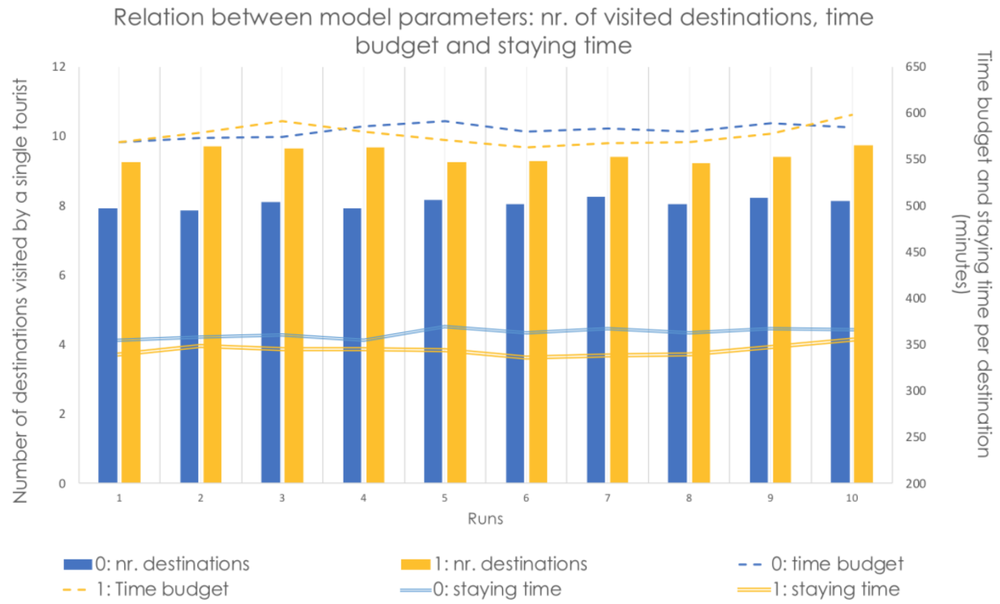


Figure 5.13. Relation between model parameters: Time budget, nr. of visited destinations and average staying time. Scenario 0 vs. scenario 1

5.2. Scenario 2: Pop-up Bloemenmarkt

The modified parameter in scenario 2 is the spatial one: a highly visited destination is moved to a new location in the city, while assuming the attractiveness remains the same. It is preferred to select a highly visited destination to assure that the changes are not due to the probabilistic nature of the model. This scenario fits one of the Gemeente Amsterdam wishes of promoting alternative destinations in the city to stimulate quieter areas and to calm down busier ones. In scenario 2, the Bloemenmarkt will be moved to a quieter zone of the study area close to the Hortus Botanicus, at the east of the city. The expectancy is that the new Bloemenmarkt location will affect the spatial configuration of the tourist movement patterns. Figure 5.14 clearly shows how a new hotspot at the east of the city has emerged. The new location affects the number of times the streets are passed around that area (figure 5.15).

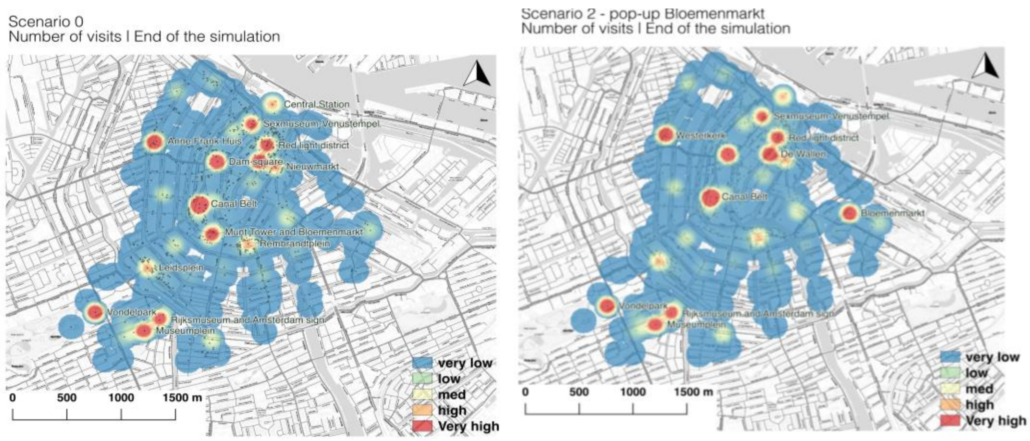


Figure. 5.14. Visits per destination - scenario 0 and scenario 2

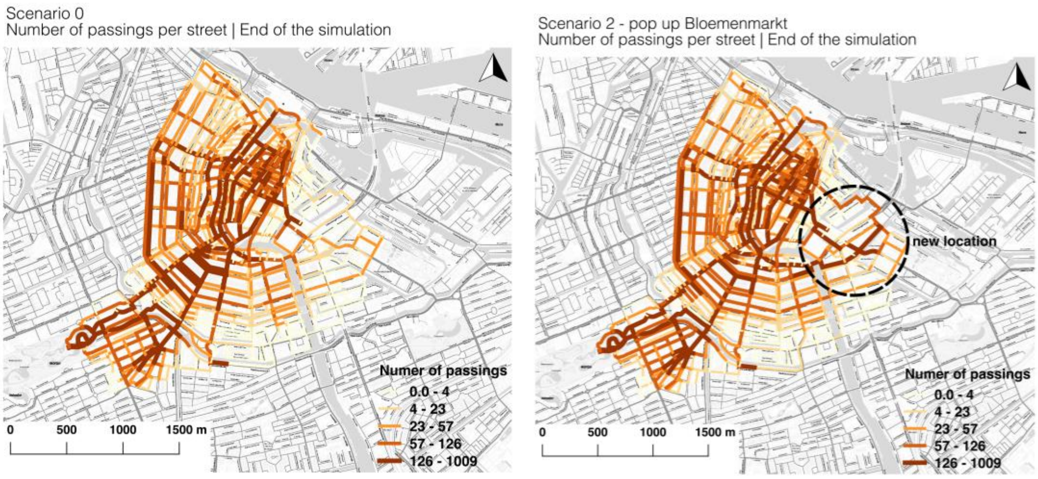


Figure 5.15. Number of passes of each street. Scenario 0 and scenario 2

Figure 5.15 shows indeed a change in the spatial distribution, although the top-13 passed streets do not show any relevant difference when compared with scenario 0 (table 5.4), still the most visited attractions, such as Canal Belt, Dam square or De Wallen, and the most common routes remain the same. However, it is worth to have a closer look to the area around the new location; 4 streets are selected in the surroundings of the pop-up Bloemenmarkt. Table 5.5 collects the number of times each of these 4 streets is passed, it confirms that certainly there is a variance in the spatial patterns, for instance, the street Plantage Middenlaan or Jonas Daniel Meijerplein are passed four and twelve more times respectively in scenario 2 than in scenario 0.

Table 5.4. Top-13 passed streets. Scenario 0 and scenario 2

Scenario 2		**Scenario 0**	
Street		**Street**	
1	KONINGSSLUIS	1	Koningsplein
2	Spiegelgracht	2	Leidsestraat
3	Weteringschans	3	Spiegelgracht
4	MUSEUMBRUG 0082	4	Museumbrug
5	Nieuwe Spiegelstraat	5	Weteringschans
6	Koningsplein	6	Nieuwe Spiegelstraat
7	Leidsestraat	7	Heiligeweg
8	Vijzelstraat	8	Leidseplein
9	Heiligeweg	9	Rokin
10	Rokin	10	Muntplein
11	Leidseplein	11	DOELENSLUIS 0220
12	Muntplein	12	Vijzelstraat
13	Museumstraat	13	Nieuwe Doelenstraat

Table 5.5. Number of passes: streets surrounding the new Bloemenmarkt location.

Scenario 0 and scenario 2

	Street	Nr of passes		
		Scenario 0	Scenario 2	Scenario 2 increase in %
1	Plantage Middenlaan	46	185	402
2	Muiderstraat	64	436	681
3	Nieuwe Herengracht	67	712	1063
4	Jonas Daniel Meijerplein	13	160	1231

The spatial parameter is the only one modified in scenario 2. The temporal, preferential or the attractional (related to the attractiveness scores) have remained the same as in scenario 0. A priori, it is not expected a global reaction in terms of relation between parameters, however, it is interesting to analyse some charts to compare them with scenario 0. Figure 5.16 plots the percentage of visits per activity type. No major differences exist with scenario 0. The charts presented in figure 5.17 to figure 5.20 plot the percentage of tourists that visit each single destination per activity type. Again, no general trend can be observed; these values increase or decrease due to the probabilistic nature of the model.

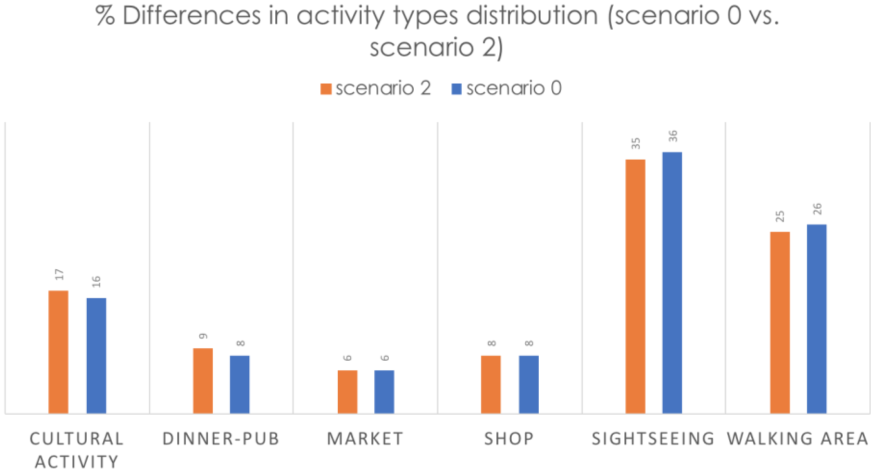


Figure 5.16. Comparison of % of visits scenario 0 vs. scenario 2

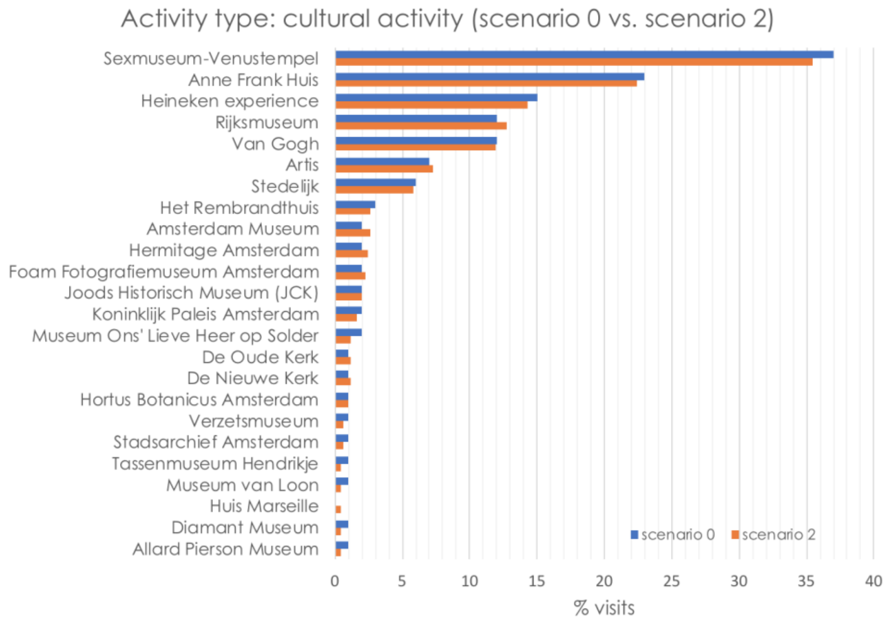


Figure 5.17. Percentage of visits of each cultural activity – scenario 0 and scenario 2

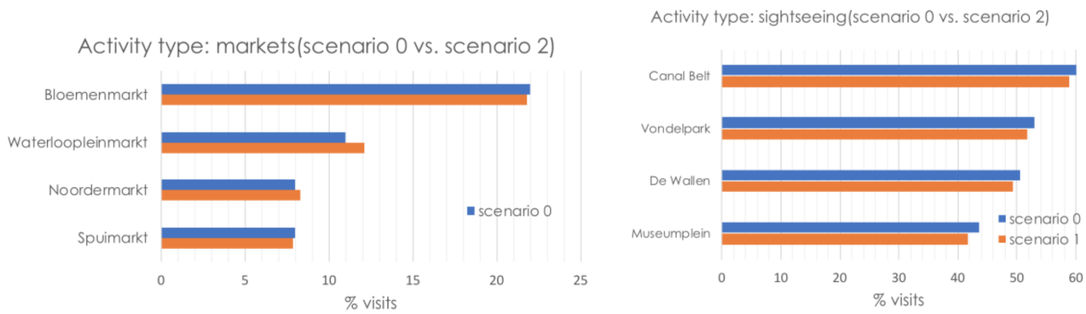


Figure 5.18. Percentage of visits of each market (left) and walking area (right) – scenario 0 and scenario 2

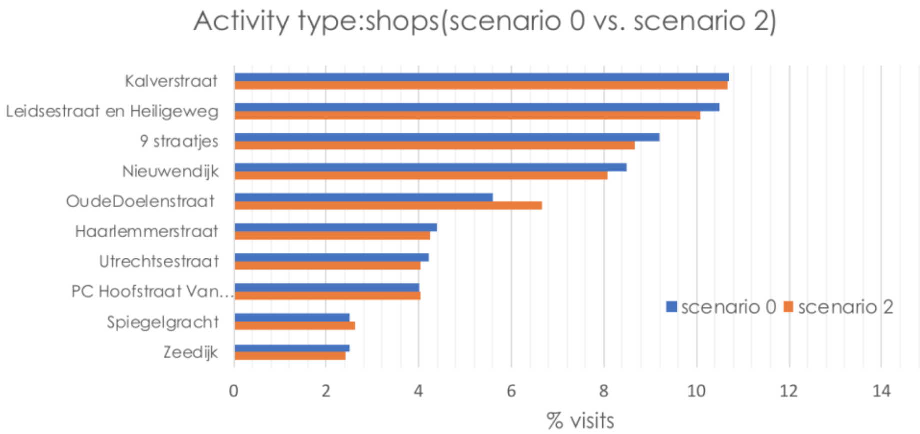


Figure 5.19. Percentage of visits of each shop – scenario 0 and scenario 2

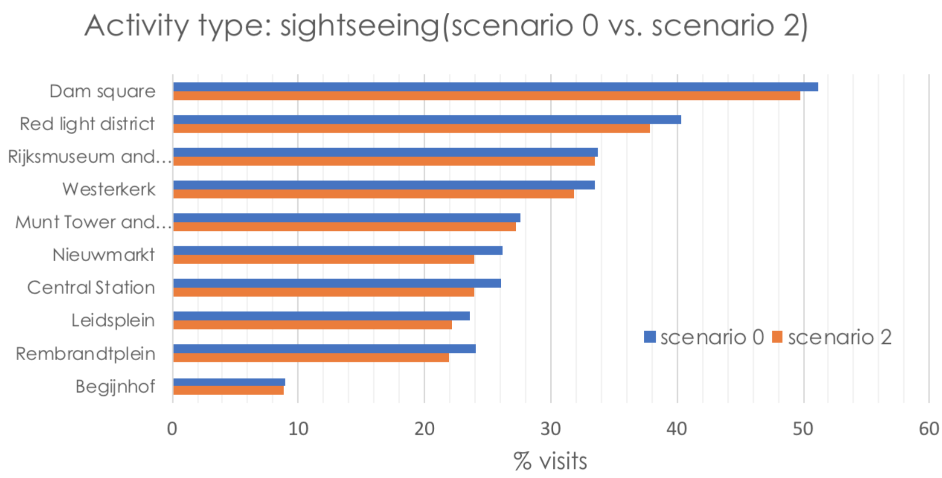


Figure 5.20. Percentage of visits of each sightseeing– scenario 0 and scenario 3

Figure 5.21 displays the top-15 visited destinations and a general trend can be observed: The percentage of visits in the scenario 2 top-15 destinations in all the runs is higher than in scenario 0. This means that the sum of the total number of visits in scenario 0, is 4068 whereas in scenario 2 it is 3957. The observed trend means that in scenario 2, each destination has been visited fewer times. Now it is required to link this finding to the variation of the spatial parameter.

The first step is to think of the parameters that might be related to the number of total visits: the higher the staying time in each destination, the lower would be the total number of visits and the lower the number of daily visited destinations. However, figure 5.22 shows that the number of daily visited destinations vary indistinctively in both scenarios.

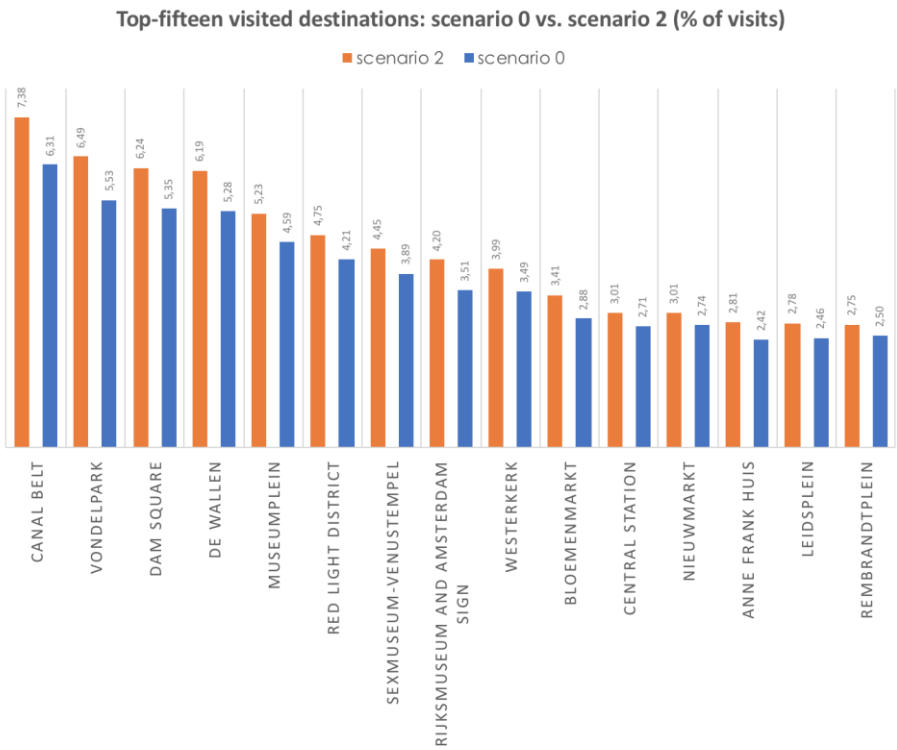


Figure 5.21. Comparison Top-15 visited destinations. Scenario 0 vs. scenario 2.

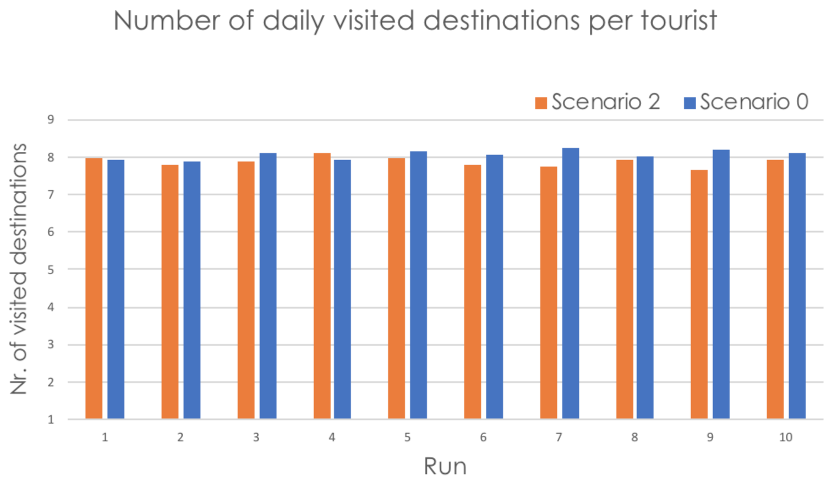
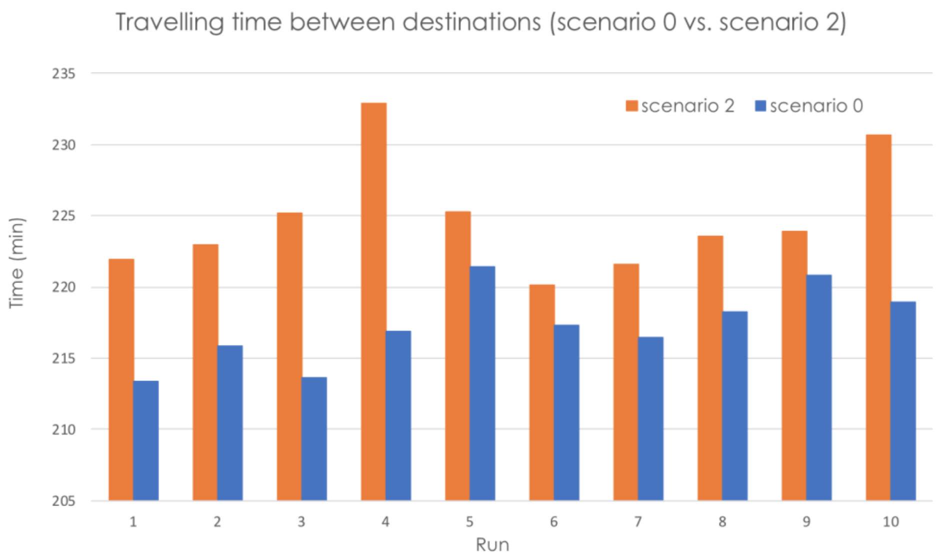


Figure 5.22. Number of daily visited destination, scenario 0 vs. scenario 2.

Another reason that might explain why destinations get fewer visits in scenario 2, is the increase in the travelling times between destinations. This fact is linked to the spatial component. Figure 5.23 plots how much time tourist spend (on average) travelling between destinations. Indeed, in scenario 2, the travelling times between destinations are always higher than in scenario 0.



5.23. Travelling times between destinations. Scenario 0 vs scenario 2

The travelling times are calculated as the differences between the time budget and the staying time on the destinations. They travelling times depend only on the distance because the speed remains constant for each tourist. Bloemenmarkt (market + sightseen) is a popular attraction amongst Amsterdam visitors; therefore, most of the tourists will visit it. Due to its new location, tourists must take a de-tour in scenario 2. Amsterdam has a compact city center and the new Bloemenmarkt location is not that far anyway, so the travelling distances, although affected, only show an increase of 10 minutes. It should be noted that it is not about the quantity of the variance but about the general trend that is revealed in figure 5.22 and 5.23 for all the runs.

5.3. Scenario 3: Museum eve

In scenario 3, one attraction will remain open four more hours than in scenario 0. Destinations closing times do not determine the agent's behavior, the preferences for activity types and the attractiveness scores do. However, the interesting bit of this scenario is to evaluate how the fact of opening a museum a few more hours, affects the number of visits it will get. Scenario 0 already revealed the impact that late closing times have on the model, for instance, the Sexmuseum is the most visited attraction only because of its late closing time (at 23:30), making it more popular than the top-1 cultural activity according to the input data: The Rijskmuseum.

This scenario also matches one of the Gemeente Amsterdam wishes of spreading the crowds out of peak hours managing the opening and closing times of museums and cruises. The selected cultural activity to be modified is the Hermitage museum, its current closing time is 17:00 and it will be extended until 21:00. Figure 5.24 shows that the Hermitage is more intensively highlighted than in scenario 0, depicting a higher number of visits, however, it still is not considered a hotspot in the museum landscape despite its extended opening hours. This is because The Hermitage is "competing" with other popular cultural activities that also close late such as Anne Frank Huis (closing at 20:00), Stedelijk museum (19:00) or The Heineken experience (19:00).

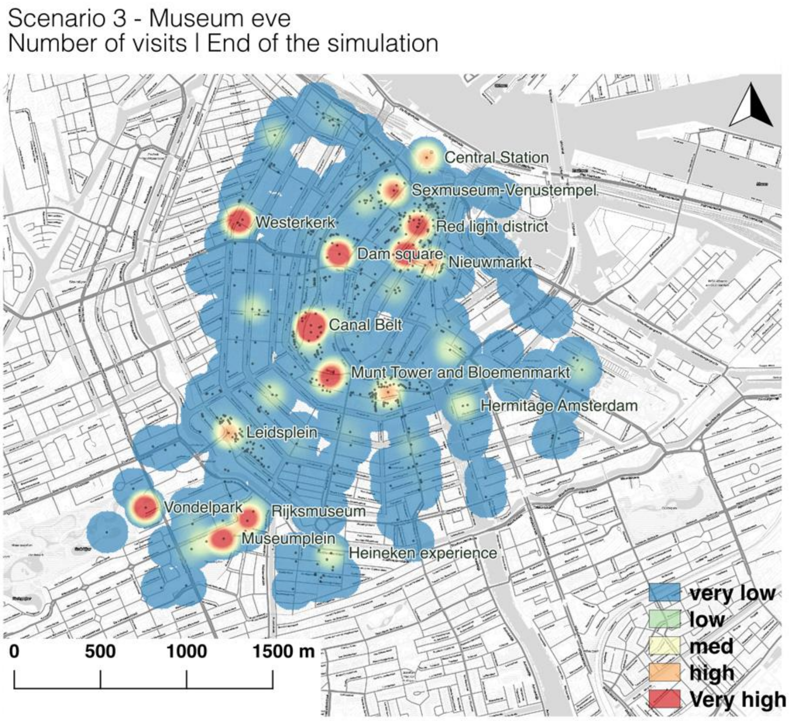


Figure. 5.24. Number of visits. scenario 3

Figure 5.25. shows that, the number of visitors of the Hermitage museum increases in 10% in scenario 3, whereas the percentage of visits of the other cultural activities such as The Sexmuseum, Anne Frank Huis or The Heineken experience, has decreased in 5%, 2% and 1.5% respectively. The Rijskmuseum, Artis or The Van Gogh museum keep the same percentage in the number of visits as in scenario 0. This is due to the Hermitage only competes with the other late-closing cultural activities from 17:00, when most of the cultural activities close, until 17:00, the number of visits is spread according the assigned attractiveness scores in the input data.

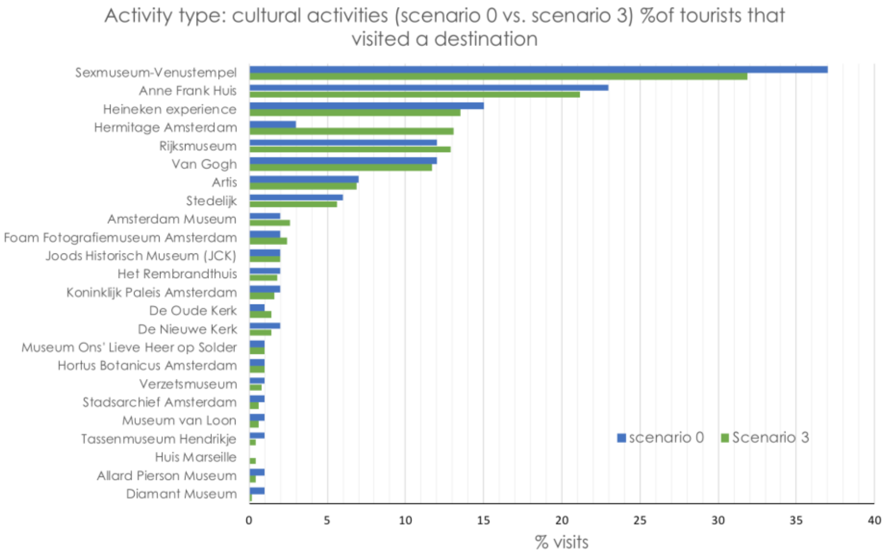


Figure 5.25. Comparison of % of visits in cultural activities. scenario 0 vs. scenario 3

Figures 5.26 to 5.28 show the distribution of tourists amongst single destinations; the plotted activity types are walking, sightseeing and shops. The distribution is quite similar between the two scenarios, supporting the stability of the model. Sightseeing and walking activities (figure 5.26 and figure 5.27 show a clear trend in terms of number of visits; this number is always lower for scenario 3. These two activity types do not have a closing time thus, in scenario 3, they have to "share" its popularity in the last hours of the day with other late-closing destination: The Hermitage.

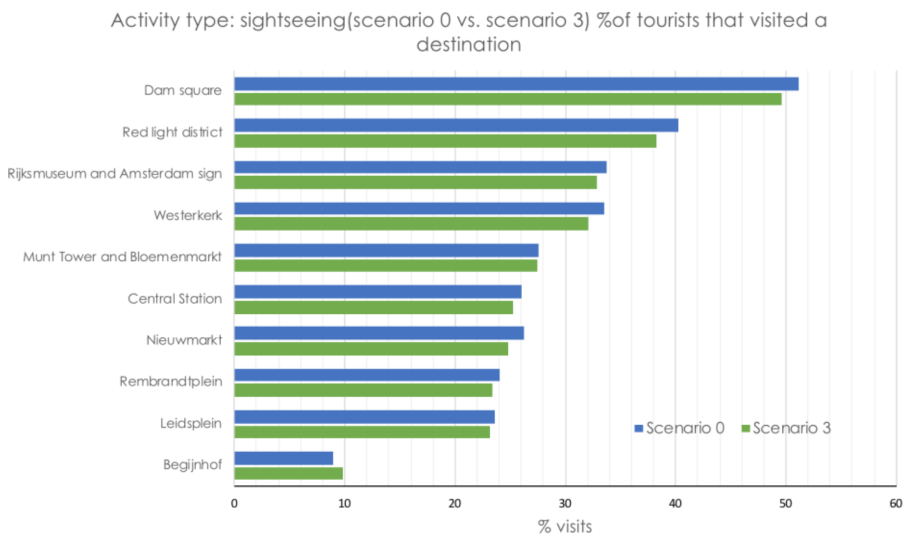


Figure 5.26. Comparison of % of visits in sightseeing activity. scenario 0 vs. scenario 3

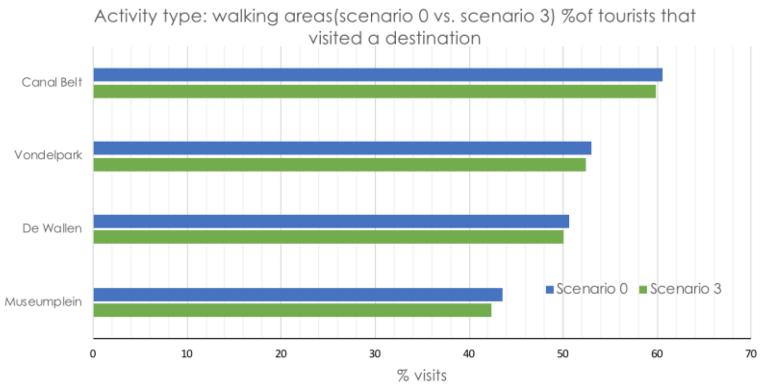


Figure 5.27. Comparison of % of visits in walking areas. scenario 0 vs. scenario 3

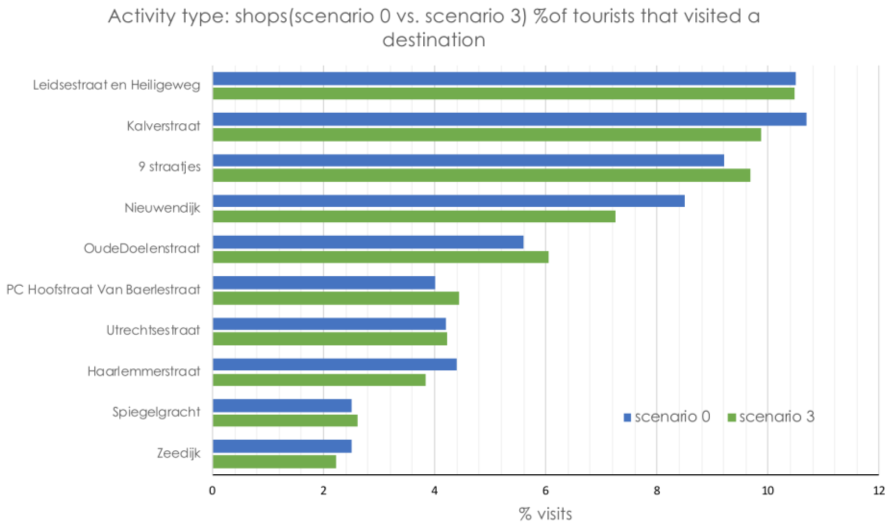


Figure 5.28. Comparison of % of visits in shops. scenario 0 vs. scenario

The probability of selecting a cultural activity has not changed from the scenario 0, thus, the chance of visiting a museum is still quite high (20.5%). From 17:00, only a few cultural activities are open: The Sexmuseum, Hermitage, Anne Frank, Heineken Experience and Stedelijk, this means that the same number of tourists have less options to choose from so the number of tourists in the late-closing cultural activities really increases from 17:00. Figure 5.29 and 5.30 illustrate this fact.

Figure 5.29 displays the spread of number of visitors along the day for The Rijksmuseum (closing time at 17:00) and The Heineken Experience (closing time at 19:00). Both cultural activities show a linear trend regarding the number of visitors until they close. Figure 5.30 displays the spread of number of visitors along the day of The Hermitage (closing time at 21:00) and The Sexmuseum (closing time at 23:30). The Hermitage distribution of the number of visits almost follows a linear distribution, although an increase is appreciated from 17:00. The increase in the Sexmuseum is much higher after 19:00-20:00; the trend until 17:00 follows the attractiveness score value, so until 17:00, The Rijskmuseum will indeed get more visits because its at. score is much higher than The Sexmuseum one.

Figure 5.29. percentage of visits along the day – Rijksmuseum and Heineken Experience. Scenario 3

Figure 5.30. percentage of visits along the day – The Hermitage and Sexmuseum. Scenario 3

It would be interesting to know what is the relation between the attractiveness scores and closing times of an attraction. Table 5.6 collects the attractiveness scores, the extra hours that the destination is open from 17:00 and the percentage of visits at the end of the simulation of 5 cultural activities. The extra opening hours make The Hermitage as visited as The Rijskmuseum at the end of the day. Anne Frank Huis and the Heineken Experience show a good balance between the attractiveness score and the extra hours they are open.

Table 5.6. Percentage of visitors, attractiveness scores, extra open hours of five cultural activities

	Cultural activity	At. score	percentage of visitors (scenario 3)	Extra opening hours from 17:00	Percentage of visitors / extra opening hours
nr. 8	Hermitage Amsterdam	0.22	13.1	4	3.28
nr. 6	Sexmuseum-Venustempel	0.36	31.9	7	4.91
nr. 5	Heineken experience	0.57	13.5	2	6.75
nr. 4	Anne Frank Huis	0.60	21.2	3	7.07
nr. 1	Rijksmuseum	1.00	12.9	0	12.90

The percentage of visitors do not match the attractiveness scores (table 5.2.) The Rijksmuseum is the most popular and it gets the lowest percentage. This fact is displayed in figure 5.31, the percentage of visitors is represented in the left axis and attractiveness scores in the right one, as it is observed, there is no correlation only Anne Frank Huis and Heineken Experience show accordance between them at scores and the percentage of visits they get.

The last right column of table 5.6. shows the percentage of visits of scenario 3 divided by the extra hours from 17:00 the cultural activity is open. Rijksmuseum closes at 17:00 but the original percentage of visits is kept. The re-calculated percentage of visits shows a direct correlation with the attractiveness scores now which can be clearly observed in figure 5.32, this chart displays the re-calculated percentage of visits in the left axis and the attractiveness scores in the right one. The clear correlation shown in figure 5.32 makes evident that the attractiveness scores of those late-closing activities should be reduced proportionally to the number of extra hours they are open, this way, the model output would fit the input data (the attractiveness scores).

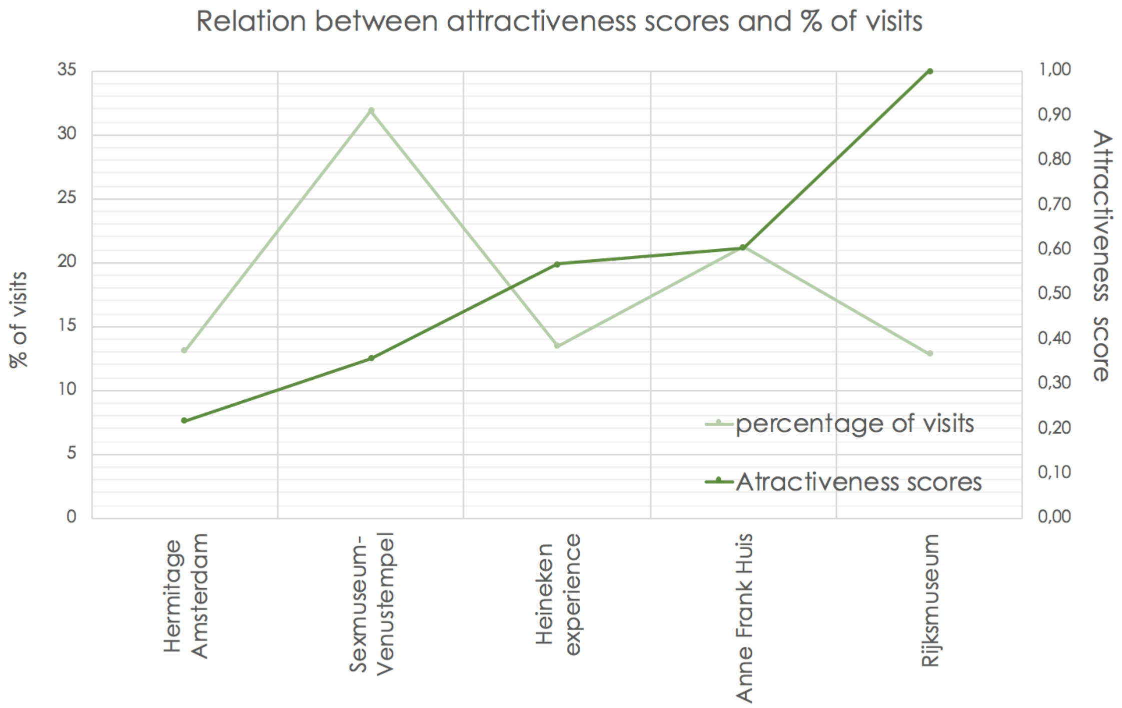


Figure 5.31. Relation between attractiveness scores and percentage of visits in scenario 3 of five cultural activities

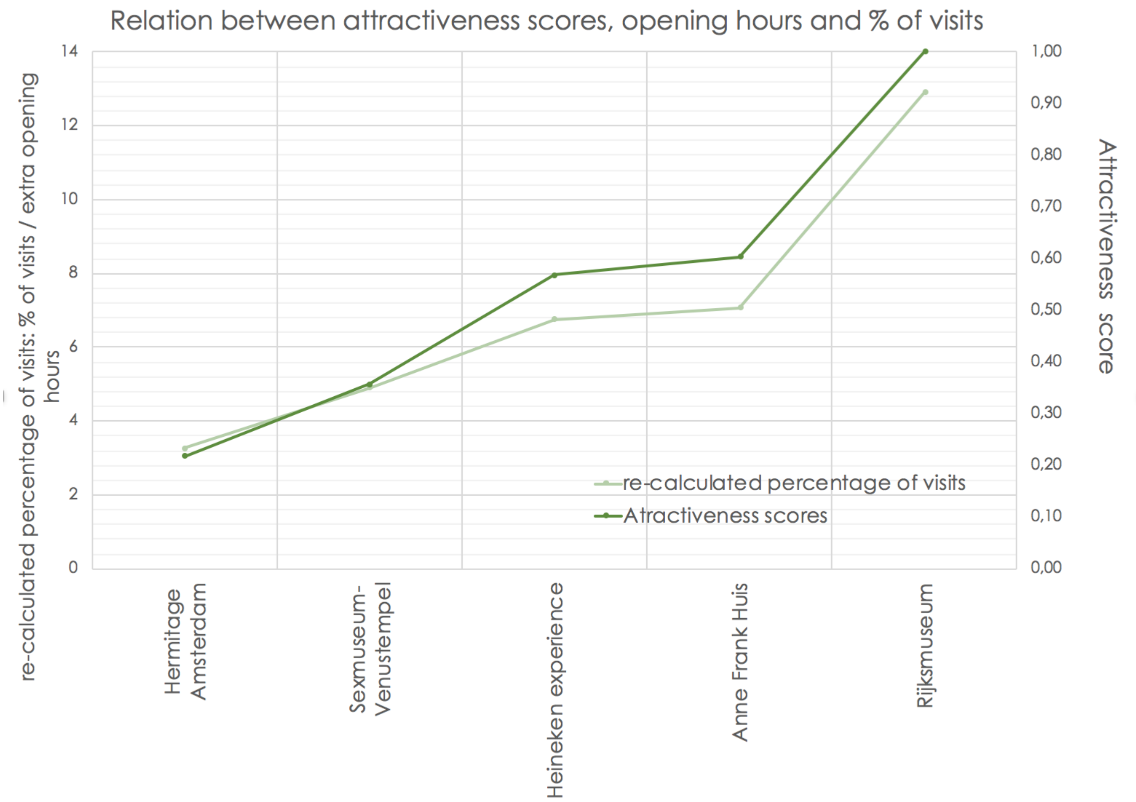


Figure 5.32. Relation between the attractiveness scores and the re-calculated percentage of visits which take into account the extra open hours from 17:00 of 5 cultural activities

Lastly, the number of passes of each street is shown in figure 5.33. Clearly, the streets surrounding The Hermitage are passed more times in scenario 3 than in scenario 0. Table

5.7. shows that the number passes of Blauwburg is only 1.3 times higher in scenario 3 than in 0; this fact makes sense since this bridge is the connection with other hotspots in the city like Waterlooplein or the Artis, so it is also highly used in scenario 0. Nieuwe Keizersgracht, Amstel and Nieuwe Herengracht are passed four, two and three times more respectively in scenario 3 than in scenario 0.

Table 5.7. Number of passes: streets surrounding The Hermitage. Scenario 0 vs. scenario 3

		Scenario 3	Scenario 0	Scenario 3 increase (%)
1	Nieuwe Keizersgracht	59	14	421,43
2	Amstel	468	201	232,84
3	Nieuwe Herengracht	57	18	316,67
4	Blauwbrug	116	91	127,47

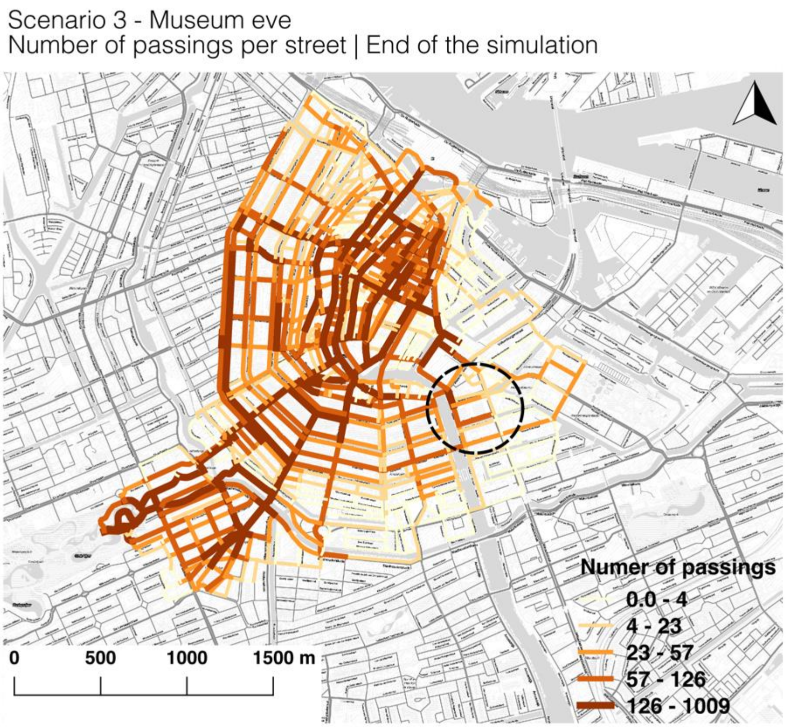


Figure 5.33. Number of passes of each street. Scenario 3

5.4 Scenarios conclusions

The analysis of each scenario permits to better comprehend the model; it reveals clear relations between its parameters and it reveals which ones have a high influence on the model. Moreover, it is also deducted how some parameters should be re-calibrated so that the model output fit the input data. The learnings from each scenario are commented here and they are summarized in table 5.8:

Scenario 1 – Winter/Summer

Tourists have a higher preference for markets than for cultural activities in this scenario, therefore, markets get more visits in this scenario. Markets have lower staying times than the cultural activities so tourists have more time to visit other destinations during their daily journey. These additional visited destinations belong to any other of the remaining types: walking, sightseeing and shopping (tourists visit only one pub-café and that constraint remains the same). Consequently, all the destinations, regardless the type, increase their percentage of visits except the cultural activities. Besides that, the increased percentage of visits of each single market is much higher than the decreased percentage of visits of the cultural activities: the same number of tourists have only 4 available markets to select from whereas there are 24 cultural activities. This difference is observed in the heat maps of figure 5.10.

The relevant impact of the staying time parameter on the model is revealed when changing the preferences for another activity type. It is a parameter to play with since it affects the total number of visited destinations and the global response of the model.

Scenario 2 – Pop-up Bloemenmarkt

The location of one popular activity (Bloemenmarkt) is moved to another not-that-touristic area of the city without changing its attractiveness score. The Bloemenmarkt is visited almost by every tourist visiting Amsterdam, therefore, on average, the travelling distances and, consequently, the travelling times, increase to reach this new location. Amsterdam city center is compact, and this new location is not that far from other activities so the travelling times do not increase dramatically.

Scenario 3 – Museum eve

Scenario 3 is considered the most revealing scenario because it leads to concrete actions to proceed with the calibration of the model.

The Hermitage museum opens its doors four hours more in scenario 3 than in scenario 0. The temporal distribution of the number of visits is evaluated and then compared with other cultural activities. The distribution of the number of visits is clearly related to the attractiveness scores until 17:00, time when most of the cultural activities close their doors. From that time, the number of open cultural attractions is reduced so the number of visits they get highly increase, "breaking" the attractiveness score rule. Therefore, at the end of the simulation, The Rijskmuseum (nr.1 cultural activity) gets 12% of the visits whereas the Sexmuseum (nr.6) gets 32%.

Table 5.8. scenarios summary: modified paramters and model reaction

Scenario	Modified paramater	Affected parameter(s)	Trend	Model reaction
scenario 1 - Winter/Summer	Preference for a specific activity type	Number of visits of each activity type	Increase / Decrease depending on the activity type	The number of visits of all the activity types increases except for the cultural activity type because tourists spend less time in each of them. The staying time in markets is lower than in cultural activities. The passed streets pattern is altered
	Preference for outdoor activities (markets) increase whereas the preference for indoor activities (cultural activities) is reduced in the same proportion	Number of daily visited destinations	Increase	
scenario 2 - Pop-up Bloemenmarkt	Location of a single attraction	Number of visits of each destination	Decrease	All destinations get fewer visitors because they spend more time traveling between destinations. The difference is not high, but the trend is clear. The passed streets pattern is considerably altered around the new Bloemenmarkt location
	The Bloemenmarkt is moved to a quieter area of the city, further from the city center	Travelling times between destinations	Increase	
scenario 3 - Museum eve	Closing time of one attraction	Number of visits The Hermitage	Increase	The model variation is only visible after 17:00 which is the time at which the other cultural activities, markets and shops close. The passed streets pattern is altered
	The Hermitage is open until 21:00; four hours more than in scenario 0	Number of visits of the remaining cultural activities that close later than 17:00	Decrease	
		Number of visits of the walking areas and sightseeing	Decrease	

Chapter 6: Conclusions, discussion and reflections

6.1. Conclusions

The objective of this research is to define and develop a modeling framework, based on theory and available data, on which to formalize and implement a simulation that allows to explore and to reveal spatio-temporal patterns of pedestrian tourists when visiting a city center. To meet the objective, four research question groups were formulized. The conclusions of this research are organized around the research questions.

1. RQ. I aims to answer which modelling approaches could be applied to the current study and which one is the most suitable one to develop the targeted objective. Besides that, it aimed to gather information about tourist decision making processes and constraints when visiting an urban destination.

The main literature review finding is that pedestrian behavior, and therefore, pedestrian movement, falls within the complex systems domain. By definition, in complex systems is difficult to predict what the results of a phenomenon will be due to interacting individuals (Joffre et al., 2015). Computer simulations offer the potential to study these complex behaviors during time adding the spatial component (Itami and Gimblett, 2001). There is none specific dataset that could be used to develop this model, therefore, this research, targets to start from a theoretical understanding of pedestrian tourist's movement when visiting an urban destination, identify then the key elements, gather data (if available), make assumptions, and, last, build the model to simulate pedestrian tourist dynamics. It is decided that, for this research, the best approach are Agent-based models. ABM are adequate because the study of pedestrians requires the understanding of the collective pedestrian flows at a macro level as well as the individual pedestrian movements at a micro level. ABM combine the two: they consist out of individual agents that dynamically interact with each other and their environment to achieve their goals (Hall and Virrantaus, 2016; Joffre et al., 2015) and these interactions might give rise to collective behavior, reveal emergence or reveal patterns at a higher level.

The evaluation of spatio-temporal tourist patterns is carried out at a tactical level, the behavior at this level is influenced by external factors (built environment) and personal factors (preferences, time-pressure or attitudes of the pedestrian) (Hoogendoorn and Bovy, 2002). The daily plan is decomposed into schedules and activities. Choice of activity areas and streets to go through are required to work at this level. The time-geography concept is implemented in this research to introduce the space-time constrains that are related to physical limits. Activity-based models are a good framework for this research as well: they are based on behavioral theories about how people participate or not in certain activities in the presence of constraints (Castiglione et al., 2014). The street network, location of activities and time spent performing an activity are required to establish the physical limits. Therefore, the tourist supply market needs to be defined. It comprises the definition of tourist activities such as activity type, average staying time or opening / closing times. The emergence of the model is the revelation of spatio-temporal patterns determined by activity patters in the city.

2. RQ. II targets to enumerate which elements and parameters should be included in the simulation so the model is accurate enough to meet the goal. It also aimed to enumerate the available data to populate the model and the assumptions that has to be taken.

To answer this question, the findings of the previous phase are decomposed into small elements. The identified key elements are the tourist's time availability to explore the city, the tourist's model entry points, the time constraints imposed by the tourist market attractions, and the definition of activity types and, optimally the definition of their popularity. Many available data sources are accessed: Onderzoek, Informatie en Statistiek datets (OIS), Surveys from Amsterdam marketing (BOMA, 2016), NBTC Holland marketing, Amsterdamse Thermometer van de Bereikbaarheid (Gemeente Amsterdam, 2016e), Kerncijfers (2017) from Amsterdam marketing and van der Drift (2015) research. The surveys describe the tourist profiles and their preferences, other datasets contain number of visitors of specific attractions. Spatial datasets are also required to locate the tourist attraction in the city, the spatial data sources are mainly maps.amsterdaml.nl, NWB2016 and data.amsterdam.nl, they also contain information about opening and closing times. Lastly, an indicative study is carried out: 5 online websites related to Amsterdam tourism are reviewed in order to determine which tourist attractions exist and how popular are they. Still some assumptions have to be taken to complete the model.

The first decision is to model first-time overnight international tourists during the first day of their visit, BOMA (2016) surveys contained specific information, numbers and percentages about this group. Also van der Drift (2015) research focused on international tourists. It is decided to model only one tourist type. The way preferences are introduced in the model is by having preferences for specific activity types. These preferences are set up based on the percentages distribution among the different activity types collected in BOMA (2016). This decision implies that all the tourists have the same probability of engaging in different activity types. BOMA (2016) data did not allow to do a clearer differentiation between tourist's groups, more assumptions could have been taken to differentiate group, but it was preferred to match as much as possible the available data so that the model could be later validated. The main model activity types are selected from BOMA, although some types have been merged, excluded or modified to match other datasets such as van der Drift (2015) dataset. The last main assumption is that tourist will have a greater probability of visiting the most popular attractions first. It is reasonable since they are first-time visitors, so they likely would target the most popular destinations during their journey. It is decided to use the limited available data as a proxy to quantify the popularity of the attractions: an attractiveness score is calculated for each attraction based on the data. The number of yearly visitors is used to establish the popularity of the cultural activities, the number of Flickr pictures is used to determine the popularity of the sightseeing activities, the indicative online research is used to establish the popularity of walking areas and markets. Lastly, the shopping streets popularity is determined by the number of retails shops per meter of street.

Other initial model parameters such as time budget and time of leaving the hotel are a determined are established from the temporal distribution of the Flickr number of pictures (van der Drift, 2015). The walking speeds are based on the literature review.

3. RQ.III has to do with the model implementation and with how to translate the previous findings into rules.

The main simulated process is the daily activity pattern of international tourists in the city of Amsterdam during the first day of their visit. First, the agent selects the available attractions based on the space-time constraints such as distances, travelling times and the opening and closing times of the destinations. Then, the agent selects the activity type, based on the re-calculated BOMA (2016) percentages, the percentage represent a probability of being selected. Lastly, the agents select the target destination: the most popular attractions will have a higher probability of being selected. The popularity is determined by the aforementioned attractiveness scores, they represent a probability ranging from 0 to 1. Once the destination is visited, and as long and the tourist has enough time to keep exploring the city, this process starts again, otherwise, the agent goes back to the hotel.

The selected modeling software is GAMA mainly because of its spatial capabilities: it is possible to populate and to represent the environment connecting GAMA with spatial (GIS) data. The initial parameters are defined in the input shape files or in the global section of the model. The dynamic parameters are updated and retrieved during and at the end of the simulation

4. RQ.IV. is related to the verification and validation of the model. It aims to depict which parameters had a major influence on the model and, lastly, what was the usefulness of the model to explore multiple scenarios.

The model verification is a phase that tests if the model works as it is designed. The running model as well as the statistical signatures of the initial variables, such as time budget or time of leaving the hotel, are checked. The travelling times between destinations and the staying time on destinations are compared to the time budget to assure the variable values are assigned as they should. The verification process is successful (see section 6.2. for further discussion).

The validation of the model aims to assure the model is a good model for what it aims to represent, in this case, spatio-temporal patterns of pedestrian tourists in a city center. The validation phase consists of monitoring that the model outputs are sufficiently close to real world data, in this case, the real-world data is the data used to populate and define the model; there are variations between the model inputs and outputs. The differences are reasoned and explained in section 4.4. and they are further discussed in section 6.2.

The scenarios evaluation is a significant exploration task that is considered as the sensitivity analysis of the model. The sensitivity analysis consists of changing parameters and evaluate the impact that these changes have on the model; only the parameters to show to have an impact on the model should be included in the calibration phase. It should be noted that the model calibration has not been performed in this study due to time limits, nevertheless, the parameters to be re-calibrated and how to carry out their calibration is discussed in section 6.2.

Finally, the model is used to generate "what-if" scenarios. The goal of testing the scenarios is not to predict the future of a specific situation but to analyze how the model reacts under specific changes, it is considered the sensitivity analysis of the study. The final selection of the parameters to be modified is made after the verification and validation of the model. The selected parameters to be changed are: 1. Preferences for activity types 2. Closing times 3. Location. The scenarios definition is based on Iamsterdam tourism marketing strategies that seek a higher spatial and temporal spread of the tourist crowds.

In the first scenario, outdoor activities (markets) are preferred over indoor activities (cultural activities), the probabilities of selecting these are interchanged. This situation might happen during the summer time. The result is compared to the initial scenario. The staying time in markets is lower than in cultural activities (this is a model assumption). Therefore, since more tourists visit the markets now, they have more time to visit many other destinations during their daily journey. This proves that the staying time on each destination has an important effect on the model. The spatial distribution is affected because markets are located in other areas than cultural activities, therefore, other areas of the city are activated, and other routes are used then the ones in the initial scenario.

In scenario two, the Bloemenmarkt is moved to another quieter area at the east of the city center. This fact directly affects the spatial distribution of tourists: the area around the new location is highly visited in scenario 2 as well as the surrounding streets. The tourists travelling times are higher in scenario 2: the Bloemenmarkt is a popular attraction in the city that most tourists seek to visit, and it is now located a bit further away from the city center.

In scenario three, the closing time of the Hermitage is extended until 21:00. This scenario is relevant because it reveals how the attractiveness scores of the attractions should be modified in regard of the number of hours they are open. This change also affects the spatio-temporal distribution of tourists in the city: the surrounding streets around the Hermitage are passed more times and at late hours in the third scenario.

6.2 Discussion and reflections

It is concluded that the defined and developed modelling framework can be used to formalize and implement a pedestrian tourist simulation: it is considered an adequate framework because **it allows to reveal spatio-temporal patterns of pedestrian tourists based on the city daily activity patterns.** The main inquiries about (Amsterdam) tourism policy makers are about the spatial distribution of tourists in hourly intervals and / or knowing which areas of the city are popular along the day. The developed model highlights which attractions, and therefore, areas, are visited by international pedestrian tourists on the first day of their visit. It emphasises not only locations that are interesting for tourists, but it also reveals locations that are not yet explored.

The model depicts the streets as well through which the tourists pass by. However, the route-choice has been left to the simplest approach: the shortest route. Initially, the goal of the study was to develop a destination-choice and a route-choice model because knowing which routes are used and why is relevant to the management of the tourism landscape. The literature review revealed that it is crucial to determine first where tourist go when visiting a city and then study which routes they select. The destination-choice process required careful planning and, irrevocably, it took up the available time for this research. Nevertheless, once the developed model is calibrated, the route-choice can be implemented on the same model.

Although the concepts of preferences and attractiveness are implemented in the model, it should not be considered a behavioral model but a descriptive one that can be used to explore why, when and where tourists make use of the tourist market infrastructure when visiting a city. This research should be considered as an exploratory study intended to illustrate what the possibilities of using this type of tools are and the usefulness they might have on managing tourism aspects.

Building a model implies simplifying a real phenomenon, therefore, many assumptions have been taken along the process. This section reflects upon the model assumptions, model calibration, data and the usefulness of the model.

6.2.1 Discussion about the model calibration

One of the main critical points is the calibration of the model. Due to time constraint the calibration of this model is not carried out, although chapter 5 includes relevant insights about how to perform it. Two model parameters must be calibrated to match the input data:

- Time of leaving the hotel

The distribution of this variable is truncated on the left side to prevent tourists leave the hotel very early in the morning when the majority of the destinations are closed. However, the truncation of the distribution delays the average and reduces the standard deviation of this variable in the model output. Therefore, the truncation should be reduced to 60 minutes instead of 120 minutes, this way, the output would fit the input data. With this modification, the distribution of tourists among activities is not affected.

- Attractiveness scores

Scenario 3 was revealing because it depicted the relation between the attractiveness score of one attraction and the number of hours it is open. A not-very-popular-destination might get higher numbers of visitors only because it is open more hours than other highly popular destinations. Therefore, the attractiveness scores of these late-closing locations should be reduced by the number of extra hours that it is open. The "extra hours" are counted from the minimum closing time of the other activities that belong to the same activity group which is normally 17:00.

6.2.2. Discussion about the model assumptions: tourist types, activity types and staying times

One potential of ABM is to reveal patterns and emergence from the interaction of different agent's groups. In this model, only one type of tourists is modelled. They select the activity type based on the percentages from BOMA (2016) but they are the same for every agent. This is the most sensitive decision to reflect on. The reason why one group is included is explained in section 6.1, it is basically to fit the input data so that the model could be compared to quantitative data. Differentiating tourist types would have implied including many more assumptions in the model.

The BOMA report presents the data condensed and it is difficult to isolate different tourist groups (by ages or by number of people travelling in the group…). However, BOMA raw data might be attainable in the short term, then, differentiating tourist's groups is completely feasible. The raw data form the surveys might give a better understanding of tourist preferences as well.

A way of improving the model is to use the staying time parameter to model different tourist groups. For instance, if a tourist prefers visiting a cultural activity, his staying time in that activity type would increase, this way typologies of tourists could be introduced in the model in terms of activity types and staying times. The model results are very sensitive to this parameter: it should be tested further to see how the model reacts.

6.2.3. Relevant elements to be included

Distance

The distance factor is only included in the destination-choice process to check if the attraction would be still open when the tourist arrives. However, the distance is a critical factor that should be included when selecting the next destination to be visited. It would be interesting to study the trade-off between distance and attractiveness. This curiosity was highlighted when evaluating scenario 2: "how far are tourists willing to travel to visit a popular attraction?". The route of each single can be tracked and mapped, it would be interesting to compare these results when distance would play a role in selecting the following destination.

Adding Airbnb, train and tram stations as entry points

Adding Airbnb, tram, metro and bus stops would be a realistic addition to the model. The destination-choice process would be the same as the established so far, the only difference would be the location of the entry points. Adding the train stops might imply modelling another city visitor type: regional visitors. Other attractions would be targeted by this group. This addition would lead to a more realistic model.

Dynamic attractiveness scores and repulsion concepts

Initially, it was considered to introduce dynamic attractiveness scores: some locations would be more popular at specific times such as restaurants at lunch/ dinner times. The repulsion concept is as interesting as the attraction one. Some tourists might reject a destination just because is crowded or the waiting time on the queue is high. This is a feasible implementation since the number of tourists visiting a specific destination is known in each step of the model.

6.2.4. Visualization: running model and outputs

Although the model visualization was very useful to verify the running model, it has a great room for improvement. Especially if it is going to be used to evaluate the impact of some decisions or used by other users. It should include at least a legend and a visual differentiation of all the activity types.

The visualization of the "number of visits of each destination" output map should be further reconsidered. As stated in chapter 4, the heat maps are an intuitive and adequate visualization for small destinations, larger areas, such as walking areas or shopping streets should be visualised with their real shapes. However, it should be explored how to combine both destinations in the same map so they represent more accurately the dynamics.

6.2.5. Discussion about the data and the model validation

The model validation in this study consist of contrasting the input data with the model outputs and reasoning and explaining the variation that it might exist. The analysis of the variations between input and output are very useful to calibrate the model. However, the proper validation of these models should be executed using other data than the one used to populate and calibrate the model. The validation of these models is challenging and it requires specific data and methodologies so that they can be really validated. It is like data should be collected having these models in mind, situation that hardly occurs. In this case, there is no specific dataset that can be used to validate the complete model. For this reason, it was decided that it is more logical to use the available data, such as number of visitors, to populate the model instead. A limited validation is included in section 4.2. for the shopping activity type and it proves that the proxy "number of shops per meter of street" is valid to quantify the shopping streets popularity.

It is important to note that lack of data should not be considered as an obstacle; data are nowadays collected at a fast pace, especially in big cities and some of it is publicly available. Gemeente Amsterdam is executing the TelPlan2018 and the crowd monitoring system Amsterdam (CMSA) in De Wallen, both projects focus on pedestrians. This data could be used to populate, calibrate and validate the model in the near-future. For instance, the number of passes of each street could be validated making use of the TelPlan2018 dataset. Furthermore, developing these tools at this moment should be considered as an advantage and a step ahead.

6.2.6 Reflections about usefulness of the model and last words

The main goal of the model is to give an insight and improve the understating of spatio-temporal patterns of pedestrian tourists when visiting an urban destination. Although the objective of the model is not especially focused on being used in tourism policy making or the development of tourism strategies, the proposed scenarios take into consideration Iamsterdam strategies to decongest the city center. The scenarios analysis shows what is the effect that some decisions, such as changing the opening hours of attractions or change their location, have on the system. However, the model is not completely ready to be used, as stated in the previous section, it should be re-calibrated first. Besides the calibration, getting the raw data from BOMA (2016) surveys would improve hugely the quality of the model.

Last, as it was mentioned at the beginning of section 6.2., the described framework it is considered as an adequate modelling framework because it can be also used to simulate pedestrian tourist movement in compact and historic centers of other European cities. The tourist market should be adapted to the new city but this research did well in identifying key elements that ought to be included in this type of models. Another advantage is that most of the data used in the model is publicly available like the BOMA surveys, the OIS datasets or the maps from maps.amsterdam.nl. Because of the nature of the data, it is likely that it already exist for other cities too. The model is basic but the advantage is that, it has been built in a such a way, that allows adding more variables and to be extended: including the trams / metros stations or implementing a route choice-model. In the mid-term, it could be used not as a planning tool but it might contribute to facilitate tourism policy design, modification of tourist attraction systems or to a better management of visitors.

Chapter 7: References

Agarwal, C., Green, G. L., Grove, J. M., Evans T. Schweik, C. (2002). A review and assessment of land-use change models: dynamics of space, time, and human choice. Center for the Study of Institutions Population and Environmental Change (Indiana University Bloomington) and the USDA Forest Service Northeastern Forest Research Station (Burlington Vermont.)

Antonini, G, Bierlaire, M., Weber, M. (2014). Simulation of pedestrian behaviour using a discrete choice model calibrated on actual motion data. Published in: *4th Swiss Transport Research Conference*. https://infoscience.epfl.ch/record/87094/files/Antonini_Bierlaire_Weber_Simulationpedestrian Behaviour_STRC_2004.pdf.

Ashworth, G, Page, S.J. (2011). Urban tourism research: Recent progress and current paradoxes. *Tourism Management* 32(1), 1-15.

Batty, M., Xie, Y., Sun, Z. (1999). Modeling urban dynamics through GIS-based cellular automata.*Computers, Environment and Urban Systems* 23(3), 205–233. http://doi.org/10.1016/S0198-9715(99)00015-0

Batty, M. (2003). Agent-based pedestrian modelling. In *Advanced Spatial Analysis,* Longley P.A. and Batty M. (eds). ESRI, New York, pp. 81-108.

Batty, M. (2005). Cities and Complexity: Understanding cities with cellular automata, agent-based models, and fractals. Cambridge, MA MIT Press.

Batty, M., Torrens, P. (2005). Modelling and prediction in a complex world. *Futures* 37, 745–766.

Batty, M. (2017). About Modelling and Simulation. Lectures on Urban Modelling. http://www.spatialcomplexity.info/

Bierlaire, M., Antonini, G., Weber, M. (2003). Behavioral dynamics for pedestrians. In *Moving through nets: the physical and social dimension of travel*. Axausen, K. (ed.) Elsevier Ltd.

Blue, V. J., Adler, J. L. (2001), Cellular automata microsimulation for modelling bi-directional pedestrian walkways. *Transportation Research* B, 35, 293-312.

Boero, R. , Squazzoni, F. (2005). Does Empirical Embeddedness Matter? Methodological Issues on Agent-Based Models for Analytical Social Science. *Journal of Artificial Societies and Social Simulation* 8 (4) 6.

Boma (2016). Bezoekersonderzoek Metropool Amsterdam 2016. Amsterdam Metropolitan Area visitors survey 2016 – Amsterdam Marketing

http://amsterdam-marketing.instantmagazine.com/kerncijfers-2016/boma-2016-english#!/cover-boma-copy

Boniface, B., Cooper, C. (2005.) World Wide Destinations – The Geography of Travel and Tourism, 4th ed. Oxford: Elsevier Butterworth-Heineman. ISBN 978-075065997

Borgers, A., Timmermans, H.J.P. (1986). A model of pedestrian route choice and demand for retail facilities within inner-city shopping areas. *Geographical Analysis* 18(2), 115-128.

Borgers, A., Timmermans, H.J.P. (2005), Modelling pedestrian behavior in downtown shopping areas. In *Proceedings of CUPUM 05, Computers in Urban Planning and Urban Management,* London, 83-15 pp.

Bovy, P.H.L., Stern, E. (1990). Route Choice: Wayfinding in Transport Networks. Kluwer Academic Publishers, Dordrecht.

Bretagnolle, A., Daude, E., Pumain, D. (2006). From theory to modelling: urban systems as complex systems. *Cybergeo European Journal of Geography* Art 335. http://cybergeo.revues.org/ 2420.

Castiglione, J., Bradley, M., Gliebe, J. (2014). Activity-based travel demand models: a primer. *The Strategic Highway Research Program Transportation Research Board of National Academies*. Project No. 031031-4034. Washington, The National Academies Press.

Cooper , C . , Fletcher , J . , Gilbert , D . and Wanhill ,S. ,(eds) (1993). An Introduction to Tourism. In *Tourism: Principles and Practice*, 1st edt, Longman Scientific & Technical, Harlow, Essex , pp. 1 – 10 .

Choi, E. (2013). Understanding Walkability: Dealing with the complexity behind pedestrian behavior. In 9th *International Space Syntax Symposium*, Seoul, Sejong University.

Daamen, W. (2004). Modelling pedestrian flows in public transport facilities. *Thesis Report*, Delft University of Technology. Delft University Press. ISBN 90-407-2521-7.373 pp.

Drift, S. van der (2015). Revealing spatial and temporal patterns from Flickr photography. A case study with tourists in Amsterdam. *Thesis Report GIRS-2015-09*. Centre for Geo-Information. Wageningen University. 85 pp.

Duives, D.C., Daamen,W., Hoogendoorn, S.P. (2013). State-of-the-art crowd motion simulation models. *Transportation Research Part C* 37, 193–209.

Gehl, J.; Svarre, B. (2013). How To Study Public Life. Springer Nature. ISBN 9781610915250.

Gemeente Amsterdam. (2016a). Drukte in Amsterdam: maatregelen voor een stad in balans. maatregelen_balan ... nten-okt_2016.pdf

Gemeente Amsterdam. (2016b). Amsterdamse thermometer van de Bereikbaarheid. Amsterdamse Ther ... aarheid_2016.pdf

Gemeente Amsterdam. (2016c). Amsterdam aantrekkelijk bereikbaar. MobiliteitsAanpack Amsterdam 2030. MobilitietAanpak_amsterdam_aantrekkelijk_en_bereikbaar_definitief.pdf

Gemeente Amsterdam. (2016d). The city-wide survey asked people how they experience crowdedness: Monitoring balance. LauraHakvoort_HowPeopleExperienceCrowdedness.pdf

Gemeente Amsterdam. (2016e). Socialemediadata voor Amsterdams toerismeonderzoek. strategische_kennisagenda_4.pdf

Gilbert, N. (2008). Agent-Based Models. Series: *Quantitative Applications in the social sciences* (07-153). Liao, T. (ed), SAGE Publications.

Griffith, C. S., Long, B. L., Sept, J. M. (2010). Hominids: An agent-based spatial simulation model to evaluate behavioural patterns of early Pleistocene hominids. *Ecological Modelling* 221, 738–760.

Grimm, V., Berger, U., Bastiansen, F., Eliassen, S., Ginot, V., Giske, J., Goss-Custard, J., Grand, T., Heinz, S., Huse, G., Huth, A., Jepsen, J.U., Jørgensen, C., Mooij, W.M., Müller, B., Pe'er, G., Piou, C., Railsback, S.F., Robbins, A.M., Robbins, M.M., Rossmanith, E., Rüger, N., Strand, E., Souissi, S., Stillman, R.A., Vabo, R., Visser, U., DeAngelis, D.L. (2006). A standard protocol for describing individual-based and agent-based models. *Ecological Modelling* 198, 115–126.

Grimm,V., Berger, U., DeAngelis, D. L., Polhill, J.G., Giske, J., Railsback, S.F. (2010). The ODD protocol: A review and first update. *Ecological Modelling* 221 2760–2768

Grinberger, A, Shoval, N.; McKercher, B. (2014) Typologies of tourists' time–space consumption: a new approach using GPS data and GIS tools. *Tourism Geographies* 16 (1), 105-123.

Ferber, J. (1999). Multi-Agent Systems: An Introduction to Distributed Artificial Intelligence. Addison Wesley, Reading, MA.

Forrest, S., Jones,T. (1994). Modelling complex adaptive systems with Echo. In *Complex Systems. Mechanism of Adaptation*, Stonier and Huo Yu (eds) IOS Press, pps. 3- 20.

Joffre, O. M., Bosma, R. H., Ligtenberg, A., Tri, V., Ha, T., Bregt, A. K. (2015). Combining participatory approaches and an agent-based model for better planning shrimp aquaculture. *Agricultural Systems* 141, 149–159.

Hall, A., Virrantaus, K. (2016). Visualizing the workings of agent-based models: Diagrams as a tool for communication and knowledge acquisition. *Computers Environment and Urban Systems* 58, 1-11.

Haklay, M., O'Sullivan, D., Thurstain-Goodwin, M. (2001), "So go down town": simulating pedestrian movement in town centres. *Environment and Planning B: Planning and Design* 28(3) 343-359.

Hill, M.R. (1982). Spatial structure and decision-making of pedestrian route selection through an urban environment. Ph.D. Thesis, University Microfilms International

Hoongendoorn, S.P., Bovy, P.H. (2002), Normative Pedestrian Behaviour Theory and Modelling. In Transportation *and Traffic Theory in the 21st Century*. Taylor,M.A. (ed.) pp.219 - 245

Hoongendoorn, S.P., Bovy, P.H. (2004). Pedestrian route-choice and activity scheduling theory and models. *Transportation Research Part B* 38, 169–190.

Huang, A., Xiao, H. (2000). Leisure-based tourist behavior: a case study of Changchun. *International Journal of Contemporary Hospitality Management* 12 (3) 210-214.

Itami, R., Gimlet. (2001). Intelligent Recreation Agents in a Virtual GIS world. *Complexity International* 8. https://www.researchgate.net/publication/229049459_Intelligent_recreation_agents_in_a_virtual_GIS_world

Knaap van der, W. (1999). Research report: GIS-oriented analysis of tourist time-space patterns to support sustainable tourism development. *Tourism Geographies* 1, 56-69.

Kerncijfers (2017). I amsterdam.pdf

Published by Iamsterdam Klügl, F. (2008). A validation methodology for agent-based simulations. *Proceedings of the ACM Symposium on Applied Computing* (SAC), Brazil 16-20.

Lau, G., Mckercher,B. (2006). Understanding tourist movement patterns in a destination: A GIS approach. *Tourism and Hospitality Research* 7 (1), 39–49.

Lee, J.S., Filatova, T., Ligmann-Zielinska, A., Hassani-Mahmooei, B., Stonedahl, F., Lorscheid, I., Voinov, A.,Polhill, G., Sun, Z., Parker, D.C. (2015). The Complexities of Agent-Based Modeling Output Analysis. *Journal of Artificial Societies and Social Simulation* 18 (4), 4.

Lew, A., McKercher, B. (2006). Modeling tourist movements a local destination analysis. *Annals of Tourism Research* 33 (2), 403–423.

Liu, Y., Feng, Y. (2012). A logistic based cellular automata model for continuous urban growth simulation: A case study of the gold coast city, Australia. In *Agent-Based Models of Geographical Systems*. Heppenstall, A. J., Crooks, A. T., See, L. M. & Batty, M. (eds.). Springer Netherlands, pp. 643–662.

McKercher, B. (2004). The myth of the average tourist. *Voice of TIC* 4, 19–23.

McKercher, B., Lew, A. (2004). Tourist Flows and the Spatial Distribution of Tourists. In *A Companion to Tourism*. Lew, Hall, William (eds), Blackwell, Oxford, pp. 36 – 47.

McKercher, B, Lau, G. (2008) Movement Patterns of Tourists within a Destination. *Tourism*

Geographies 10 (3) 355-374.

Middleton, J. (2010). Sense and the city: exploring the embodied geographies of urban walking. *Social and Cultural Geography* 11 (6), 575-596.

Miller, H.J. (1991). Modelling accessibility using space-time prism concepts within geographical information systems. *International Journal of Geographical Information Systems* 5(3), 287-301.

Moss, S. (2002). Policy analysis from first principles. *Proceedings of the National Academy of Sciences* 99 (Suppl.3), 7267-7274.

NBTC Holland marketing – Top50 Nederlandse dagsttracties
https://www.nbtc.nl/nl/homepage/top50-nederlandse-dagattracties-bekend.htm
http://kerncijfers.nbtc.nl/nl/magazine/11936/821915/inkomend_verblijfsbezoek.html

Onderzoek, Informatie en Statistiek. (2016).
https://www.ois.amsterdam.nl/feiten-en-cijfers/amsterdam/economie-en-haven/toerisme/

Parker, D. C., Meretsky, V. (2004). Measuring pattern outcomes in an agent-based model of edge-effect externalities using spatial metrics. *Agriculture, Ecosystems and Environment* 101(2–3), 233–250.

Parry, H. R., Bithell, M. (2012). Large scale agent-based modelling: A review and guidelines for model scaling. In *Agent- Based Models of Geographical Systems*. Heppenstall, A. J., Crooks, A. T., See, L. M. & Batty, M., (eds.). Springer Netherlands, pp. 271–308.

Pearce, D. G. (1995). Tourism today: A geographic analysis. Longman Scientific & Technical, Harlow, Essex.

Pinkster, F., Boterman, W. (2017). When the spell is broken: gentrification, urban tourism and privileged discontent in the Amsterdam canal district. *Cultural Geographies* 24(3), 457–472.

Pires, B., Crooks, A.T. (2017). Modeling the emergence of riots: a geosimulation approach", *Computers, Environment and Urban Systems* 61, 66-80.

Pizzitutti, F., Mena, C. F., Walsh, S. J. (2014). Modelling tourism in the Galapagos Islands: An agent-based model approach. *Journal of Artificial Societies and Social Simulation* 17(1), 14.

Schadschneider, A., W. Klingsch, W., Kluepfel, H., Kretz, T., Rogsch, Ch., Seyfried,A. (2008). Evacuation dynamics: empirical results, modeling and applications. *Encyclopedia of Complexity and Systems Science*. In Meyers R. A. (ed.) pages 3142–3176. Springer, Berlin. ISBN 978-0-387-75888-6.

Schreckenberg, M., Sharma, S. (2002). Pedestrian and Evacuation Dynamics, Springer Verlag. ISBN 978-3-540-42690-5.

Senevarante, P.N., Morall, J.F. (1986). Analysis of factors affecting the choice of route of pedestrians. *Transportation Planning and Technology* 10, 147–159.

Spaccapietra, S., Parent, C., Damiani, M.L.;,de Macedo, J.A., Porto, F., Vangenot, C. (2008). A conceptual view on trajectories. *Data and Knowledge Engineering 65*, 126–146.

Sun, S., Parker, D. C., Huang, Q., Filatova, T., Robinson, D. T., Riolo, R. L., Hutchins, M., Brown, D. G. (2014). Market impacts on land-use change: An agent-based experiment. *Annals of the Association of American Geographers* 104(3), 460–484.

Taillandier P., Vo DA., Amouroux E., Drogoul A. (2012). GAMA: A Simulation Platform That Integrates Geographical Information Data, Agent-Based Modeling and Multi-scale Control. In *Principles and Practice of Multi-Agent Systems*. Desai, N., Liu A., Winikoff M. (eds). PRIMA 2010. Lecture Notes in Computer Science, vol 7057. Springer, Berlin, Heidelberg.

Torrens, P. M. (2006). Simulating sprawl. *Annals of the Association of American Geographers, 96(2), 248–275.*

Troitzsch, K.G. (2004). Valisating simulation models. *Proceedings of the 18th European Simulation Multiconference*, SCS Europe.

Transport for London. (2010). Pedestrian Comfort Level Guidance. London.

Appendix I – Data sources

- **Bezoekersonderzoek Metropool Amsterdam 2016** (BOMA, 2016). Amsterdam Metropolitan Area visitors survey 2016 – Amsterdam Marketing http://amsterdam-marketing.instantmagazine.com/kerncijfers-2016/boma-2016-english#!/cover-boma-copy
- **NBTC Holland marketing – Top50 Nederlandse dagsttracties** https://www.nbtc.nl/nl/homepage/top50-nederlandse-dagattracties-bekend.htm and http://kerncijfers.nbtc.nl/nl/magazine/11936/821915/inkomend_verblijfsbezoek.html
- **Onderzoek, Informatie en Statistiek**

https://www.ois.amsterdam.nl/feiten-en-cijfers/amsterdam/economie-en-haven/toerisme/

Cultuur en monumenten:

i. **Museum visitors per year** (data until 2016). Bezoekers (x 1.000) aan musea verenigd in het OAM – Overleg Amsterdamse Musea, 2012-2016. Accessed from https://www.ois.amsterdam.nl/feiten-en-cijfers/amsterdam/economie-en-haven/toerisme/# on 26/01/2018. Excel format. 2017_jaarboek_894.xlsx

ii. **01_Visitors_museums**_201602_Visitors_concerthalls_theaters_2014-2016**.** Theater visitors en concerttzaal. 8.9.1 Voorstellingen en bezoekers (x 1.000) naar theater of concertzaal, 2014-2016EXCE. accessed from https://www.ois.amsterdam.nl/feiten-en-cijfers/amsterdam/economie-en-haven/toerisme/# on 26/01/2018.Excel format. 2017_jaarboek_891.xlsx

- **City data, Stad vol data** https://data.amsterdam.nl/#?mpb=topografie&mpz=9&mpv=52.3719:4.9012&pgn=home

Theme: Toerisme en cultuur

Portal of data maintained by Gemeente Amsterdam. The data is publised from different parties: Amsterdam marketing, Amsterdam museums, cultural company Noord-hollland, Gemeente Amsterdam (economy, monuments and archeology, OIS, city archive, Stadsdeel Wests, Stadsdeel Zuidoost), Open cultural data...

There are a total of 29 datasets in several formats (api, csv, html, json, xls, xml).

i. **Monumenten** (not used by now). Accessed 26-01-2018. Last update: 415 dagen geleden (07 december 2016) Published by : Gemeente Amsterdam, Monumenten en Archeologie (erfgoed@amsterdam.nl) https://maps.amsterdam.nl/open_geodata/?k=155 download csv file.

ii. **Attracties** (used and I guess it will be modified). Accessed 26-01-2018. Last update: 416 dagen geleden (07 december 2016). Published by Amsterdam marketing. http://open.data.amsterdam.nl/Attracties.csv the shape file is here: H:\02_Thesis\GIS_THESIS\Atractions_destinations Only used for the locations os the shape file because these files don't have the numbers

iii. **Hotels** in metropoolregio Amsterdam (CSV). Accessed 26-01-2018. Last update: 416 dagen geleden (07 december 2016). Published by Hotelloods . including the aantal beds http://open.data.amsterdam.nl/uploads/hotels_in_metropoolregio_amsterdam/Lijst hotels MRA 2012.csv
iv. **Musea en galleries** (CSV). Accessed 26-01-2018. Last update: 416 dagen geleden (07 december 2016). Published by Amsterdam marketing. Only used for the locations os the shape file because these files don't have the numbers http://open.data.amsterdam.nl/MuseaGalleries.csv http://open.data.amsterdam.nl/EtenDrinken.csv
v. **Theaters (CSV).** Accessed 26-01-2018. Last update: 416 dagen geleden (07 december 2016). Published by Amsterdam marketing. Only used for the locations os the shape file because these files don't have the numbers http://open.data.amsterdam.nl/Theater.csv
vi. **Eten en drinken** (not used by now). Accessed 26-01-2018. Last update: 416 dagen geleden (07 december 2016). Published by Amsterdam marketing. So it doesn't include all the shops in Amsterdam. http://open.data.amsterdam.nl/EtenDrinken.csv

- **Funktiekaart** – non-residential land use map. Obtained from R&D internal server. 13 different land-uses in all Amsterdam. Last time update march 2016. Checking time starting October 2016. To be visualized in: https://maps.amsterdam.nl/functiekaart/?LANG=es
    i. Shops with open front to calculate shop density
    ii. Leisure and cultural activities for the museums (above 60.000 yearly visitors)
    iii. Religion – for the churches

- **UNESCO_architecture quality** https://maps.amsterdam.nl/monumenten/?LANG=en

- **Main green infrastructure**: https://maps.amsterdam.nl/hoofdgroenstructuur/?LANG=en
- **Markets https://maps.amsterdam.nl/markten/?LANG=en**

Appendix II – Indicative and qualitative study

	Consulted websites (through Google as search engine)	Specification	URL Link
1	Iamsterdam	Things to do in Amsterdam	https://www.iamsterdam.com/en/see-and-do/things-to-do
		Attractions and sights	https://www.iamsterdam.com/en/see-and-do/things-to-do/attractions-and-sights
		Shopping	https://www.iamsterdam.com/en/see-and-do/shopping
2	Tripadvisor	Things to do in Amsterdam	https://en.tripadvisor.com.hk/Attractions-g188590-Activities-oa30-Amsterdam_North_Holland_Province.html
		Museums	https://www.tripadvisor.nl/Attractions-g188590-Activities-c49-Amsterdam_North_Holland_Province.html
		Sights and Landmarks	https://en.tripadvisor.com.hk/Attractions-g188590-Activities-c47-Amsterdam_North_Holland_Province.html
3	Lonely Planet	Top things to do	https://www.lonelyplanet.com/the-netherlands/amsterdam/top-things-to-do/a/poi/360839
			https://www.lonelyplanet.com/the-netherlands/amsterdam
4	TimeOut	20 essential things to do	https://www.timeout.com/amsterdam/en/things-to-do/20-essential-things-to-do-in-amsterdam
		Shopping	https://www.amsterdam.info/shopping/
5	Amsterdam.info	Top 10 Atractions	https://www.amsterdam.info/sights/top10/
		Museums	https://www.amsterdam.info/museums/
		Shopping	https://www.amsterdam.info/shopping/

Table classification

X	Attractions that show up in the first page as a title or in the top ten
o	Attractions that show up in the middle of the text or in pages that required "second click"

	Counts X	Counts o	Iamsterdam	Tripadvisor	Lonely Planet	Time Out	Amsterdam.info
Areas and parks							
Amsterdam Canal Belt (including de Negen Straatjes)	5	0	X	X	X	X	X
De Wallen - Red light district	3	0		X	X	X	
Museum Plein	3	0		X		X	X
Jordaan	2	0	X			X	
De Pijp	2	0		X		X	
Amstel	1	0		X			
Vondelpark	4	0	X	X	X	X	
Westerpark	0	1	o				

Sarphatipark	0	1	o				
Rembrandtpark	0	1	o				
Sights	0	0					
Begijnhof	3	0	X	X			X
Oude Kerk	1	0					X
Amsterdam Brown Cafes	2	0			X		X
Magere Brug	3	0	X	X			X
Centraal Station	1	0		X			
Dutch National Opera	1	0		X			
Nieuwmarkt - De Waag	1	0		X			
Leidsplein	1	0		X			
Portuguese synagogue	1	0		X			
St. Nicholas	1	0		X			
National monument - Dam Square	1	0		X			
Munt Tower	1	0		X			
Westerkerk	2	0		X		X	
Amsterdam Sign	1	0	X				
Royal Palace	1	0				X	
Pathe Tuschinskitheater	0	1			o		
RembrandtPlein	0	0					
De Foodhallen	0	1			o		
Schuttersgalerij	1	0					X
Museums	0	0					
Rijksmuseum	5	0	X	X	X	X	X
Van gogh museum	5	0	X	X	X	X	X
Het Scheepvaart Museum - OUT	2	0		X			X
Anne Frank Huis	5	0	X	X	X	X	X
Stedelijk	3	1	X		o	X	X
Het Rembrandthuis	3	0	X	X	X		
Hermitage Amsterdam	2	0		X	X		
Verzetsmuseum (resistance museum) - OUT	1	1		X	o		
Museum Willet-Holthuysen	1	1		X	o		
Museum Ons' Lieve Heer op Solder	0	1				o	
Joods Historisch Museum	0	1				o	
EYE Museum -OUT	2	0	X			X	
ARTIS -OUT	0	1					o
Hortus Botanicus -OUT	0	1					o
NEMO -OUT	0	1					o
Markets and shopping areas	0	0					
Nieuwedijk-Kalverstraat	3	0	X			X	X
Leidstraat	1	0	X				
Bloemenmarkt	3	0	X			X	X
Van Baerlestraat	0	1	o				
P.C. Hooftstraat	2	1	o			X	X
Czaar Peterstraat (east)	0	1	o				

De Bijenkorf (mall)	1	2	o			X	o
Magna Plaza (mall)	1	2	o			X	o
Kalvetoren (mall)	0	1					o
Spiegelgracht and Nieuwe Spiegelstraat (art and antiques)	0	2	o				o
Cornelis Schuytstraat	0	2	o			o	
Utrechtsestraat	1	1	X			o	
Beethovenstraat (out of the area)	0	2	o			o	
Jodenbreestraat	0	1				o	
Haarlemmerstraat	1	1	X			o	
Westerstraat in the Jordaan	0	1				o	
Dappermarkt	0	1				o	
Spui (books)	1	1	X			o	
Waterlooplein Flea market	1	1	X			o	
De Looier Antiques Market	0	2	o			o	
Albert Cuyp	1	1	X			o	
Noordermarkt	1	1	X			o	
De Negen straatjes	2	0	X			X	
The Frozen Fountain (Gallery)	0	1				o	
Droog (Gallery)	0	1				o	
Exhibitions and shows	0	0					
Heinken experience	2	0	X				X
Madame Tussauds	1	0					X
Amsterdam Dungeon	1	0					X
Brouwerij 't IJ	1	1	X			o	
House of Bols	0	1					o
Genever Experience	0	1					o
Reypeaner Cheese Tasting Room	0	2				o	o
Xtra Cold Ice Bar	0	1					o
Tun Fun	0	1					o

Amsterdam.info

Book now: | Amsterdam Hotel | Amsterdam Hostel | Tickets Online | Canal Cruise

- Attractions
- Museums
- Accommodation
- Hotels
- Restaurants
- Transportation
- Nightlife & Fun
- Events & Festivals
- Shopping
- Tours & Trips

Google Custom Sear

Amsterdam » Attractions » Top 10

What to see in Amsterdam - Top Ten Attractions

Amsterdam is a unique city. Despite the obvious presence of thousands of visitors, its life remained authentic. To observe it is enough to stroll along the canal streets or to sit for a while in one of Amsterdam many cafés. Nevertheless, there are places in the city you should not miss during your visit. Here is our list of the best of the best.

To avoid waiting lines we advice you to buy your tickets in advance online through our Amsterdam attractions and museums tickets webpage.

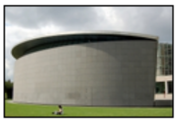
Amsterdam canal ring

The city old centre is formed from canal rings, which give you the feeling of space, freedom and peace. Walk through these canal streets or better – take a trip with a boat by boarding one of the tourist cruises or by renting the boat yourself. Anther way to explore the Venice of the North is to take a ride on a bicycle. Any way you decide for – enjoy this city, one of the most beautiful in the world. If you like boats there is also a large upcoming event about historical sail ships called Amsterdam SAIL.

Rijksmuseum

The Rijksmuseum is the largest and the most attractive museum in the Netherlands, with more than one million visitors each year. Opened in spring of 2013 after a decade of renovation, the museum has a wonderful collection of the 17th C. Dutch Golden Age masterpieces. Famous "The Night Watch" by Rembrandt as well as other celebrated paintings like Vermeer's "The Milkmaid" and "Woman reading a letter", "The Windmill at Wijk bij Duurstede" by van Ruisdael, "The Burgomaster of Delft and his Daughter" by Jan Steen and many more. These marvellous paintings reflect history and character of the Dutch. Unique sculptures and various antiquities as traditional furniture, Delftware, silver, ship models and doll houses complete the show.

Van Gogh Museum



This modern museum houses some 200 paintings and 550 sketches showing Van Gogh in all his moods. This biggest in the world collection, combined with hundreds of letters by Van Gogh, and selected works by his friends and contemporaries, form the core of the museum's collection.

- Amsterdam tourist exhibits and shows
- Amsterdam canal cruises
- Red light district
- Amsterdam windmills
- FOAM art center
- Jordaan in Amsterdam

https://www.amsterdam.info/sights/top10/

20 essential things to do in Amsterdam

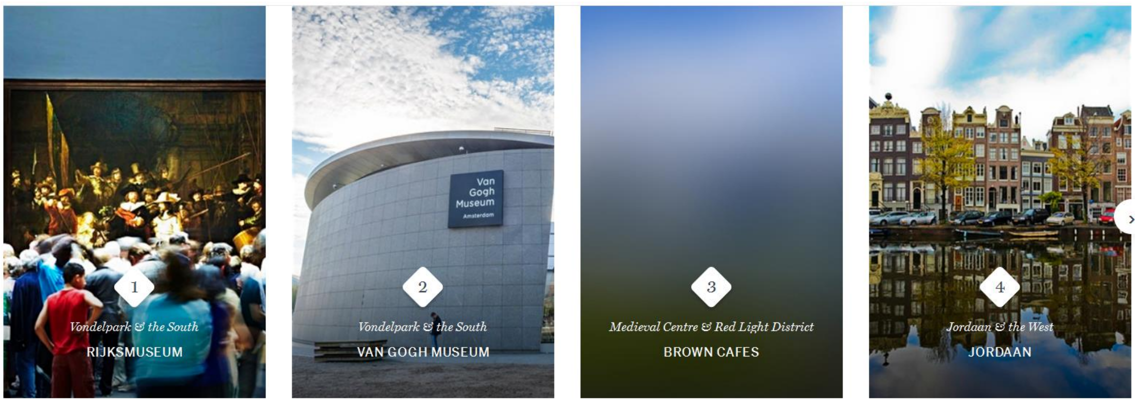
The very best things to do in Amsterdam, including the city's best museums, restaurants, shops,

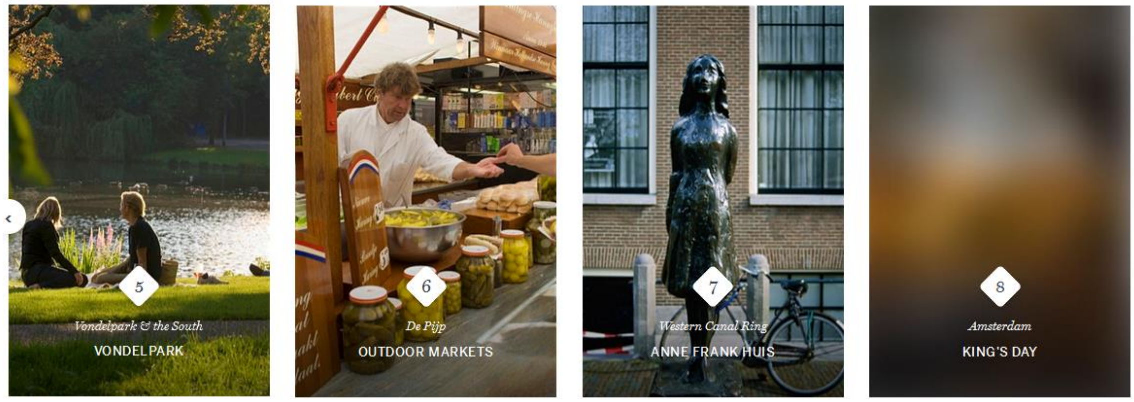
Share Tweet

© Shutterstock/Artur Bogacki

Until recently, the Netherlands' capital was something of a work-in-progress, its world-class art museums – among them the Rijksmuseum, the Stedelijk museum of modern art and the Van Gogh Museum – shuttered for ambitious renovations that temporarily shifted the focus away from the city's rich artistic heritage towards its sleazy, hedonistic side. Although Amsterdam's clubs, bars and nightlife, and the notorious Red Light District, are as vibrant as ever, now that the bandages are off it can revel once more in its unique status as one of Europe's most diverse and boundary-pushing destinations - a

https://www.timeout.com/amsterdam/en/things-to-do/20-essential-things-to-do-in-amsterdam





Top sights in Amsterdam

1 **Rijksmuseum**
VONDELPARK & THE SOUTH

2 **Anne Frank Huis**
WESTERN CANAL RING

3 **Museum het Rembrandthuis**
NIEUWMARKT, PLANTAGE & THE EASTERN ISLANDS

4 **Vondelpark**
VONDELPARK & THE SOUTH

5 **Van Gogh Museum**
VONDELPARK & THE SOUTH

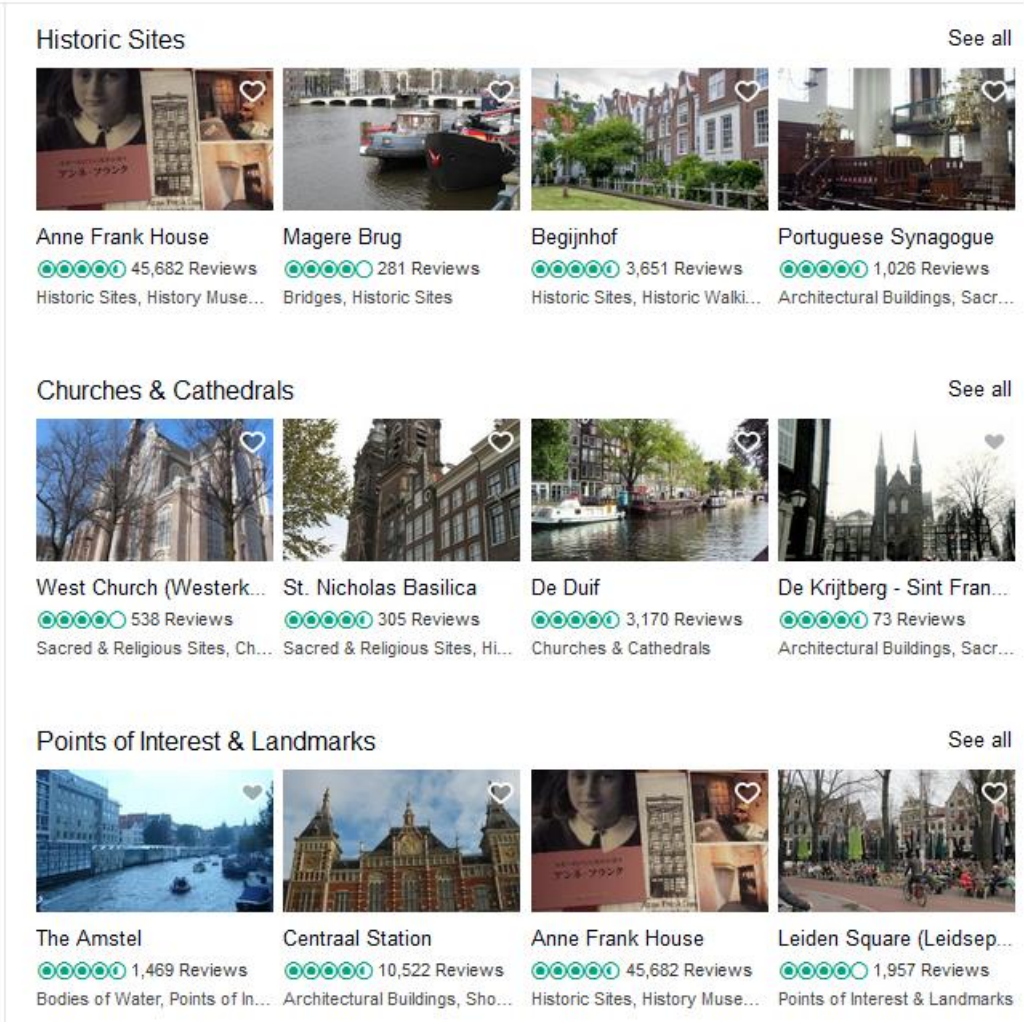
6 **Hermitage Amsterdam**
SOUTHERN CANAL RING

7 **De Hallen**
VONDELPARK & THE SOUTH

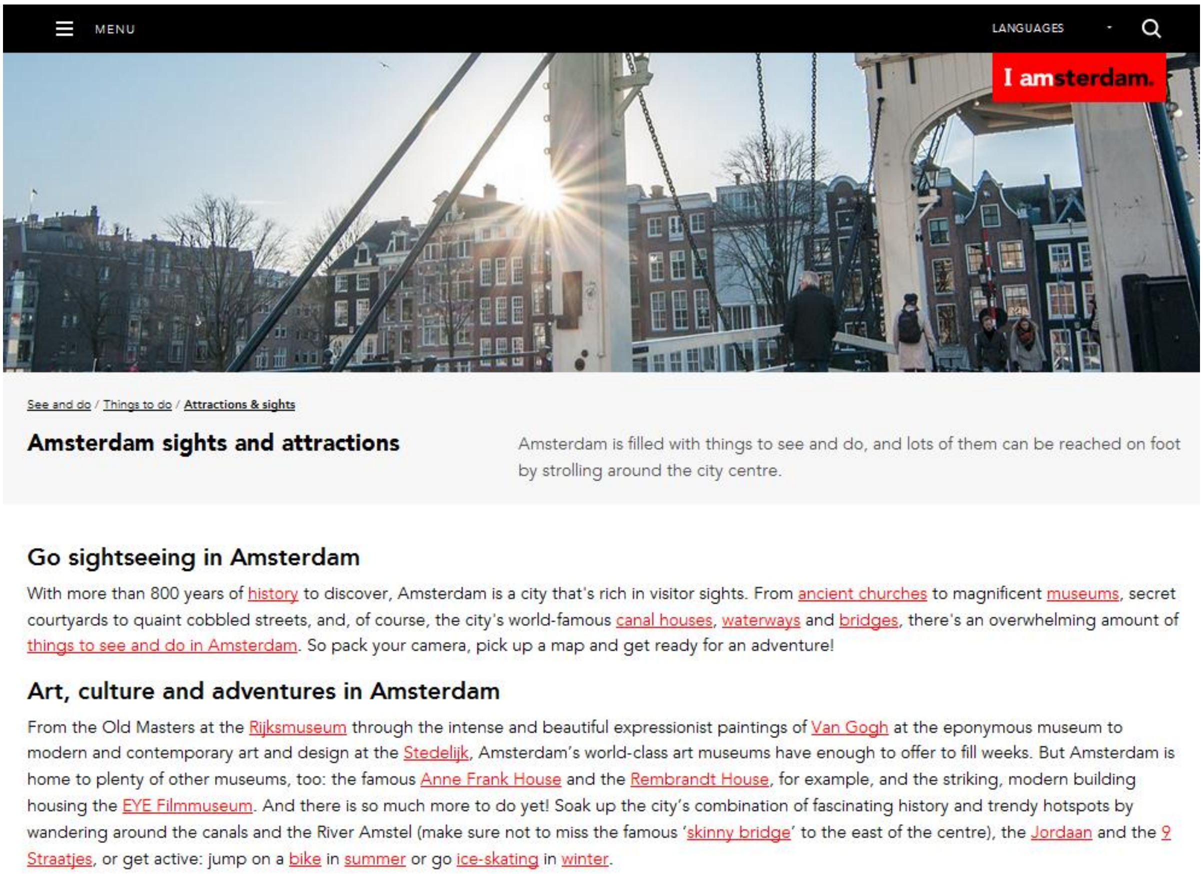
8 **Royal Palace**
MEDIEVAL CENTRE & RED LIGHT DISTRICT

https://www.lonelyplanet.com/the-netherlands/amsterdam

Amsterdam Landmarks



https://en.tripadvisor.com.hk/Attractions-g188590-Activities-c47-Amsterdam_North_Holland_Province.html



https://www.iamsterdam.com/en/see-and-do/things-to-do/attractions-and-sights

Appendix III – Quantification of the attractiveness scores

As it is explained in the main report, the attractiveness score, of a destination being selected. The quantification of each destination is made based on data, more assumptions, the indicative online research. Then, this data has to be standardized so the attractiveness score (represents the probability) ranges from 0 to 1.
First steps concern the normalization of the data - when dealing with parameters of different units and scales, all parameters should have the same scale for a fair comparison between them.

Data normalization means transforming all variables in the data to a specific range.
The methods are usually well known for rescaling data. *Normalization*, which scales all numeric variables in the range [0,1].

$$x_{new} = \frac{x - x_{min}}{x_{max} - x_{min}}$$

The x_{max} and x_{min} will vary for each activity type; they depend on the dataset scale that is used to quantify the attraction.

- **Walking areas**

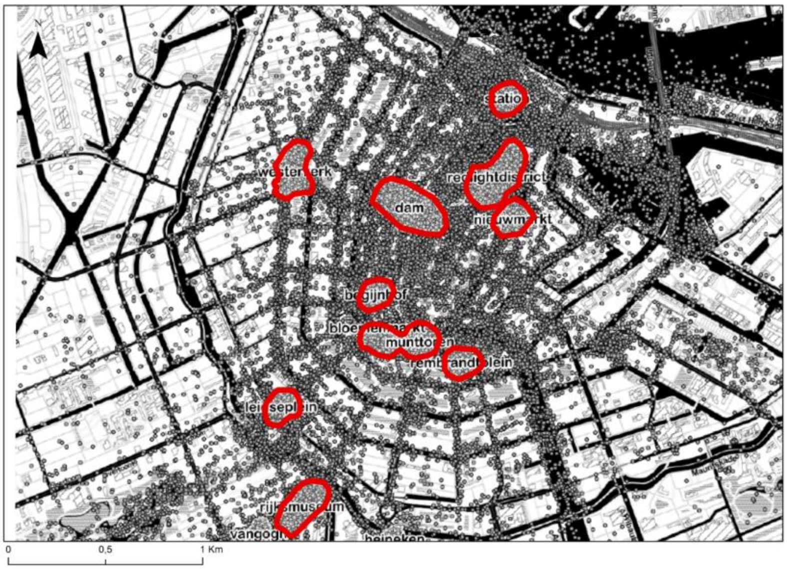
Destination	Number of counts	Atractiveness score
Canal Belt	5	1
De Wallen	3	0,6
Vondelpark	4	0,8
Museumplein	2	0,4

- **Sightseeing activities**

Van der Drift (2015) identified tourist hotspots based on Flickr pictures

Identified hotspots van der Drift (2015)			Attractiveness score
Importance	Destination	Number of pictures	
1	Dam Square	1605	1,000
2	Red Light District and Oude kerk	921	0,574
3	Rijksmuseum and Museum square	718	0,447
4	Westerkerd and Anne Frank house	662	0,412
5	Munt Tower and Flower market	473	0,295
6	Central Station	416	0,259
7	Nieuwmarkt	396	0,247
8	Begijnhof	380	0,237
9	Leidseplein	362	0,226
10	Rembrandt Square	353	0,220

Layer has been drawn from the Sander's referenced map



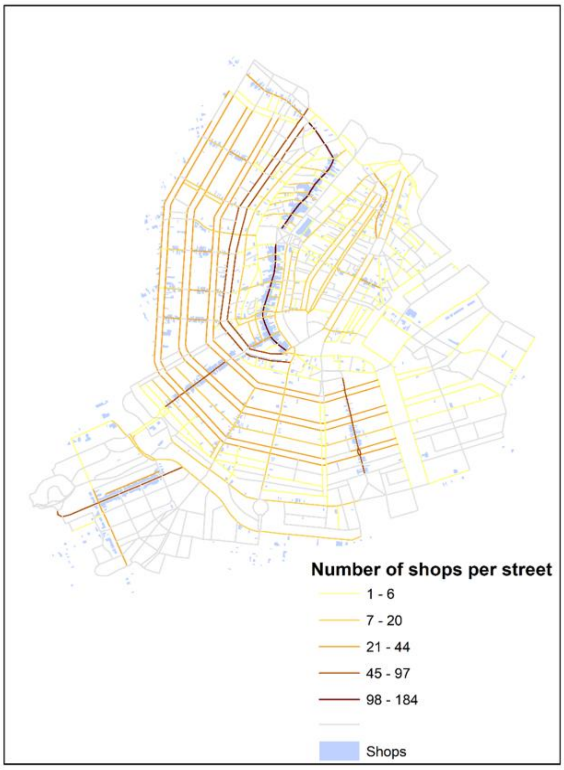
- **Cultural activities**

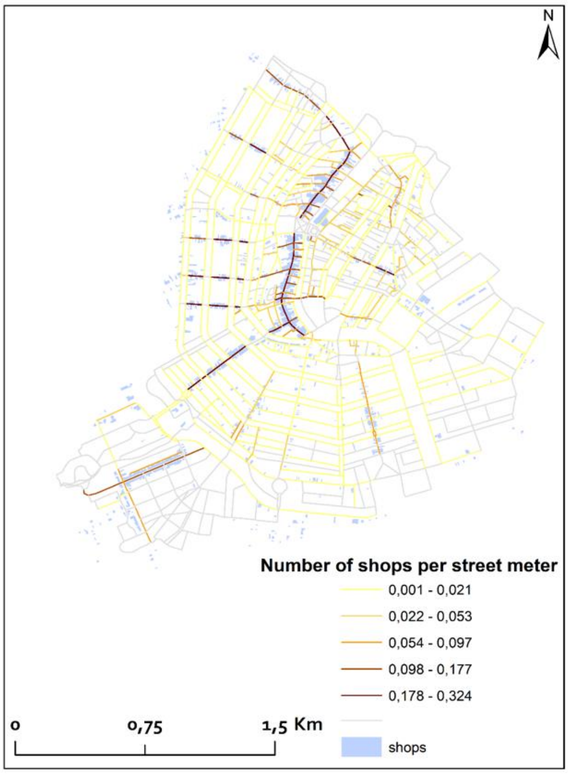
The maximum is the maximum number of visitors (Rijksmuseum - 2144000). The minimum is the minimum number of visitors that have visited a museum – even if the museum is not in the final list because it does not reach out the 60.000 yearly visitors. In this case is 2000 (Multatuli huis). If I take the minimum from my list (65.000 – huis Marseille) then the probability of visiting this museum (when normalized) is zero. Taking the minimum as cero doesn't make sense in this case because at least one visitor will visit a specific museum so better taking the data from the real dataset.

Destination	Number of visitors 2016	Attractiveness score
Rijksmuseum	2144000	1,000
Van Gogh	2077000	0,969
Artis	1353000	0,631
Anne Frank Huis	1296000	0,604
Heineken experience	1220280	0,569
Sexmuseum-Venustempel	768912	0,358
Stedelijk	655000	0,305
Hermitage Amsterdam	468000	0,218
Amsterdam Museum	413000	0,192
Joods Historisch Museum (JCK)	328000	0,152
De Nieuwe Kerk	261000	0,121
Het Rembrandthuis	248000	0,115
Foam Fotografiemuseum Amsterdam	244000	0,113
Koninklijk Paleis Amsterdam	238000	0,110
Hortus Botanicus Amsterdam	169000	0,078
De Oude Kerk	136000	0,063
Museum Ons' Lieve Heer op Solder	118000	0,054
Stadsarchief Amsterdam	108000	0,049
Verzetsmuseum	104000	0,048
Museum van Loon	94000	0,043
Allard Pierson Museum	73000	0,033
Diamant Museum	71000	0,032
Tassenmuseum Hendrikje	70000	0,032
Huis Marseille	65000	0,029

- **Shopping activities**


Retail-shops + visible front shops
0
0.5
1 km


Number of shops per street
1 - 6
7 - 20
21 - 44
45 - 97
98 - 184
Shops


N
Number of shops per street meter
0,001 - 0,021
0,022 - 0,053
0,054 - 0,097
0,098 - 0,177
0,178 - 0,324
0
0,75
1,5 Km
shops

ID	Name	At_score	Shopping_street	Average	Final score
393	Utrechtsestraat	0,300	Utrechtsestraat		0,300
255	Nieuwe Spiegelstraat	0,125	Spiegelgracht	0,186	0,186
366	Spiegelgracht	0,247			
295	P Cornelisz Hooftstr	0,383	PC Hoofstraat, Van Baerlestraat	0,305	0,305
336	Schapenburger pad	0,291			
395	Van Baerlestraat	0,240			
138	Heiligeweg	0,950	Leidsestraat en Heiligeweg	0,765	0,765
214	Leidsestraat	0,579			
330	Rozenboomsteeg	0,713	Kalverstraat	0,781	0,781
162	Kalverstraat	0,849			
248	Nieuwe Hoogstraat	0,613	OudeDoelenstraat Oude-NieuweHoogstraat Damstraat	0,472	0,472

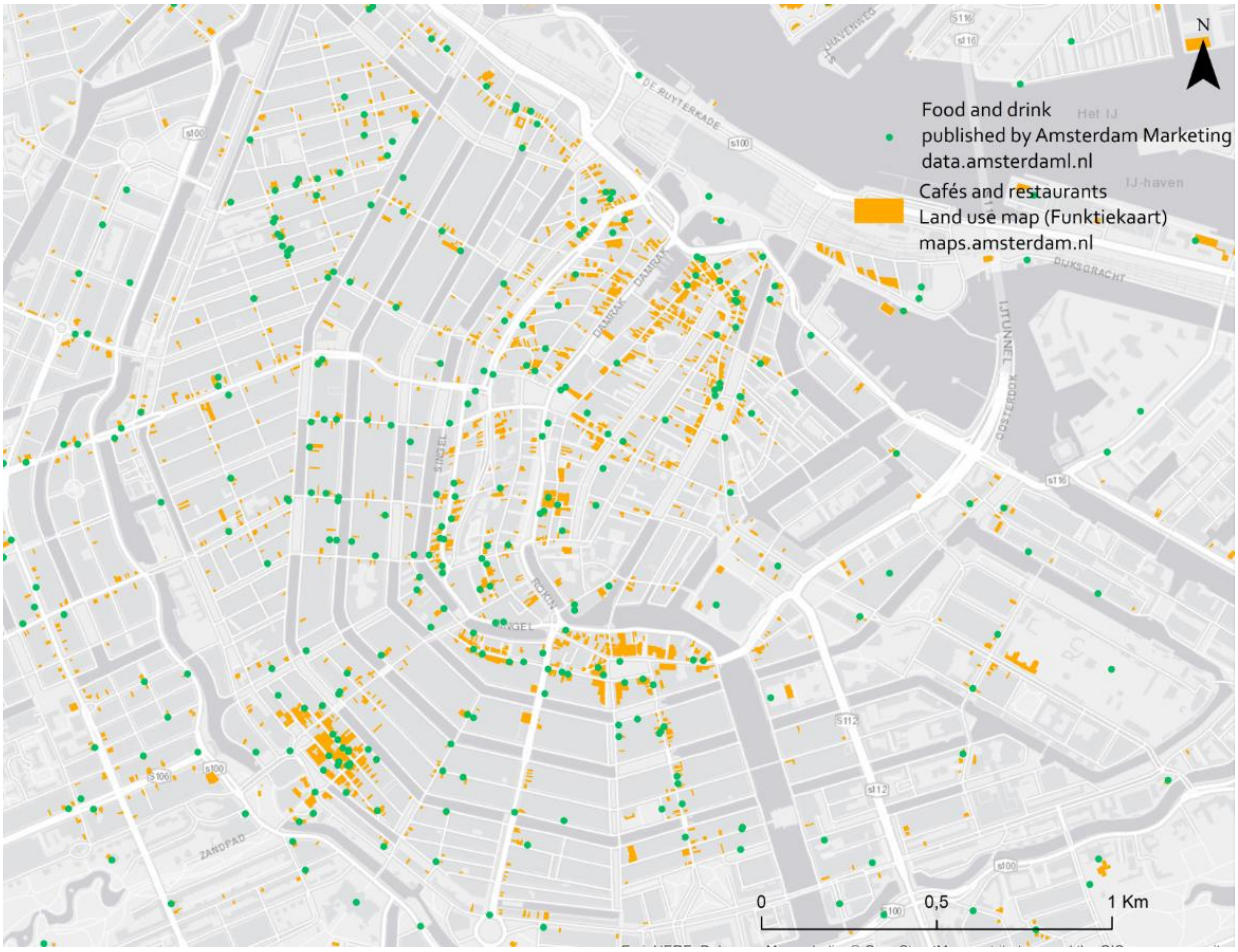
277	Oude Hoogstraat	0,330			
439	Zeedijk	0,173	Zeedijk		0,173
260	Nieuwendijk	0,601	Nieuwendijk		0,601
130	Haarlemmerstraat	0,337	Haarlemmerstraat		0,337
51	Berenstraat	0,648	Negen straatjes	0,739	0,739
114	Gasthuismolensteeg	0,766			
153	Huidenstraat	0,791			
135	Hartenstraat	0,783			
280	Oude Spiegelstraat	1,000			
318	Reestraat	0,545			
331	Runstraat	0,865			
427	Wijde Heisteeg	0,598			
435	Wolvenstraat	0,654			

Importance	Destination	Attractiveness score
1	Kalverstraat	0,781
2	Leidsestraat en Heiligeweg	0,765
3	9 straatjes	0,739
4	Nieuwendijk	0,601
5	OudeDoelenstraat Oude-NieuweHoogstraat Damstraat	0,472
6	Haarlemmerstraat	0,337
7	PC Hoofstraat, Van Baerlestraat	0,305
8	Utrechtsestraat	0,300
9	Spiegelgracht	0,186
10	Zeedijk	0,173

- **Visit a market**

Destination	Number of counts	Attractiveness score
Bloemenmarkt	3	0,6
Spuimarkt	1	0,2
Waterloopleinmarkt	1	0,2
Noordermarkt	1	0,2

- **Visit a café of a pub**



Appendix IV – Final destinations included and their characteristics

The times are expressed in minutes. Simulation starts at 6:00, so it is time zero. The opening and closing times are expressed from this zero value. For example, an opening time of 240 minutes means that the attraction opens at 10:00. 240 minutes = 4 hours; 6:00 + 4 hours = 10:00

FID	Destination name	Activity type	Quanticiation source	Quantici ation value	At. score	Probability of selecting a specific activity type	Open time	Close time	Min staying time	Max staying time
0	Central Station	Sightseeing	Daily nr of pictures	416	0,26	0,23	0	0	0	10
1	Dam square	Sightseeing	Daily nr of pictures	1605	1,00	0,23	0	0	0	10
2	Westerkerk	Sightseeing	Daily nr of pictures	662	0,41	0,23	0	0	0	10
3	Begijnhof	Sightseeing	Daily nr of pictures	380	0,24	0,23	120	660	0	10
4	Red light district	Sightseeing	Daily nr of pictures	921	0,57	0,23	0	0	0	10
5	Nieuwmarkt	Sightseeing	Daily nr of pictures	396	0,25	0,23	0	0	0	10

6	Rembrandtplein	Sightseeing	Daily nr of pictures	353	0,22	0,23	0	0	0	10
7	Leidsplein	Sightseeing	Daily nr of pictures	362	0,23	0,23	0	0	0	10
8	Munt Tower and Bloemenmarkt	Sightseeing	Daily nr of pictures	473	0,29	0,23	0	0	0	10
9	Rijksmuseum and Amsterdam sign	Sightseeing	Daily nr of pictures	718	0,45	0,23	0	0	0	10
10	Museum Ons' Lieve Heer op Solder	Cultural activity	Nr of visitors 2016	118000	0,05	0,21	240	720	60	180
11	Allard Pierson Museum	Cultural activity	Nr of visitors 2016	73000	0,03	0,21	240	660	60	180
12	Amsterdam Museum	Cultural activity	Nr of visitors 2016	413000	0,19	0,21	240	660	60	180
13	Koninklijk Paleis Amsterdam	Cultural activity	Nr of visitors 2016	238000	0,11	0,21	240	660	60	180
14	De Nieuwe Kerk	Cultural activity	Nr of visitors 2016	261000	0,12	0,21	240	660	60	180
15	Sexmuseum-Venustempel	Cultural activity	Nr of visitors 2016	768912	0,36	0,21	210	1050	60	180
16	Tassenmuseum Hendrikje	Cultural activity	Nr of visitors 2016	70000	0,03	0,21	240	660	60	180
17	Foam Fotografiemuseum Amsterdam	Cultural activity	Nr of visitors 2016	244000	0,11	0,21	240	720	60	180
18	Huis Marseille	Cultural activity	Nr of visitors 2016	65000	0,03	0,21	300	660	60	180
19	Hortus Botanicus Amsterdam	Cultural activity	Nr of visitors 2016	169000	0,08	0,21	240	660	60	180
20	Hermitage Amsterdam	Cultural activity	Nr of visitors 2016	468000	0,22	0,21	240	660	60	180
21	Verzetsmuseum	Cultural activity	Nr of visitors 2016	104000	0,05	0,21	240	660	60	180
22	Het Rembrandthuis	Cultural activity	Nr of visitors 2016	248000	0,11	0,21	240	720	60	180
23	Anne Frank Huis	Cultural activity	Nr of visitors 2016	1296000	0,60	0,21	240	840	60	180
24	Artis	Cultural activity	Nr of visitors 2016	1353000	0,63	0,21	180	660	60	180
25	Joods Historisch Museum (JCK)	Cultural activity	Nr of visitors 2016	328000	0,15	0,21	300	660	60	180
26	Museum van Loon	Cultural activity	Nr of visitors 2016	94000	0,04	0,21	240	660	60	180
27	Diamant Museum	Cultural activity	Nr of visitors 2016	71000	0,03	0,21	180	660	60	180
28	Stedelijk	Cultural activity	Nr of visitors 2016	655000	0,30	0,21	240	720	60	180
29	Heineken experience	Cultural activity	Nr of visitors 2016	1220280	0,57	0,21	270	780	60	180
30	Van Gogh	Cultural activity	Nr of visitors 2016	2077000	0,97	0,21	180	660	60	180
31	Rijksmuseum	Cultural activity	Nr of visitors 2016	2144000	1,00	0,21	180	660	60	180
32	Stadsarchief Amsterdam	Cultural activity	Nr of visitors 2016	108000	0,05	0,21	240	660	60	180

33	De Oude Kerk	Cultural activity	Nr of visitors 2016	136000	0,06	0,21	240	720	60	180
34	Bloemenmarkt	Market	Indicative online research - number of times they are announce on websites	3	0,60	0,08	180	690	10	45
35	Spuimarkt	Market	Indicative online research - number of times they are announce on websites	1	0,20	0,08	240	660	10	45
36	Waterloopleinmarkt	Market	Indicative online research - number of times they are announce on websites	1	0,20	0,08	210	720	10	45
37	Noordermarkt	Market	Indicative online research - number of times they are announce on websites	1	0,20	0,08	180	660	10	45
38	Vondelpark/3	Dinner-pub			1,00	0,12	720	1020	45	90
39	Lempicka	Dinner-pub			1,00	0,12	720	1020	45	90
40	Koko	Dinner-pub			1,00	0,12	720	1020	45	90
41	Olivar	Dinner-pub			1,00	0,12	720	1020	45	90
42	Mugen	Dinner-pub			1,00	0,12	720	1020	45	90
43	Next Friday	Dinner-pub			1,00	0,12	720	1020	45	90
44	Leegstand	Dinner-pub			1,00	0,12	720	1020	45	90
45	Villa Nieuwmarkt	Dinner-pub			1,00	0,12	720	1020	45	90
46	Fonteyn	Dinner-pub			1,00	0,12	720	1020	45	90
47	Bern	Dinner-pub			1,00	0,12	720	1020	45	90
48	The Cotton Club	Dinner-pub			1,00	0,12	720	1020	45	90
49	Cuba	Dinner-pub			1,00	0,12	720	1020	45	90
50	Cafe De Vriendschap	Dinner-pub			1,00	0,12	720	1020	45	90
51	Stevens	Dinner-pub			1,00	0,12	720	1020	45	90
52	Tuinfeest	Dinner-pub			1,00	0,12	720	1020	45	90
53	Butterfly	Dinner-pub			1,00	0,12	720	1020	45	90
54	Bredero	Dinner-pub			1,00	0,12	720	1020	45	90
55	Rock Planet	Dinner-pub			1,00	0,12	720	1020	45	90
56	Rick's	Dinner-pub			1,00	0,12	720	1020	45	90
57	Susies Saloon	Dinner-pub			1,00	0,12	720	1020	45	90
58	De Zeevaart	Dinner-pub			1,00	0,12	720	1020	45	90

59	Pleinzicht	Dinner-pub			1,00	0,12	720	1020	45	90
60	Old Town	Dinner-pub			1,00	0,12	720	1020	45	90
61	De Pul / The Pint	Dinner-pub			1,00	0,12	720	1020	45	90
62	De Stoof	Dinner-pub			1,00	0,12	720	1020	45	90
63	De Burgh	Dinner-pub			1,00	0,12	720	1020	45	90
64	Excalibur	Dinner-pub			1,00	0,12	720	1020	45	90
65	The Black Tiger	Dinner-pub			1,00	0,12	720	1020	45	90
66	Old Sailor	Dinner-pub			1,00	0,12	720	1020	45	90
67	Red Light Bar	Dinner-pub			1,00	0,12	720	1020	45	90
68	Remember	Dinner-pub			1,00	0,12	720	1020	45	90
69	Torenzicht	Dinner-pub			1,00	0,12	720	1020	45	90
70	T Loosje	Dinner-pub			1,00	0,12	720	1020	45	90
71	Del Mondo	Dinner-pub			1,00	0,12	720	1020	45	90
72	Poco Loco	Dinner-pub			1,00	0,12	720	1020	45	90
73	Gewaeght Café	Dinner-pub			1,00	0,12	720	1020	45	90
74	Old Wembley	Dinner-pub			1,00	0,12	720	1020	45	90
75	In De Waag	Dinner-pub			1,00	0,12	720	1020	45	90
76	Muse	Dinner-pub			1,00	0,12	720	1020	45	90
77	De Zon	Dinner-pub			1,00	0,12	720	1020	45	90
78	Latei	Dinner-pub			1,00	0,12	720	1020	45	90
79	A-Fusion	Dinner-pub			1,00	0,12	720	1020	45	90
80	Dijk 120	Dinner-pub			1,00	0,12	720	1020	45	90
81	Cafe De Mill	Dinner-pub			1,00	0,12	720	1020	45	90
82	Lime	Dinner-pub			1,00	0,12	720	1020	45	90
83	De Zeemeeuw	Dinner-pub			1,00	0,12	720	1020	45	90
84	Oost West	Dinner-pub			1,00	0,12	720	1020	45	90
85	Emmelot	Dinner-pub			1,00	0,12	720	1020	45	90
86	The Bulldog	Dinner-pub			1,00	0,12	720	1020	45	90
87	De Ooievaar	Dinner-pub			1,00	0,12	720	1020	45	90
88	Trinity	Dinner-pub			1,00	0,12	720	1020	45	90
89	Thai Mekhong River	Dinner-pub			1,00	0,12	720	1020	45	90
90	Cafe Verhoeff	Dinner-pub			1,00	0,12	720	1020	45	90
91	De Kletskop	Dinner-pub			1,00	0,12	720	1020	45	90
92	Café 'T Mandje	Dinner-pub			1,00	0,12	720	1020	45	90
93	Maria	Dinner-pub			1,00	0,12	720	1020	45	90
94	San Francisco	Dinner-pub			1,00	0,12	720	1020	45	90
95	Zilt	Dinner-pub			1,00	0,12	720	1020	45	90
96	De Bakkerswinkel	Dinner-pub			1,00	0,12	720	1020	45	90
97	Rodizio Braziliaans Grill Restaurant	Dinner-pub			1,00	0,12	720	1020	45	90
98	Casablanca	Dinner-pub			1,00	0,12	720	1020	45	90
99	The Queen's Head	Dinner-pub			1,00	0,12	720	1020	45	90

100	De Engel Next Door	Dinner-pub			1,00	0,12	720	1020	45	90
101	De Engel Van Amsterdam	Dinner-pub			1,00	0,12	720	1020	45	90
102	De Barderij	Dinner-pub			1,00	0,12	720	1020	45	90
103	De Roode Baron	Dinner-pub			1,00	0,12	720	1020	45	90
104	Het Elfde Gebod	Dinner-pub			1,00	0,12	720	1020	45	90
105	In 'T Aepjen	Dinner-pub			1,00	0,12	720	1020	45	90
106	The Globe	Dinner-pub			1,00	0,12	720	1020	45	90
107	Corso	Dinner-pub			1,00	0,12	720	1020	45	90
108	Bananenbar	Dinner-pub			1,00	0,12	720	1020	45	90
109	Butterfly Thai Cafe	Dinner-pub			1,00	0,12	720	1020	45	90
110	Van Wijs	Dinner-pub			1,00	0,12	720	1020	45	90
111	Majestic	Dinner-pub			1,00	0,12	720	1020	45	90
112	Bierfabriek	Dinner-pub			1,00	0,12	720	1020	45	90
113	Lunch & Diner	Dinner-pub			1,00	0,12	720	1020	45	90
114	Queen	Dinner-pub			1,00	0,12	720	1020	45	90
115	Schreijertoren / Voc-Café	Dinner-pub			1,00	0,12	720	1020	45	90
116	Il Girasole	Dinner-pub			1,00	0,12	720	1020	45	90
117	Old Dutch Pancakes	Dinner-pub			1,00	0,12	720	1020	45	90
118	Lunchcafe Studio 2	Dinner-pub			1,00	0,12	720	1020	45	90
119	Frenzi	Dinner-pub			1,00	0,12	720	1020	45	90
120	Puccini	Dinner-pub			1,00	0,12	720	1020	45	90
121	Tisfris	Dinner-pub			1,00	0,12	720	1020	45	90
122	De Engelbewaarder	Dinner-pub			1,00	0,12	720	1020	45	90
123	Stopera	Dinner-pub			1,00	0,12	720	1020	45	90
124	San Diego	Dinner-pub			1,00	0,12	720	1020	45	90
125	De Staalmeesters	Dinner-pub			1,00	0,12	720	1020	45	90
126	De Gaeper	Dinner-pub			1,00	0,12	720	1020	45	90
127	De Doelen	Dinner-pub			1,00	0,12	720	1020	45	90
128	Van Beeren	Dinner-pub			1,00	0,12	720	1020	45	90
129	Captein & Co	Dinner-pub			1,00	0,12	720	1020	45	90
130	Frontline	Dinner-pub			1,00	0,12	720	1020	45	90
131	Katoen	Dinner-pub			1,00	0,12	720	1020	45	90
132	De Jaren	Dinner-pub			1,00	0,12	720	1020	45	90
133	Crea	Dinner-pub			1,00	0,12	720	1020	45	90
134	De Pool	Dinner-pub			1,00	0,12	720	1020	45	90
135	The Tara	Dinner-pub			1,00	0,12	720	1020	45	90
136	De Dam	Dinner-pub			1,00	0,12	720	1020	45	90
137	Esprit	Dinner-pub			1,00	0,12	720	1020	45	90

138	Tropico Cafe / Bar	Dinner-pub			1,00	0,12	720	1020	45	90
139	Club Nl	Dinner-pub			1,00	0,12	960	1140	45	150
140	Lieverdje	Dinner-pub			1,00	0,12	720	1020	45	90
141	Dansen Bij Jansen	Dinner-pub			1,00	0,12	960	1140	45	150
142	Bar 020	Dinner-pub			1,00	0,12	720	1020	45	90
143	Havelaar	Dinner-pub			1,00	0,12	720	1020	45	90
144	Tokyo	Dinner-pub			1,00	0,12	720	1020	45	90
145	The Pool Hole	Dinner-pub			1,00	0,12	720	1020	45	90
146	Nota Bene	Dinner-pub			1,00	0,12	720	1020	45	90
147	Eetcafe Carels Iii	Dinner-pub			1,00	0,12	720	1020	45	90
148	Schutter	Dinner-pub			1,00	0,12	720	1020	45	90
149	Pakhuis	Dinner-pub			1,00	0,12	720	1020	45	90
150	Club Miami	Dinner-pub			1,00	0,12	960	1140	45	150
151	Gollem	Dinner-pub			1,00	0,12	720	1020	45	90
152	Luden	Dinner-pub			1,00	0,12	720	1020	45	90
153	De Zwart	Dinner-pub			1,00	0,12	720	1020	45	90
154	Hoppe	Dinner-pub			1,00	0,12	720	1020	45	90
155	Café	Dinner-pub			1,00	0,12	720	1020	45	90
156	Luxembourg	Dinner-pub			1,00	0,12	720	1020	45	90
157	De Brabantse Aap	Dinner-pub			1,00	0,12	720	1020	45	90
158	Cafe Lange Leo	Dinner-pub			1,00	0,12	720	1020	45	90
159	T Spui-Tje	Dinner-pub			1,00	0,12	720	1020	45	90
160	Haesje Claes	Dinner-pub			1,00	0,12	720	1020	45	90
161	De Koningshut	Dinner-pub			1,00	0,12	720	1020	45	90
162	Antikraak	Dinner-pub			1,00	0,12	720	1020	45	90
163	Cafe Van Daele	Dinner-pub			1,00	0,12	720	1020	45	90
164	Scheltema	Dinner-pub			1,00	0,12	720	1020	45	90
165	Beer Temple	Dinner-pub			1,00	0,12	720	1020	45	90
166	Diep	Dinner-pub			1,00	0,12	720	1020	45	90
167	Speijk	Dinner-pub			1,00	0,12	720	1020	45	90
168	Le Petit Latin	Dinner-pub			1,00	0,12	720	1020	45	90
169	The Minds	Dinner-pub			1,00	0,12	720	1020	45	90
170	T Schuim	Dinner-pub			1,00	0,12	720	1020	45	90
171	Corner House	Dinner-pub			1,00	0,12	720	1020	45	90
172	St Pauls	Dinner-pub			1,00	0,12	720	1020	45	90
173	Cote Ouest	Dinner-pub			1,00	0,12	720	1020	45	90
174	De Drie Fleschjes	Dinner-pub			1,00	0,12	720	1020	45	90
175	Belgique	Dinner-pub			1,00	0,12	720	1020	45	90
176	Tetra	Dinner-pub			1,00	0,12	720	1020	45	90
177	Bordo	Dinner-pub			1,00	0,12	720	1020	45	90
178	De Vergulde Lantaarn	Dinner-pub			1,00	0,12	720	1020	45	90

179	Dominus	Dinner-pub			1,00	0,12	720	1020	45	90
180	Five Bells	Dinner-pub			1,00	0,12	720	1020	45	90
181	Akhnaton	Dinner-pub			1,00	0,12	960	1140	45	150
182	Delta	Dinner-pub			1,00	0,12	720	1020	45	90
183	Nieuwe Kafe	Dinner-pub			1,00	0,12	720	1020	45	90
184	Villa Zeezicht	Dinner-pub			1,00	0,12	720	1020	45	90
185	Van Zuylen	Dinner-pub			1,00	0,12	720	1020	45	90
186	Sluisje	Dinner-pub			1,00	0,12	720	1020	45	90
187	De baronnes	Dinner-pub			1,00	0,12	720	1020	45	90
188	Barista	Dinner-pub			1,00	0,12	720	1020	45	90
189	De Spaanse Ruiter	Dinner-pub			1,00	0,12	720	1020	45	90
190	Die Port Van Cleve	Dinner-pub			1,00	0,12	720	1020	45	90
191	Prik	Dinner-pub			1,00	0,12	720	1020	45	90
192	Istanbul	Dinner-pub			1,00	0,12	720	1020	45	90
193	Willie's The Flying Dutchman	Dinner-pub			1,00	0,12	720	1020	45	90
194	Crepe Bar	Dinner-pub			1,00	0,12	720	1020	45	90
195	Haarlemsch Koffiehuis	Dinner-pub			1,00	0,12	720	1020	45	90
196	Victoria	Dinner-pub			1,00	0,12	720	1020	45	90
197	Teasers	Dinner-pub			1,00	0,12	720	1020	45	90
198	Van Beeren	Dinner-pub			1,00	0,12	720	1020	45	90
199	San Stefano	Dinner-pub			1,00	0,12	720	1020	45	90
200	Mooy	Dinner-pub			1,00	0,12	720	1020	45	90
201	Koepelcafé	Dinner-pub			1,00	0,12	720	1020	45	90
202	Van Speyk	Dinner-pub			1,00	0,12	720	1020	45	90
203	Tio Pepe	Dinner-pub			1,00	0,12	720	1020	45	90
204	London Bridge	Dinner-pub			1,00	0,12	720	1020	45	90
205	Goudvisclub	Dinner-pub			1,00	0,12	720	1020	45	90
206	Koggeschip De Wilde Man	Dinner-pub			1,00	0,12	720	1020	45	90
207	Josélito	Dinner-pub			1,00	0,12	720	1020	45	90
208	Wonderbar	Dinner-pub			1,00	0,12	720	1020	45	90
209	De Karpershoek	Dinner-pub			1,00	0,12	720	1020	45	90
210	Alfa	Dinner-pub			1,00	0,12	720	1020	45	90
211	Cafe De Waal De Ster	Dinner-pub			1,00	0,12	720	1020	45	90
212	English Breakfast	Dinner-pub			1,00	0,12	720	1020	45	90
213	Blarny Stone	Dinner-pub			1,00	0,12	720	1020	45	90
214	Lost In Amsterdam Lounge Cafe	Dinner-pub			1,00	0,12	720	1020	45	90
215	De Bekeerde Suster	Dinner-pub			1,00	0,12	720	1020	45	90
216	Temple Bar	Dinner-pub			1,00	0,12	720	1020	45	90
217	De Molen	Dinner-pub			1,00	0,12	720	1020	45	90

218	Yip Fellows	Dinner-pub			1,00	0,12	720	1020	45	90
219	Euro Pub	Dinner-pub			1,00	0,12	720	1020	45	90
220	Winston	Dinner-pub			1,00	0,12	960	1140	45	150
221	Belushis	Dinner-pub			1,00	0,12	720	1020	45	90
222	Durty Nelly	Dinner-pub			1,00	0,12	720	1020	45	90
223	Argos	Dinner-pub			1,00	0,12	720	1020	45	90
224	Stones	Dinner-pub			1,00	0,12	720	1020	45	90
225	Slainte	Dinner-pub			1,00	0,12	720	1020	45	90
226	The Tribe	Dinner-pub			1,00	0,12	720	1020	45	90
227	Ziggy's	Dinner-pub			1,00	0,12	720	1020	45	90
228	The Warehouse	Dinner-pub			1,00	0,12	960	1140	45	150
229	Big Shots	Dinner-pub			1,00	0,12	720	1020	45	90
230	The Eagle Bar	Dinner-pub			1,00	0,12	720	1020	45	90
231	Dirty Dicks	Dinner-pub			1,00	0,12	720	1020	45	90
232	Hot Or Not	Dinner-pub			1,00	0,12	720	1020	45	90
233	Drink 'N Sink	Dinner-pub			1,00	0,12	720	1020	45	90
234	Hill Street Blues	Dinner-pub			1,00	0,12	720	1020	45	90
235	Old Quarter	Dinner-pub			1,00	0,12	720	1020	45	90
236	In De Olofspoort	Dinner-pub			1,00	0,12	720	1020	45	90
237	Buster's	Dinner-pub			1,00	0,12	720	1020	45	90
238	Internationaal	Dinner-pub			1,00	0,12	720	1020	45	90
239	Hunters	Dinner-pub			1,00	0,12	720	1020	45	90
240	Getto Food & Drinks	Dinner-pub			1,00	0,12	720	1020	45	90
241	Het Paleis	Dinner-pub			1,00	0,12	720	1020	45	90
242	Amstelhoeck	Dinner-pub			1,00	0,12	720	1020	45	90
243	Dante	Dinner-pub			1,00	0,12	720	1020	45	90
244	Greendayz	Dinner-pub			1,00	0,12	720	1020	45	90
245	In De Wildeman	Dinner-pub			1,00	0,12	720	1020	45	90
246	Proeflokaal Wijnand Fockinck	Dinner-pub			1,00	0,12	720	1020	45	90
247	Grand Cafe Mint	Dinner-pub			1,00	0,12	720	1020	45	90
248	Museum Cafe	Dinner-pub			1,00	0,12	720	1020	45	90
249	Cuckoos Nest	Dinner-pub			1,00	0,12	720	1020	45	90
250	Players Cafe	Dinner-pub			1,00	0,12	720	1020	45	90
251	Bvb	Dinner-pub			1,00	0,12	720	1020	45	90
252	Bitterzoet	Dinner-pub			1,00	0,12	960	1140	45	150
253	Meatballs	Dinner-pub			1,00	0,12	720	1020	45	90
254	The Lobby	Dinner-pub			1,00	0,12	720	1020	45	90
255	Van Rijn	Dinner-pub			1,00	0,12	720	1020	45	90
256	Il Momento	Dinner-pub			1,00	0,12	720	1020	45	90
257	The Sopranos Pianobar	Dinner-pub			1,00	0,12	720	1020	45	90
258	Greenwoods	Dinner-pub			1,00	0,12	720	1020	45	90
259	Feijoa	Dinner-pub			1,00	0,12	720	1020	45	90

260	Jantjes Verjaardag	Dinner-pub			1,00	0,12	960	1140	45	150
261	Nasty	Dinner-pub			1,00	0,12	720	1020	45	90
262	Coco's Outback	Dinner-pub			1,00	0,12	720	1020	45	90
263	Cinema Club & Cafe	Dinner-pub			1,00	0,12	960	1140	45	150
264	Coco's Mine	Dinner-pub			1,00	0,12	720	1020	45	90
265	Woody's	Dinner-pub			1,00	0,12	720	1020	45	90
266	Santorini Greek Taverna	Dinner-pub			1,00	0,12	720	1020	45	90
267	Cesco Slovenski Bar	Dinner-pub			1,00	0,12	720	1020	45	90
268	Los	Dinner-pub			1,00	0,12	720	1020	45	90
269	Entre Nous	Dinner-pub			1,00	0,12	720	1020	45	90
270	Crazy	Dinner-pub			1,00	0,12	720	1020	45	90
271	Amstel Fifty Four	Dinner-pub			1,00	0,12	720	1020	45	90
272	Chez Rene	Dinner-pub			1,00	0,12	720	1020	45	90
273	Bar Regular & Jack	Dinner-pub			1,00	0,12	720	1020	45	90
274	Otten	Dinner-pub			1,00	0,12	720	1020	45	90
275	Centrum	Dinner-pub			1,00	0,12	720	1020	45	90
276	Bolle Jan	Dinner-pub			1,00	0,12	720	1020	45	90
277	Café	Dinner-pub			1,00	0,12	720	1020	45	90
278	Peter Beense	Dinner-pub			1,00	0,12	720	1020	45	90
279	Knalle Bij Rich!	Dinner-pub			1,00	0,12	720	1020	45	90
280	Reality	Dinner-pub			1,00	0,12	720	1020	45	90
281	T Luifeltje	Dinner-pub			1,00	0,12	720	1020	45	90
282	La Madonnina	Dinner-pub			1,00	0,12	720	1020	45	90
283	Irish Pub	Dinner-pub			1,00	0,12	720	1020	45	90
284	Frame	Dinner-pub			1,00	0,12	720	1020	45	90
285	Dwarsliggertje	Dinner-pub			1,00	0,12	720	1020	45	90
286	De Duivel	Dinner-pub			1,00	0,12	720	1020	45	90
287	Ludwig Ii	Dinner-pub			1,00	0,12	720	1020	45	90
288	Casa Maria	Dinner-pub			1,00	0,12	720	1020	45	90
289	The Other Club	Dinner-pub			1,00	0,12	720	1020	45	90
290	Prime	Dinner-pub			1,00	0,12	960	1140	45	150
291	Club Smokey	Dinner-pub			1,00	0,12	960	1140	45	150
292	La Bastille	Dinner-pub			1,00	0,12	720	1020	45	90
293	De Heeren Van Aemstel	Dinner-pub			1,00	0,12	960	1140	45	150
294	Oue	Dinner-pub			1,00	0,12	720	1020	45	90
295	Leegstand	Dinner-pub			1,00	0,12	720	1020	45	90
296	Lellebel	Dinner-pub			1,00	0,12	720	1020	45	90
297	The Old Bell	Dinner-pub			1,00	0,12	720	1020	45	90
298	Rain	Dinner-pub			1,00	0,12	960	1140	45	150
299	Lange Reis	Dinner-pub			1,00	0,12	720	1020	45	90
300	Leegstand	Dinner-pub			1,00	0,12	720	1020	45	90

301	Barkode	Dinner-pub			1,00	0,12	960	1140	45	150
302	Roque	Dinner-pub			1,00	0,12	960	1140	45	150
303	The Music Box	Dinner-pub			1,00	0,12	720	1020	45	90
304	Vive La Vie	Dinner-pub			1,00	0,12	720	1020	45	90
305	L'opera	Dinner-pub			1,00	0,12	720	1020	45	90
306	Three Sisters	Dinner-pub			1,00	0,12	720	1020	45	90
307	De Kroon	Dinner-pub			1,00	0,12	720	1020	45	90
308	Caffe	Dinner-pub			1,00	0,12	720	1020	45	90
309	Escape	Dinner-pub			1,00	0,12	960	1140	45	150
310	Monico	Dinner-pub			1,00	0,12	720	1020	45	90
311	Tante Roosje	Dinner-pub			1,00	0,12	720	1020	45	90
312	Rembrandt	Dinner-pub			1,00	0,12	720	1020	45	90
313	Montmarte	Dinner-pub			1,00	0,12	720	1020	45	90
314	Mulligans	Dinner-pub			1,00	0,12	720	1020	45	90
315	Hot Spot	Dinner-pub			1,00	0,12	720	1020	45	90
316	Van Leeuwen	Dinner-pub			1,00	0,12	720	1020	45	90
317	Vooges	Dinner-pub			1,00	0,12	720	1020	45	90
318	Brug 34	Dinner-pub			1,00	0,12	720	1020	45	90
319	Staceys Pennywell	Dinner-pub			1,00	0,12	720	1020	45	90
320	Coffee & Jazz	Dinner-pub			1,00	0,12	720	1020	45	90
321	Bouwman	Dinner-pub			1,00	0,12	720	1020	45	90
322	Krom	Dinner-pub			1,00	0,12	720	1020	45	90
323	Kapitein Zeppos	Dinner-pub			1,00	0,12	720	1020	45	90
324	Harkema	Dinner-pub			1,00	0,12	720	1020	45	90
325	Gasthuys	Dinner-pub			1,00	0,12	720	1020	45	90
326	De Buurvrouw	Dinner-pub			1,00	0,12	720	1020	45	90
327	Van Kerkwijk	Dinner-pub			1,00	0,12	720	1020	45	90
328	Bubles And Wines	Dinner-pub			1,00	0,12	720	1020	45	90
329	Nes Café	Dinner-pub			1,00	0,12	720	1020	45	90
330	De Brakke Grond	Dinner-pub			1,00	0,12	720	1020	45	90
331	Supperclub	Dinner-pub			1,00	0,12	960	1140	45	150
332	Club Stereo	Dinner-pub			1,00	0,12	960	1140	45	150
333	Soho	Dinner-pub			1,00	0,12	720	1020	45	90
334	Club Nyx	Dinner-pub			1,00	0,12	960	1140	45	150
335	Dwars	Dinner-pub			1,00	0,12	720	1020	45	90
336	Morlang	Dinner-pub			1,00	0,12	720	1020	45	90
337	Walem	Dinner-pub			1,00	0,12	720	1020	45	90
338	De Pels	Dinner-pub			1,00	0,12	720	1020	45	90
339	Herengracht	Dinner-pub			1,00	0,12	720	1020	45	90
340	Odeon	Dinner-pub			1,00	0,12	960	1140	45	150
341	Brandon	Dinner-pub			1,00	0,12	720	1020	45	90
342	Da Portare Via	Dinner-pub			1,00	0,12	720	1020	45	90
343	Arendsnest	Dinner-pub			1,00	0,12	720	1020	45	90

344	Cafe Cake	Dinner-pub			1,00	0,12	720	1020	45	90
345	De Admiraal	Dinner-pub			1,00	0,12	720	1020	45	90
346	Wheels	Dinner-pub			1,00	0,12	720	1020	45	90
347	Bar 22	Dinner-pub			1,00	0,12	720	1020	45	90
348	Schumich	Dinner-pub			1,00	0,12	720	1020	45	90
349	Kobalt	Dinner-pub			1,00	0,12	720	1020	45	90
350	The Bottle	Dinner-pub			1,00	0,12	720	1020	45	90
351	Porto	Dinner-pub			1,00	0,12	720	1020	45	90
352	Kandinsky	Dinner-pub			1,00	0,12	720	1020	45	90
353	De Raedt	Dinner-pub			1,00	0,12	720	1020	45	90
354	Singel	Dinner-pub			1,00	0,12	720	1020	45	90
355	Greenwood's	Dinner-pub			1,00	0,12	720	1020	45	90
356	Il Panorama	Dinner-pub			1,00	0,12	720	1020	45	90
357	Molentje	Dinner-pub			1,00	0,12	720	1020	45	90
358	Red Amsterdam	Dinner-pub			1,00	0,12	720	1020	45	90
359	The Web	Dinner-pub			1,00	0,12	720	1020	45	90
360	Il Pacioccone	Dinner-pub			1,00	0,12	720	1020	45	90
361	Zwart	Dinner-pub			1,00	0,12	720	1020	45	90
362	Het Pleidooi	Dinner-pub			1,00	0,12	720	1020	45	90
363	De Deugniet	Dinner-pub			1,00	0,12	720	1020	45	90
364	Grasshopper	Dinner-pub			1,00	0,12	720	1020	45	90
365	Backstage	Dinner-pub			1,00	0,12	720	1020	45	90
366	Wonder Bar Two	Dinner-pub			1,00	0,12	720	1020	45	90
367	Aan 'T Water	Dinner-pub			1,00	0,12	720	1020	45	90
368	De Haven Van Texel	Dinner-pub			1,00	0,12	720	1020	45	90
369	The End	Dinner-pub			1,00	0,12	720	1020	45	90
370	Ktv Bar	Dinner-pub			1,00	0,12	720	1020	45	90
371	De Hartjes	Dinner-pub			1,00	0,12	720	1020	45	90
372	Molly Malones	Dinner-pub			1,00	0,12	720	1020	45	90
373	Cooldown	Dinner-pub			1,00	0,12	720	1020	45	90
374	Sushi Me	Dinner-pub			1,00	0,12	720	1020	45	90
375	Leegstand	Dinner-pub			1,00	0,12	720	1020	45	90
376	Van Harte	Dinner-pub			1,00	0,12	720	1020	45	90
377	Tomaz	Dinner-pub			1,00	0,12	720	1020	45	90
378	De Dokter	Dinner-pub			1,00	0,12	720	1020	45	90
379	Bubbels	Dinner-pub			1,00	0,12	960	1140	45	150
380	Cooldown Café	Dinner-pub			1,00	0,12	960	1140	45	150
381	Brasserie Flo	Dinner-pub			1,00	0,12	720	1020	45	90
382	Rouge	Dinner-pub			1,00	0,12	720	1020	45	90
383	Leegstand	Dinner-pub			1,00	0,12	720	1020	45	90
384	Wine Cellar	Dinner-pub			1,00	0,12	720	1020	45	90
385	De Pilsener Club	Dinner-pub			1,00	0,12	720	1020	45	90
386	Taboo	Dinner-pub			1,00	0,12	720	1020	45	90

387	Proeflokaal Brouwerij De Parel	Dinner-pub			1,00	0,12	720	1020	45	90
388	Bar Italia	Dinner-pub			1,00	0,12	720	1020	45	90
389	Meuwese Espresso	Dinner-pub			1,00	0,12	720	1020	45	90
390	Heffer	Dinner-pub			1,00	0,12	720	1020	45	90
391	Icebar	Dinner-pub			1,00	0,12	720	1020	45	90
392	Ome Joop	Dinner-pub			1,00	0,12	720	1020	45	90
393	Red Star	Dinner-pub			1,00	0,12	720	1020	45	90
394	La Vie Deux	Dinner-pub			1,00	0,12	720	1020	45	90
395	Frascati Cafe	Dinner-pub			1,00	0,12	720	1020	45	90
396	Club Air	Dinner-pub			1,00	0,12	960	1140	45	150
397	Wijnsalon De Apotheek	Dinner-pub			1,00	0,12	720	1020	45	90
398	In De Buurt	Dinner-pub			1,00	0,12	720	1020	45	90
399	East Dok Cafe	Dinner-pub			1,00	0,12	720	1020	45	90
400	Lobby Bar	Dinner-pub			1,00	0,12	720	1020	45	90
401	City Cafe	Dinner-pub			1,00	0,12	720	1020	45	90
402	Samhoud Place	Dinner-pub			1,00	0,12	720	1020	45	90
403	Moes	Dinner-pub			1,00	0,12	720	1020	45	90
404	Old Nickel	Dinner-pub			1,00	0,12	720	1020	45	90
405	Sapori Traiteur	Dinner-pub			1,00	0,12	720	1020	45	90
406	Lunchroom T	Dinner-pub			1,00	0,12	720	1020	45	90
407	Café Caprice	Dinner-pub			1,00	0,12	720	1020	45	90
408	El Rincon	Dinner-pub			1,00	0,12	720	1020	45	90
409	De Myrabelle	Dinner-pub			1,00	0,12	720	1020	45	90
410	De Wetering	Dinner-pub			1,00	0,12	720	1020	45	90
411	Buffet Van Odette	Dinner-pub			1,00	0,12	720	1020	45	90
412	Heuvel	Dinner-pub			1,00	0,12	720	1020	45	90
413	Le Patron	Dinner-pub			1,00	0,12	720	1020	45	90
414	De Smoeshaan	Dinner-pub			1,00	0,12	720	1020	45	90
415	Kale	Dinner-pub			1,00	0,12	720	1020	45	90
416	Brecht	Dinner-pub			1,00	0,12	720	1020	45	90
417	Mankind	Dinner-pub			1,00	0,12	720	1020	45	90
418	Mulder	Dinner-pub			1,00	0,12	720	1020	45	90
419	De Fles	Dinner-pub			1,00	0,12	720	1020	45	90
420	Schiller	Dinner-pub			1,00	0,12	720	1020	45	90
421	De Biecht	Dinner-pub			1,00	0,12	720	1020	45	90
422	Marcella	Dinner-pub			1,00	0,12	720	1020	45	90
423	Nel	Dinner-pub			1,00	0,12	720	1020	45	90
424	De Duif	Dinner-pub			1,00	0,12	960	1140	45	150
425	Oosterling	Dinner-pub			1,00	0,12	720	1020	45	90
426	Cuban Cigars	Dinner-pub			1,00	0,12	720	1020	45	90
427	Onder De Ooievaar	Dinner-pub			1,00	0,12	720	1020	45	90

428	Cafe De Huyschkaemer	Dinner-pub			1,00	0,12	720	1020	45	90
429	Aguada	Dinner-pub			1,00	0,12	720	1020	45	90
430	De Magere Brug	Dinner-pub			1,00	0,12	720	1020	45	90
431	Eik En Linde	Dinner-pub			1,00	0,12	720	1020	45	90
432	Smit & Voogt	Dinner-pub			1,00	0,12	720	1020	45	90
433	Cafe Koosje	Dinner-pub			1,00	0,12	720	1020	45	90
434	Meneer Nilson	Dinner-pub			1,00	0,12	720	1020	45	90
435	Plancius	Dinner-pub			1,00	0,12	720	1020	45	90
436	Hps	Dinner-pub			1,00	0,12	720	1020	45	90
437	Cafe Waterlooplein	Dinner-pub			1,00	0,12	720	1020	45	90
438	De Druif	Dinner-pub			1,00	0,12	720	1020	45	90
439	Cafe Angels	Dinner-pub			1,00	0,12	720	1020	45	90
440	Hooischip	Dinner-pub			1,00	0,12	720	1020	45	90
441	Blauwbrug Taveerne	Dinner-pub			1,00	0,12	720	1020	45	90
442	Rembrandt Corner	Dinner-pub			1,00	0,12	720	1020	45	90
443	Waterloo	Dinner-pub			1,00	0,12	720	1020	45	90
444	Pollux	Dinner-pub			1,00	0,12	720	1020	45	90
445	Museumcafe	Dinner-pub			1,00	0,12	720	1020	45	90
446	Chupitus	Dinner-pub			1,00	0,12	720	1020	45	90
447	Hard Rock Café	Dinner-pub			1,00	0,12	720	1020	45	90
448	Aran Irish Pub	Dinner-pub			1,00	0,12	720	1020	45	90
449	De Zotte	Dinner-pub			1,00	0,12	720	1020	45	90
450	Leegstand	Dinner-pub			1,00	0,12	720	1020	45	90
451	Gespot	Dinner-pub			1,00	0,12	720	1020	45	90
452	Pieper	Dinner-pub			1,00	0,12	720	1020	45	90
453	George	Dinner-pub			1,00	0,12	720	1020	45	90
454	De Eland	Dinner-pub			1,00	0,12	720	1020	45	90
455	De Laurierboom	Dinner-pub			1,00	0,12	720	1020	45	90
456	Palladium	Dinner-pub			1,00	0,12	720	1020	45	90
457	De Kring Club Up	Dinner-pub			1,00	0,12	960	1140	45	150
458	Blinq	Dinner-pub			1,00	0,12	720	1020	45	90
459	De Heineken Hoek	Dinner-pub			1,00	0,12	720	1020	45	90
460	Sportscafe	Dinner-pub			1,00	0,12	720	1020	45	90
461	Amsterdamned	Dinner-pub			1,00	0,12	720	1020	45	90
462	Van Dyck Bar	Dinner-pub			1,00	0,12	960	1140	45	90
463	Kop Van Jut	Dinner-pub			1,00	0,12	720	1020	45	90
464	Milano	Dinner-pub			1,00	0,12	720	1020	45	90
465	De Spiegel	Dinner-pub			1,00	0,12	720	1020	45	90
466	Bar Saloon	Dinner-pub			1,00	0,12	720	1020	45	90
467	Mulliners	Dinner-pub			1,00	0,12	720	1020	45	90
468	No 129	Dinner-pub			1,00	0,12	720	1020	45	90

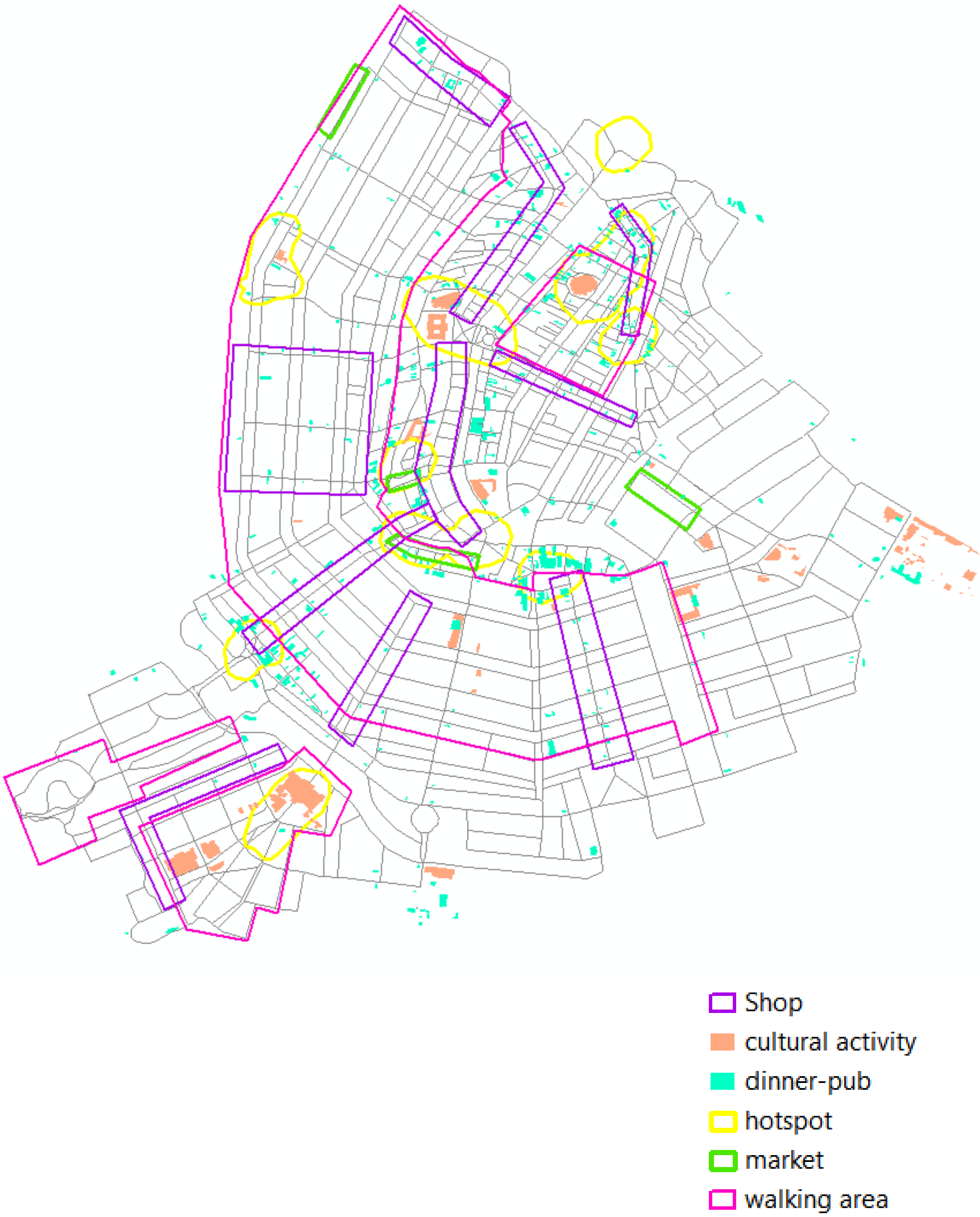
469	De Gieter	Dinner-pub			1,00	0,12	720	1020	45	90
470	Punto Latino	Dinner-pub			1,00	0,12	960	1140	45	150
471	Mango's	Dinner-pub			1,00	0,12	960	1140	45	150
472	Bo Cinq	Dinner-pub			1,00	0,12	720	1020	45	90
473	De Spuyt	Dinner-pub			1,00	0,12	720	1020	45	90
474	L&B Whiskycafe	Dinner-pub			1,00	0,12	720	1020	45	90
475	Hartje	Dinner-pub			1,00	0,12	960	1140	45	150
476	Maxim	Dinner-pub			1,00	0,12	720	1020	45	90
477	Surprise	Dinner-pub			1,00	0,12	720	1020	45	90
478	Alto	Dinner-pub			1,00	0,12	720	1020	45	90
479	N Joy!	Dinner-pub			1,00	0,12	960	1140	45	90
480	Club Candala	Dinner-pub			1,00	0,12	720	1020	45	90
481	The News	Dinner-pub			1,00	0,12	960	1140	45	150
482	The Cave	Dinner-pub			1,00	0,12	960	1140	45	150
483	Bourbon Streat	Dinner-pub			1,00	0,12	720	1020	45	90
484	Cafe 19	Dinner-pub			1,00	0,12	720	1020	45	90
485	Cafe De Krul	Dinner-pub			1,00	0,12	720	1020	45	90
486	Cooldown	Dinner-pub			1,00	0,12	960	1140	45	150
487	Verbouwing	Dinner-pub			1,00	0,12	720	1020	45	90
488	Stoop & Stoop	Dinner-pub			1,00	0,12	720	1020	45	90
489	Dan Murphys	Dinner-pub			1,00	0,12	720	1020	45	90
490	Lumina	Dinner-pub			1,00	0,12	720	1020	45	90
491	Mokum	Dinner-pub			1,00	0,12	720	1020	45	90
492	Kooper	Dinner-pub			1,00	0,12	720	1020	45	90
493	De Waard	Dinner-pub			1,00	0,12	720	1020	45	90
494	Bamboo	Dinner-pub			1,00	0,12	720	1020	45	90
495	Brasilian Bar	Dinner-pub			1,00	0,12	960	1140	45	150
496	Le Pub	Dinner-pub			1,00	0,12	720	1020	45	90
497	Hoopman	Dinner-pub			1,00	0,12	720	1020	45	90
498	Reynders	Dinner-pub			1,00	0,12	720	1020	45	90
499	Hole In The Wall	Dinner-pub			1,00	0,12	720	1020	45	90
500	Maurya Indian Lounge	Dinner-pub			1,00	0,12	720	1020	45	90
501	Jimmy Woo	Dinner-pub			1,00	0,12	960	1140	45	150
502	Eylders	Dinner-pub			1,00	0,12	720	1020	45	90
503	Biblos	Dinner-pub			1,00	0,12	720	1020	45	90
504	Mp	Dinner-pub			1,00	0,12	720	1020	45	90
505	Lust	Dinner-pub			1,00	0,12	720	1020	45	90
506	De Spijker	Dinner-pub			1,00	0,12	720	1020	45	90
507	Leegstand	Dinner-pub			1,00	0,12	960	1140	45	150
508	De Oude Wester	Dinner-pub			1,00	0,12	720	1020	45	90
509	De Westertoren	Dinner-pub			1,00	0,12	720	1020	45	90
510	De Twee Zwaantjes	Dinner-pub			1,00	0,12	720	1020	45	90
511	De Prins	Dinner-pub			1,00	0,12	720	1020	45	90

512	Roem	Dinner-pub			1,00	0,12	720	1020	45	90
513	Smalle	Dinner-pub			1,00	0,12	720	1020	45	90
514	Het Bruine Paard	Dinner-pub			1,00	0,12	720	1020	45	90
515	Het Papeneiland	Dinner-pub			1,00	0,12	720	1020	45	90
516	Tabac	Dinner-pub			1,00	0,12	720	1020	45	90
517	De Vergulde Gaper	Dinner-pub			1,00	0,12	720	1020	45	90
518	De Klepel	Dinner-pub			1,00	0,12	720	1020	45	90
519	Het Kalfje	Dinner-pub			1,00	0,12	720	1020	45	90
520	De Ii Prinsen	Dinner-pub			1,00	0,12	720	1020	45	90
521	Spanjer En Van Twist	Dinner-pub			1,00	0,12	720	1020	45	90
522	Van Puffelen - Paris Brest	Dinner-pub			1,00	0,12	720	1020	45	90
523	De Hoek	Dinner-pub			1,00	0,12	720	1020	45	90
524	De Doffer	Dinner-pub			1,00	0,12	720	1020	45	90
525	Stout	Dinner-pub			1,00	0,12	720	1020	45	90
526	Harlem	Dinner-pub			1,00	0,12	720	1020	45	90
527	De Blauwe Druif	Dinner-pub			1,00	0,12	720	1020	45	90
528	Barney's	Dinner-pub			1,00	0,12	720	1020	45	90
529	Lof	Dinner-pub			1,00	0,12	720	1020	45	90
530	Barneys	Dinner-pub			1,00	0,12	720	1020	45	90
531	Du Lac	Dinner-pub			1,00	0,12	720	1020	45	90
532	De Catacombe	Dinner-pub			1,00	0,12	960	1140	45	150
533	Kalkhoven	Dinner-pub			1,00	0,12	720	1020	45	90
534	Nieuwe Werck	Dinner-pub			1,00	0,12	720	1020	45	90
535	Sara's Lounge	Dinner-pub			1,00	0,12	720	1020	45	90
536	Los Pilones	Dinner-pub			1,00	0,12	720	1020	45	90
537	59	Dinner-pub			1,00	0,12	720	1020	45	90
538	De Klos	Dinner-pub			1,00	0,12	720	1020	45	90
539	Genootschap Der Geneugten	Dinner-pub			1,00	0,12	720	1020	45	90
540	Sneeker Pan	Dinner-pub			1,00	0,12	720	1020	45	90
541	The Final Touch	Dinner-pub			1,00	0,12	720	1020	45	90
542	Church	Dinner-pub			1,00	0,12	960	1140	45	150
543	Best	Dinner-pub			1,00	0,12	960	1140	45	150
544	Tapvreugd	Dinner-pub			1,00	0,12	720	1020	45	90
545	Dwaze Zaken	Dinner-pub			1,00	0,12	720	1020	45	90
546	Kroonprins	Dinner-pub			1,00	0,12	720	1020	45	90
547	De Groote Swaen	Dinner-pub			1,00	0,12	720	1020	45	90
548	Cafe Batavia 1920	Dinner-pub			1,00	0,12	720	1020	45	90
549	De Zeepost	Dinner-pub			1,00	0,12	720	1020	45	90
550	Guadalupe Mexican Restaurant	Dinner-pub			1,00	0,12	720	1020	45	90

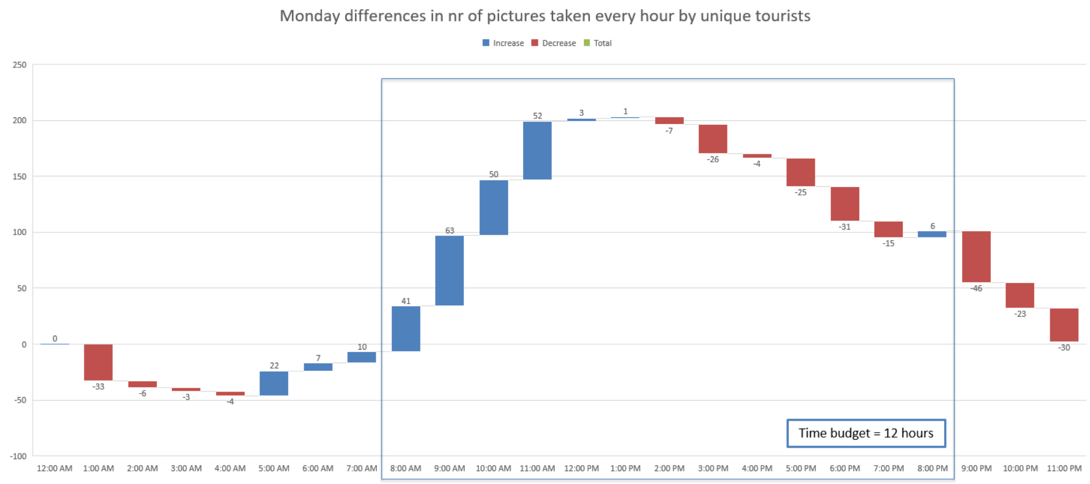
551	Weber	Dinner-pub			1,00	0,12	720	1020	45	90
552	401	Dinner-pub			1,00	0,12	720	1020	45	90
553	Lux 403	Dinner-pub			1,00	0,12	720	1020	45	90
554	Sugar Factory	Dinner-pub			1,00	0,12	960	1140	45	150
555	Sluyswacht	Dinner-pub			1,00	0,12	720	1020	45	90
556	Smit's	Dinner-pub			1,00	0,12	720	1020	45	90
557	West Indisch Huis	Dinner-pub			1,00	0,12	960	1140	45	150
558	De Pizzabakkers	Dinner-pub			1,00	0,12	720	1020	45	90
559	Artis	Dinner-pub			1,00	0,12	960	1140	45	150
560	Eeterij De Piste	Dinner-pub			1,00	0,12	720	1020	45	90
561	Waterhole	Dinner-pub			1,00	0,12	720	1020	45	90
562	P. 96	Dinner-pub			1,00	0,12	720	1020	45	90
563	Orff Bar Cafe	Dinner-pub			1,00	0,12	720	1020	45	90
564	De Balie Cafe	Dinner-pub			1,00	0,12	720	1020	45	90
565	De Krater	Dinner-pub			1,00	0,12	720	1020	45	90
566	London	Dinner-pub			1,00	0,12	720	1020	45	90
567	Players	Dinner-pub			1,00	0,12	720	1020	45	90
568	Ibiza Club	Dinner-pub			1,00	0,12	960	1140	45	150
569	Feest Van Joop	Dinner-pub			1,00	0,12	960	1140	45	150
570	Tuinhuis Aan De Gracht	Dinner-pub			1,00	0,12	960	1140	45	150
571	G. Harkema	Dinner-pub			1,00	0,12	720	1020	45	90
572	La Bastille	Dinner-pub			1,00	0,12	720	1020	45	90
573	Club Up	Dinner-pub			1,00	0,12	960	1140	45	150
574	Lumina	Dinner-pub			1,00	0,12	720	1020	45	90
575	Belushi's	Dinner-pub			1,00	0,12	720	1020	45	90
576	Verbouwing	Dinner-pub			1,00	0,12	720	1020	45	90
577	Leegstand	Dinner-pub			1,00	0,12	720	1020	45	90
578	Pompa	Dinner-pub			1,00	0,12	720	1020	45	90
579	Cobra	Dinner-pub			1,00	0,12	720	1020	45	90
580	Sama Sebo	Dinner-pub			1,00	0,12	720	1020	45	90
581	Concertgebou wcafe	Dinner-pub			1,00	0,12	720	1020	45	90
582	Welling	Dinner-pub			1,00	0,12	720	1020	45	90
583	Leegstand	Dinner-pub			1,00	0,12	720	1020	45	90
584	Taverna Barcelona	Dinner-pub			1,00	0,12	720	1020	45	90
585	Berkhout	Dinner-pub			1,00	0,12	720	1020	45	90
586	Barca	Dinner-pub			1,00	0,12	720	1020	45	90
587	Vrienden	Dinner-pub			1,00	0,12	720	1020	45	90
588	O-Donnell's	Dinner-pub			1,00	0,12	720	1020	45	90
589	Simpel	Dinner-pub			1,00	0,12	720	1020	45	90
590	Cafe De Kroeg	Dinner-pub			1,00	0,12	720	1020	45	90
591	Pijp	Dinner-pub			1,00	0,12	720	1020	45	90
592	Kingfisher	Dinner-pub			1,00	0,12	720	1020	45	90

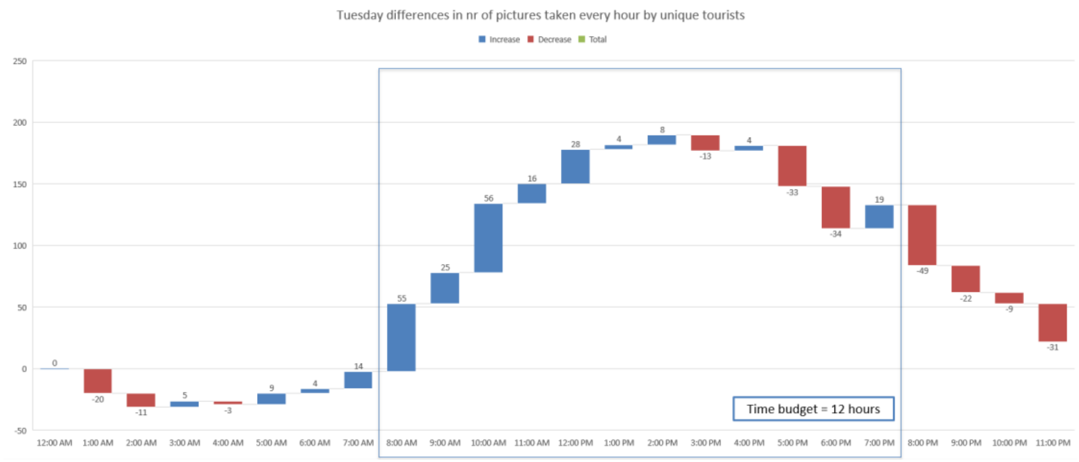
593	Nina	Dinner-pub			1,00	0,12	720	1020	45	90
594	Van Hoeck	Dinner-pub			1,00	0,12	720	1020	45	90
595	Marie	Dinner-pub			1,00	0,12	720	1020	45	90
596	Het Blauwe Theehuis	Dinner-pub			1,00	0,12	720	1020	45	90
597	Momo	Dinner-pub			1,00	0,12	720	1020	45	90
598	L'ozio	Dinner-pub			1,00	0,12	720	1020	45	90
599	Wiener	Dinner-pub			1,00	0,12	720	1020	45	90
600	Museumrestaurant Hermitage	Dinner-pub			1,00	0,12	720	1020	45	90
601	De Bazel Conference Centre	Dinner-pub			1,00	0,12	960	1140	45	150
602	Savoy	Dinner-pub			1,00	0,12	960	1140	45	150
603	Pc Hoofstraat, Van Baerlestraat	Shop	Number of shops / m of street		0,30	0,13	240	720	30	150
604	Utrechtsestraat	Shop	Number of shops / m of street		0,30	0,13	240	720	30	150
605	Leidsestraat en Heiligeweg	Shop	Number of shops / m of street		0,76	0,13	240	720	30	150
606	Spiegelgracht	Shop	Number of shops / m of street		0,19	0,13	240	720	30	150
607	Kalverstraat	Shop	Number of shops / m of street		0,78	0,13	240	720	30	150
608	Nieuwendijk	Shop	Number of shops / m of street		0,60	0,13	240	720	30	150
609	Haarlemmerstraat	Shop	Number of shops / m of street		0,34	0,13	240	720	30	150
610	Oudedoelenstraat Oude-nieuwehoogstraat Damstraat	Shop	Number of shops / m of street		0,47	0,13	240	720	30	150
611	Zeedijk	Shop	Number of shops / m of street		0,17	0,13	240	720	30	150
612	9 straatjes	Shop	Number of shops / m of street		0,74	0,13	240	720	30	150
613	Canal Belt	Walking area	Indicative online research - number of times they are announce on websites	5	1,00	0,23	0	0	30	45
614	De Wallen	Walking area	Indicative online research - number of	3	0,60	0,23	0	0	30	45

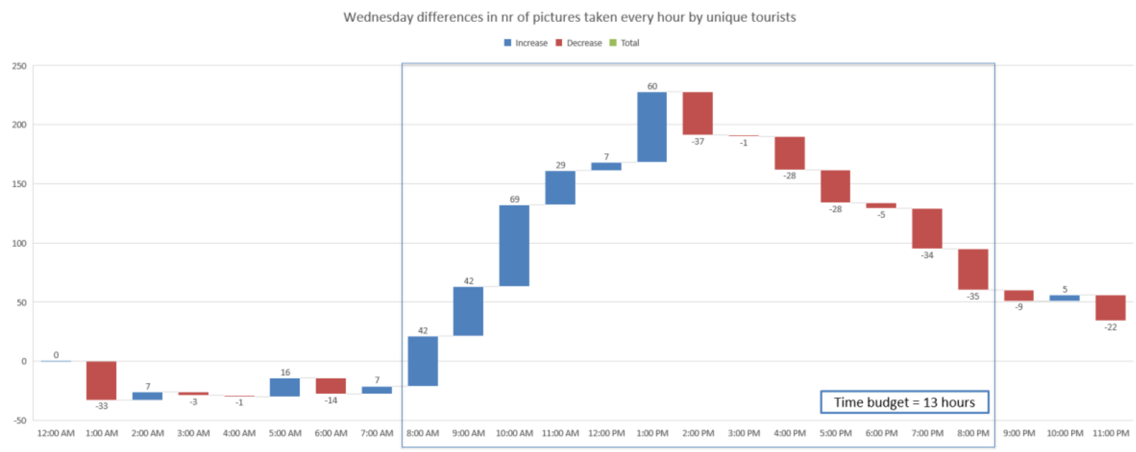
			times they are announce on websites							
615	Vondelpark	Walking area	Indicative online research - number of times they are announce on websites	4	0,80	0,23	0	1020	30	45
616	Museumplein	Walking area	Indicative online research - number of times they are announce on websites	2	0,40	0,23	0	0	30	45

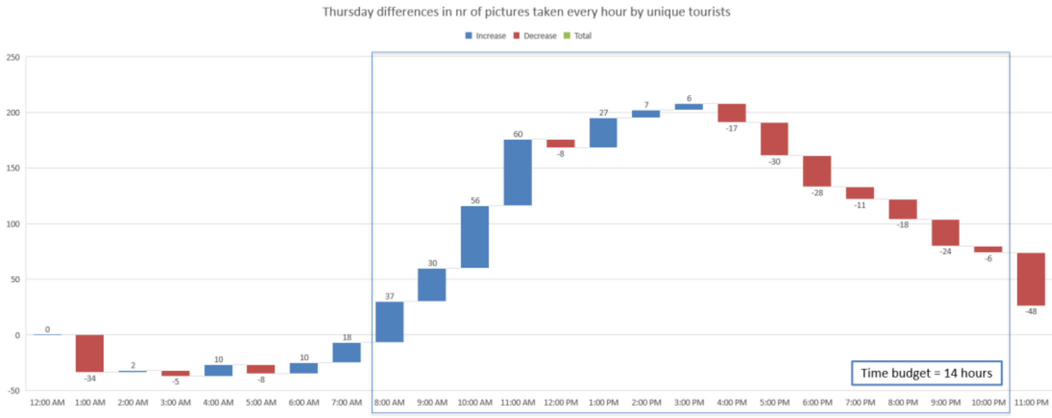

Shop
cultural activity
dinner-pub
hotspot
market
walking area

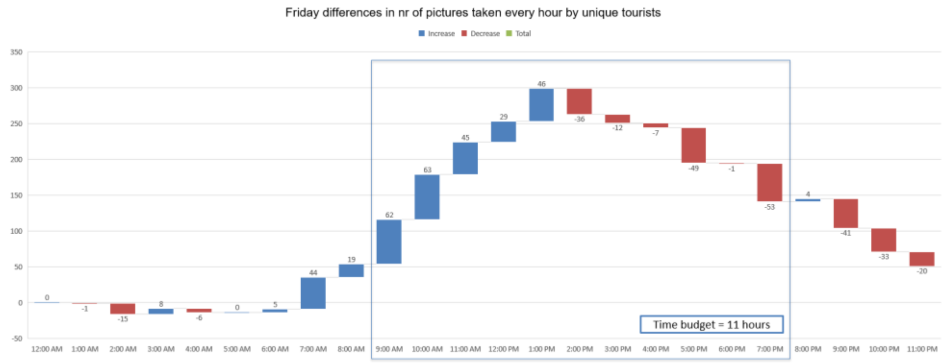
Appendix V – Time of leaving the hotel and time budget

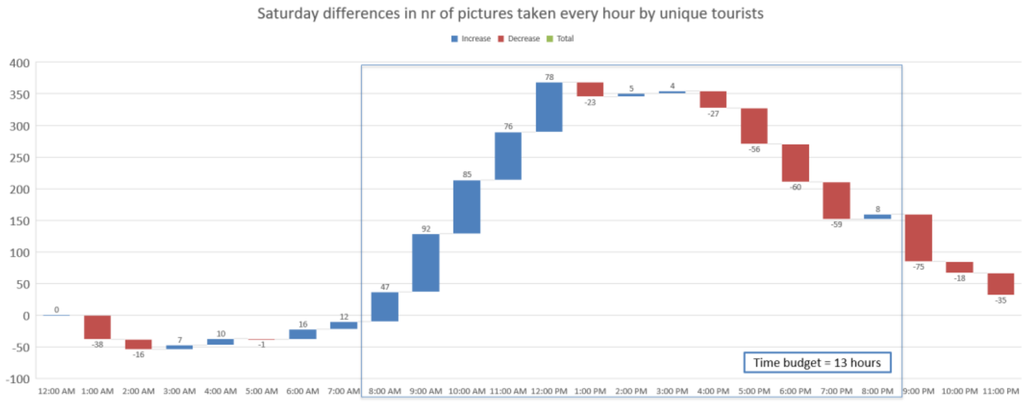


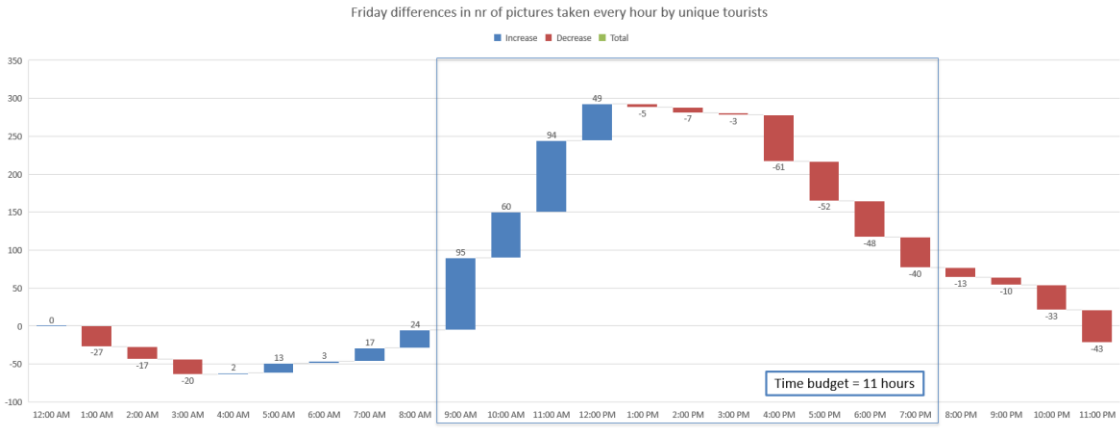





Thursday differences in nr of pictures taken every hour by unique tourists
Increase
Decrease
Total
Time budget = 14 hours


Friday differences in nr of pictures taken every hour by unique tourists
Increase
Decrease
Total
Time budget = 11 hours


Saturday differences in nr of pictures taken every hour by unique tourists
Increase
Decrease
Total
Time budget = 13 hours



This Table is made from the graphics presented in the appendix.

Day	Time of starting activity	Time of decreasing activity	Duration
Monday	8:00	21:00	13
Tuesday	8:00	20:00	12
Wednesday	8:00	21:00	13
Thursday	8:00	22:00	14
Friday	9:00	20:00	11
Saturday	8:00	21:00	13
Sunday	9:00	20:00	11

Appendix VI – ODD protocol

This section follows the section 3.5 Model description in Chapter 3. The Overview of the model is explained in that section. To complete the model description the design concepts and details are here explained:

Design concepts:

i. Basic principles

The basic principle of the model is that tourists travel from activity to activity along their daily journey until their time budget is over, at that moment, they will go back to their hotels. An activity-based model is implemented that determines in which activities tourist will engage at due to spatio-temporal constraints, such as traveling distances or opening times. Tourists will select an activity type based on preferences. Afterwards, tourists will pick one attraction within the previously selected activity type based on the attractions attractiveness scores.

ii. Emergence and observation

At the global level, the following values are monitored: The streets that each tourist passes along his daily journey (1), the number of times a street is passed (2), The number of visitors that each destination gets (3), the destinations that a single tourist visits along his daily journey (4). (1) and (4) are obtained at the end of the simulation. (2) and (3) are collected every 30 steps (30 minutes) so that the evolution in time can be analysed. Regarding emergence, the increasing number of visits in each destination and the number of passes of each street is considered as an emergent phenomenon.

iii. Adaptation

Adaption is not explicitly implemented in the model. Tourists adapt in the way of excluding the already visited destinations or excluding destinations are already closed or will be closed by the time of arriving.

iv. Objectives

The objective of each tourist is visit as many destinations as possible given their time budget. Their objective is also not repeating an already visited destination.

v. Learning

Learning is not part of the model.

vi. Prediction

Predicting is not part of the model as the purpose of it is to understand the current situation and identify factors that affect the movement of tourists.

vii. Interaction

There is not interaction between tourists are the moment. Tourists only interact with the destination specie.

viii. Stochasticity

Stochasticity is present in several model processes. Tourists are assigned a "time budget" and "time of leaving the hotel" based on Gauss distributions. They are randomly assigned with a walking speed between 0.7 and 1.3 m/s. Probability in included when selecting an activity type and it is also included when selecting the target destination. Last, the staying time in each activity is assigned every time the tourist enters the destination. It is randomly assigned between a minimum and a maximum value established per activity type.

ix. Collectives

There is only one tourist collective represented in the model.

Details:

i. Initialization

The simulation starts at 6:00. When the simulation starts, tourists are created in each hotel proportionally to the number of beds in that hotel. Tourists are assigned with a "time of leaving the hotel" and a "time budget" variable that follows a gauss distribution. When the value of "time of leaving the hotel" equalizes the current simulation time, tourist leave the hotel and the main modeled process starts, the main modeled process is selecting a destination to be visited. The initialization of the destinations consists of uploading the destination characteristics such as type, attractiveness scores and opening times from the shape files.

ii. Input data

The spatial input data used to model the environment is: (1) the street network, (2) the tourist destinations, (3) the hotels.
The initial parameters are shown by specie:
Tourist: hotel, time of leaving the hotel, time budget and speed
Hotel: number of beds
Destination: name, type, opening time, closing time, attractiveness score, minimum staying time and maximum staying time.
The preferences for activity types are defined in the global section of the model.

iii. Sub-models

There are not sub-models in the simulation

Appendix VII – Number of runs and number of agents

	2% (500 agents)						10% (3200 agents)					
Run	**Visits Dam square**	**%**	**Visits Rijksmuseum**	**%**	**Visits De Wallen**	**%**	**Visits Dam square**	**%**	**Visits Rijksmuseum**	**%**	**Visits De Wallen**	**%**
I	242	49	60	12	250	50	1575	51	380	12	1537	50
II	255	51	71	14	256	52	1586	52	389	13	1523	49
III	266	54	59	12	256	52	1555	51	380	12	1528	50
IV	253	51	57	11	243	49	1574	51	403	13	1511	49
V	243	49	51	10	246	50	1516	49	409	13	1571	51
VI	251	51	72	15	238	48	1544	50	395	13	1576	51
VII	256	52	62	13	260	52	1521	49	373	12	1486	48
VIII	246	50	62	13	249	50	1587	52	368	12	1499	49
IX	259	52	55	11	266	54	1568	51	373	12	1528	50
X	252	51	69	14	250	50	1521	49	401	13	1495	49
XI	241	49	55	11	237	48						
XII	240	48	60	12	229	46						
XIII	269	54	61	12	256	52						
XIV	231	47	66	13	233	47						
XV	266	54	66	13	251	51						
XVI	246	50	71	14	247	50						
XVII	257	52	54	11	237	48						
XVIII	273	55	67	14	250	50						
XIX	249	50	66	13	244	49						
XX	245	49	60	12	248	50						

Coefficient of Variation of the variable "number of Visits"

		2% (500 agents)						10% (3200 agents)					
Runs		**Visits Dam square**	**%**	**Visits Rijksmuseum**	**%**	**Visits De Wallen**	**%**	**Visits Dam square**	**%**	**Visits Rijksmuseum**	**%**	**Visits De Wallen**	**%**
5	**Mean**	251,80	50,77	59,60	12,02	250,20	50,44	1561,20	50,70	392,20	12,74	1534,00	49,82
	ST	9,83	1,98	7,27	1,46	5,85	1,18	27,62	0,90	13,29	0,43	22,72	0,74
	CV	**0,04**	**0,04**	**0,12**	**0,12**	**0,02**	**0,02**	**0,02**	**0,02**	**0,03**	**0,03**	**0,01**	**0,01**
10	**Mean**	252,30	50,87	61,80	12,46	251,40	50,69	1554,70	50,49	387,10	12,57	1525,40	49,54
	SD	7,36	1,48	6,97	1,41	8,29	1,67	27,62	0,90	14,36	0,47	30,14	0,98
	CV	**0,03**	**0,03**	**0,11**	**0,11**	**0,03**	**0,03**	**0,02**	**0,02**	**0,04**	**0,04**	**0,02**	**0,02**
15	**Mean**	251,33	50,67	61,73	12,45	248,00	50,00						
	SD	10,93	2,20	6,11	1,23	10,40	2,10						
	CV	**0,04**	**0,04**	**0,10**	**0,10**	**0,04**	**0,04**						
20	**Mean**	252,00	50,81	62,20	12,54	247,30	49,86						
	SD	10,86	2,34	6,48	1,31	10,18	2,05						
	CV	**0,04**	**0,05**	**0,10**	**0,10**	**0,04**	**0,04**						

Standard deviation **ST**

Coefficient of Variation **CV**