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Transport and Telecommunication, 2024, volume 25, no. 4, 370-377
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia
DOI 10.2478/ttj-2024-0027

A MODULAR SIMULATION TESTBED FOR LOGISTICS AND URBAN PLANNING IN TOURISM

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This paper introduces a modular simulation testbed developed for decision support in logistics and urban planning within the tourism sector, specifically applied to Şanlıurfa, Turkey, as part of the GeostaloVR project. The testbed integrates tourism value chains, urban development processes, and mobility flows to facilitate scenario testing and evaluation. By incorporating real-world data, the simulation framework enables the analysis of key performance indicators for sustainable urban tourism development. This approach aims to advance the application of modeling techniques to address complex challenges in urban tourism in order to provide valuable insights for stakeholders involved in urban and logistics planning.

Keywords: Urban planning, tourism value chain analysis, tourism development, modular simulation testbed

1. Introduction

In recent times, due to the escalating phenomenon of global warming, research attention has increasingly shifted towards the promotion of sustainability across various domains (Bungău *et al*., 2024). It is notably apparent that there is a pressing need for collaborative efforts directed towards fostering environmentally-conscious advancements within our societal framework (Omar *et al.*, 2024). Moreover, there has been a notable increase in urban population in recent years, presenting a challenging task for urban planners and researchers involved in the field of transportation planning to formulate decisions and enhance the infrastructure in alignment with current requirements (Banister, 2000). Tourism is a sector in which urban planning and mobility planning have a significant influence on revenue generation and tourism development (Xie, 2023). Consequently, there is a growing interest among researchers from various disciplines in optimizing the logistics process, enhancing touristic destinations, managing tourist flow, and improving mobility flow to foster sustainable tourism development in urban areas.

To accomplish the aforementioned objectives, we have formulated an interdisciplinary research project in collaboration with two research institutions and three industry partners from Turkey and Germany. We named this project "Geodesign for Urban and Logistics Planning in the Tourism Sector with VR Visualization" (GeostaloVR). The objective of this research project is to develop a simulation-based geodesign platform for planning logistics, mobility flows, and tourism for Şanlıurfa city in Turkey. Additionally, with the help of VR visualization, we aim to provide a human-centered digital planning process and interactions for evaluating different scenarios in urban and tourism planning. Figure 1 represents the concept of the GeostaloVR project.

As part of this international collaborative research project, we (Otto von Guericke University Magdeburg), as a research partner, are responsible for the development of the simulation testbed for urban, tourism, logistics, and mobility flow planning in the city of Şanlıurfa. We aim to build two simulation models: a microscopic simulation testbed for logistics and urban planning and a traffic simulation to optimize traffic congestion. In this paper, we present the microscopic simulation model as a testbed to observe the logistics and urban planning processes in the context of tourism development. Furthermore, to develop this simulation testbed, we first conducted a comprehensive tourism value chain analysis to identify the typical processes, activities, and components that contribute to sustainable tourism development, culminating in a framework for tourism value creation.

We chose Şanlıurfa as our operational area for the simulation testbed. Additionally, we received the required input data such as operational area boundaries, tourist flow, delivery vehicles, tourist destinations, and infrastructure data (hotels, supermarkets, bus stops, etc.), and modal split from our research partner, Harran University, Turkey.

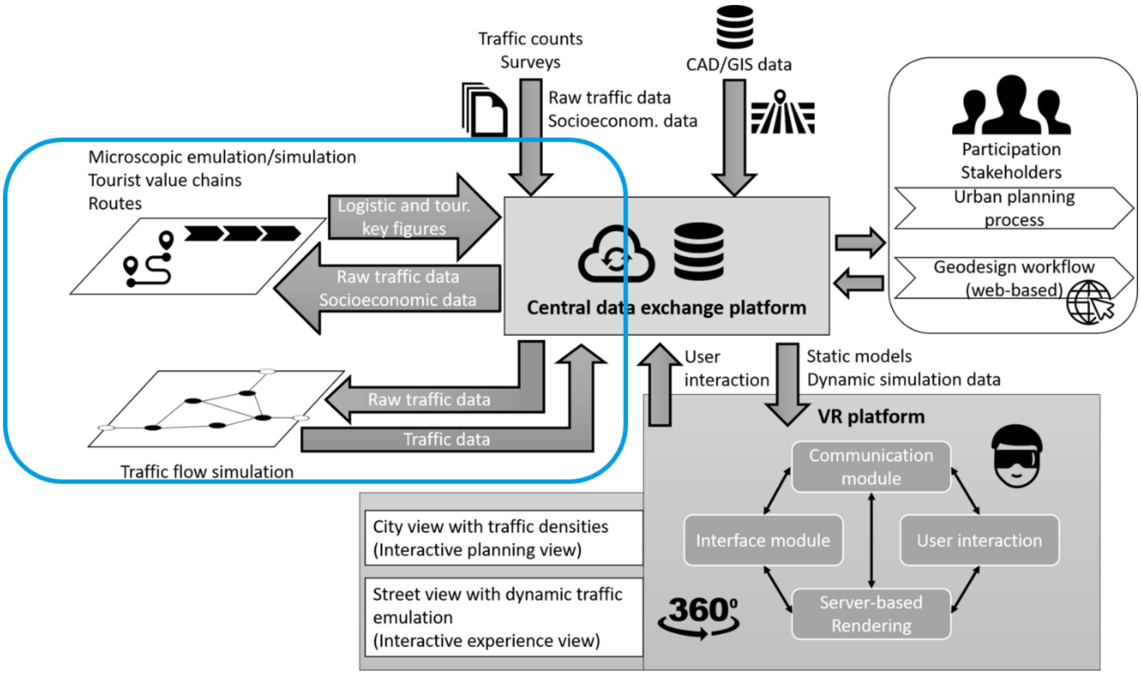

Figure 1. Concept of GeostaloVR project

The remainder of this paper is structured as follows. In Section 2, we present the literature review on tourism value chain analysis, urban planning processes, and simulation modelling in the context of tourism and urban planning. Section 3 describes the conceptual framework of tourism value chain creation and the conceptual model for the modular simulation testbed. Section 4 provides a detailed description of the development of the simulation testbed and key performance indicators to evaluate the planning processes. Section 5 concludes with a summary of the paper and future work.

2. Literature Study

Simulation modelling is a pivotal and recognized tool for improving decision-making processes in urban planning and tourism. The integration of simulation models with urban planning and tourism value chains can provide valuable insights for sustainable development and efficient resource management. In this section, we present a short literature study on tourism value chain analysis and simulation modelling in the context of tourism and urban planning.

2.1. Tourism Value Chain Analysis and Urban Planning

(Fuchs and Höpken, 2005) address the issue of dealing with insufficient information and data for decision making and decision support techniques in tourism. Data Envelopment Analysis (DEA) synthesizes the entire procedure of converting destination inputs into intricate tourism outcomes that encompass customer satisfaction with the diverse value-chain activities in a comprehensive manner.

The handbook (Partale, 2020) provides detailed analysis and practical approaches for the development of tourism and other supporting industries through the creation and management of tourism value chains. (Yılmaz and Bititci, 2006) designed a model for measuring value chain performance in the tourism sector. This research provides a process flow between the activities that measure the efficiency of tourism products and services in the value chain. (Miličević, 2021) described the tourism value chain system with the main activities in the tourism industry. This study shows how different actors in the value chain generate revenue from the tourism supply chain. (Tajzadeh-Namin, 2012) presented a systematic study on value creation in the tourism industry and the important activities to promote the tourism sector.

(Boivin and Tanguay, 2019) presented a case study on how the attractiveness of urban tourism contributes to the development of the tourism sector in Quebec City and Bordeaux, both UNESCO World Heritage Sites. In addition, a survey was conducted with a statistical comparative analysis of the two cities to investigate tourists' perceptions.

(Liu, 2022) conducted theoretical research to identify ambiguities in the context of the value chain literature. It summarizes the spatiality of the tourism value chain by focusing on spatial stickiness and the experiential value of tourism resources to reduce ambiguities and enhance understanding of value creation and distribution in the tourism industry.

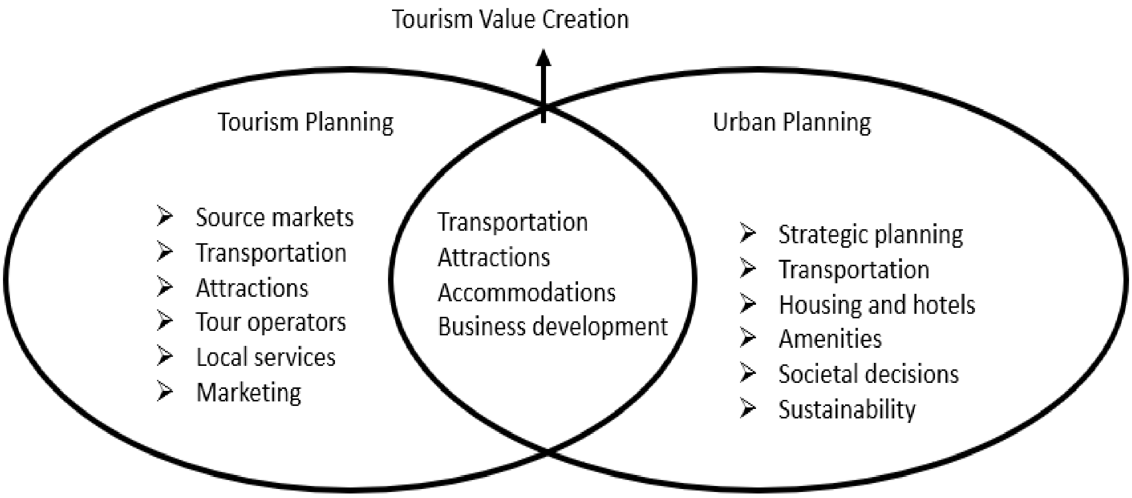

Figure 2. Tourism Value Creation

Analysing the value chain for tourism and urban planning requires a comprehensive understanding of the key components and activities that drive the development and sustainability of these sectors. Figure 2 shows the key elements of tourism value creation from tourism and urban planning processes, inspired from (Sutomo *et al.*, 2023). The tourism value chain for urban planning is dynamic and requires continuous collaboration between different actors. These actors include government agencies, private sector companies, local communities, and tourism organizations. Effective management and coordination of these components can contribute to the creation of sustainable and vibrant urban tourism destinations.

2.2. Simulation Modelling in Tourism and Urban planning

In tourism planning, agent-based simulations combined with Geographic Information Systems (GIS) are increasingly used to support the design and development of tourism services and policies. These simulations help tourism bureaus and policymakers assess different scenarios and improve tourism services by understanding interactions between tourists and Recreational Business Districts (RBDs) (Chao *et al.*, 2011a) (Chao *et al.*, 2011b).

Additionally, GIS has been widely adopted for its powerful spatial data handling capabilities, and the development of Geographical Simulation Systems (GSS) further enhances these capabilities by integrating cellular automata and multi-agent systems. This integration allows for the simulation, prediction, and optimization of complex human-environment interactions, aiding in solving land use problems and facilitating urban planning (Li *et al.*, 2006). Ultimately, these studies collectively highlight the benefits of GIS and multi-agent-systems in enhancing the functionality and utility of simulation models.

3. Conceptual Framework for Simulation Model

Based on the tourism value chain analysis in the previous section, we developed a conceptual framework for the simulation testbed (see Figure 3). In this framework, various components involved in tourism and urban planning are represented as a layered architecture. The components of the simulation testbed are defined by their functionality. Each component is developed as a stand-alone module, designed for easy adaptability to changes and future extensions.

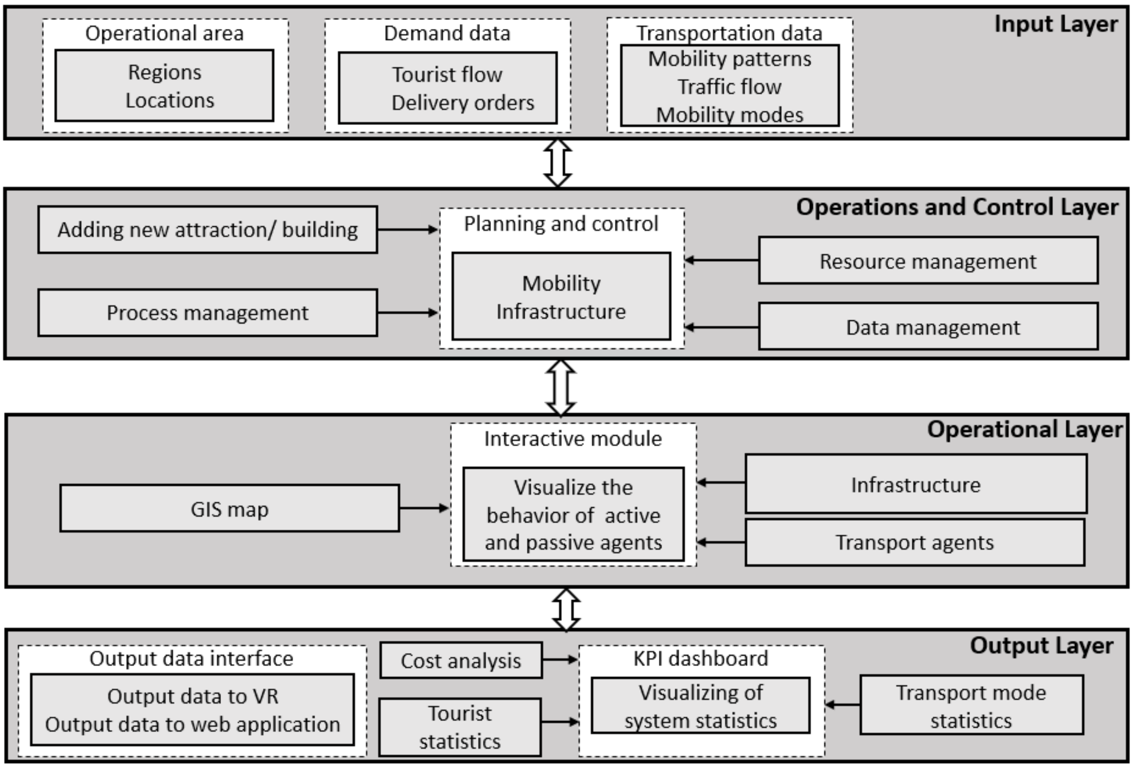

Figure 3. Conceptual framework for simulation model

Input Layer:

The input layer acts as an intuitive interface for integrating required data such as tourists flow, locations of hotels, touristic attractions, delivery depots, zonal data, mobility patterns and transport data, which are stored in a database and called upon on simulation start.

Operations and Control Layer:

This layer contains modules responsible for the dynamic allocation of agents - such as tourists - to accommodations and destinations on initialization of the scenario. It is responsible for transportation planning and obtaining statistics from other modules.

Operational Layer:

This layer is associated with visual representation of the dynamic and static infrastructural components of the planning such as the operational area (in our case, Şanlıurfa city), buildings and attractions and visualizing the movement of tourists and transportation entities.

Output Layer:

The output layer aggregates overall statistics and key performance indicators (KPIs) after a simulation run and displays them to the user via the dashboard. Additionally, the output data interface module is responsible for sharing the simulation's output data with the VR application and the Web application.

4. Implementation of Simulation Testbed

4.1. Software Tools

Simulation modelling is used to study real-world scenarios in a virtual environment. It helps in planning the most complex processes, which involve significant costs.

Within the scope of this paper, we opted for the AnyLogic tool to develop the modular simulation testbed due to the requirement of building stand-alone models to evaluate different scenarios in the course of tourism and urban planning. Moreover, AnyLogic provides custom interfaces, multi-method modelling, custom user interfaces, GIS map integration within the tool, and the integration of custom libraries to realize the behaviour of the components in the decision support system model. In order to provide flexibility and dynamic planning, we designed the testbed to be modular in nature. The behaviour of each component of the system is developed as a separate module to integrate new features without affecting the behaviour of entire model.

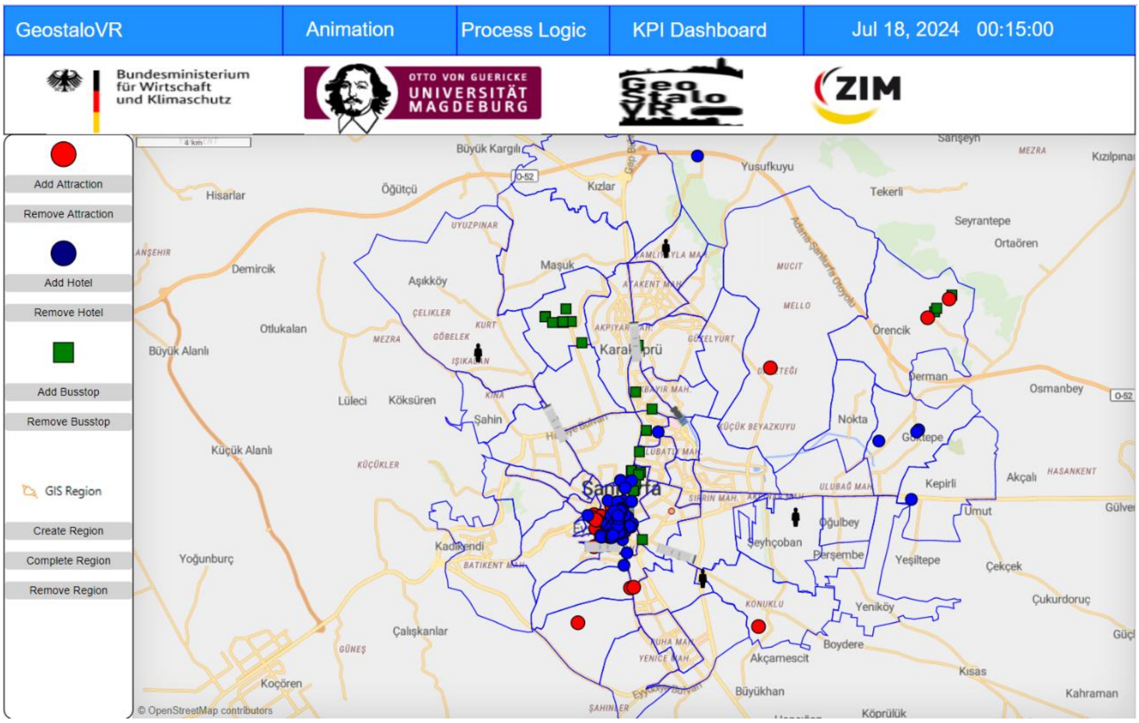

Figure 4. Simulation testbed animation window with GIS map

4.2. Input Data for Simulation Testbed

Throughout the project, the input data requirements for the simulation model were identified and collected with the assistance of external research partners from Şanlıurfa. The data necessary for implementing the decision support system for tourism and urban planning in the simulation testbed includes operational areas with regions, attractions, accommodations, and logistics-specific infrastructure in the form of a GIS coordinate system in an Excel file. In addition, we have collected seasonal tourist flow data for an average week in summer, winter, spring, and fall, as well as data on delivery traffic at accommodations, mobility between accommodations, and tourist locations.

4.3. Model Components and their Interaction

We have developed a dynamic agent-based simulation model to represent real-world entities such as tourists, hotels, buses, trucks, tourist attractions, and bus stops, which interact with one another to simulate the system's behaviour. The operational area (Şanlıurfa, Turkey) and the components of the model are visualized in the animation window (see Figure 4). Each model component is represented as an agent, as depicted in Figure 5. The output data from the simulation model are stored in our database on the OVGU server.

Simulation Input Data Interface:

Input data is retrieved from the OVGU database via the input data interface, which includes tourist flow, attraction locations, hotel locations, bus stop locations, schedules, delivery data, and regional data. The interactive GIS map visualizes these entities at their respective locations and allows for adding or removing attractions and hotels, as well as creating or removing regions during runtime.

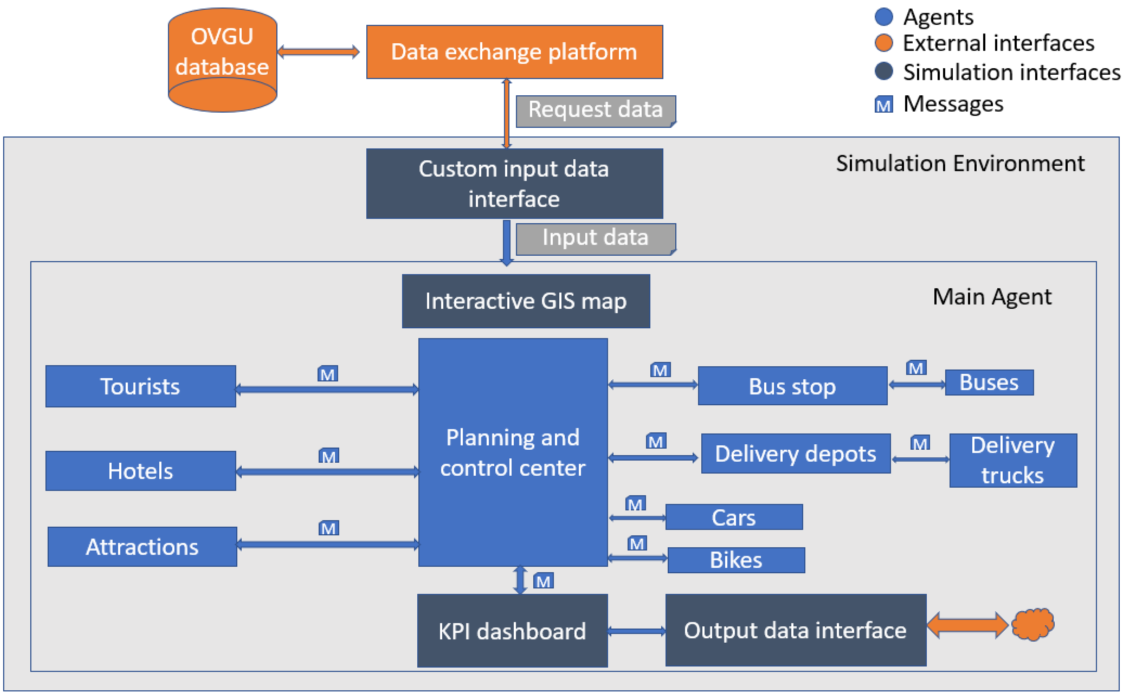

Figure 5. Agents interaction in the simulation model

Main Agent:

The main agent serves as the primary communication hub for other agents, including tourists, hotels, attractions, the planning and control center, bus stops, and vehicles, interfacing with the interactive GIS map. The main agent's functions—CreateRegions, CreateAttractions, and CreateHotels—initiate agents at the start of the simulation and update them during runtime.

Planning and Control Center:

This agent is responsible for exchanging messages and collecting necessary data from the other agents, using the data to generate statistics for all agents. The collected data is visualized in charts and graphs on the KPI dashboard. The output data interface exports simulation results to the OVGU database, making them accessible for other GeostaloVR project applications.

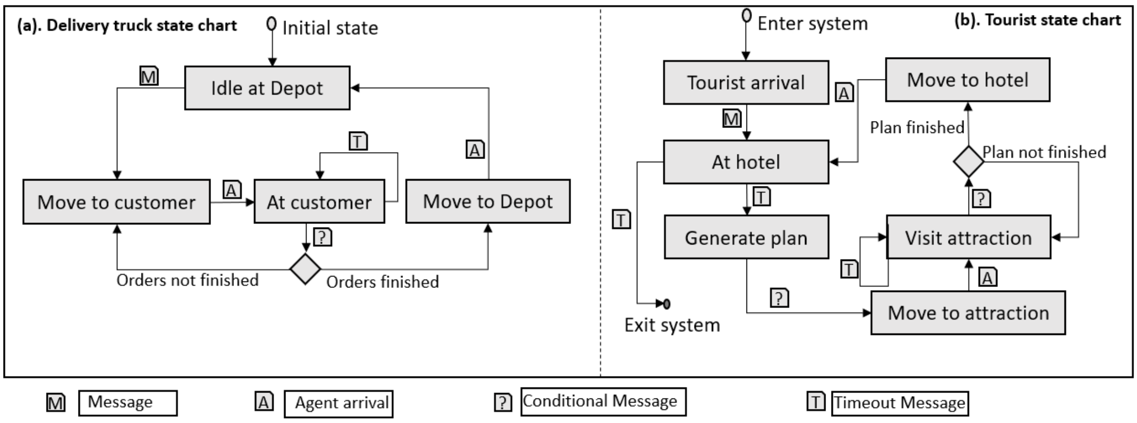

Figure 6. State charts of delivery truck agent and tourist agent

Dynamic Agents:

Dynamic agents include movable entities such as tourists, buses, delivery trucks, cars, and bikes. Their behaviour is modelled using state charts, and they interact with other agents through messaging, replicating real-world dynamics. Figure 6 (a) represents the simplified state chart of delivery truck agent and Figure 6 (b) illustrates the basic behaviour of the tourist in the system.

Static Agents:

Static agents, including bus stops, attractions, hotels, and delivery depots, are non-movable entities. They interact through messages and variables, reflecting changes in the state of other agents.

KPI Dashboard:

Figure 7 illustrates the representation of the KPI dashboard within the simulation testbed. Here, statistics about the agents are aggregated and displayed.

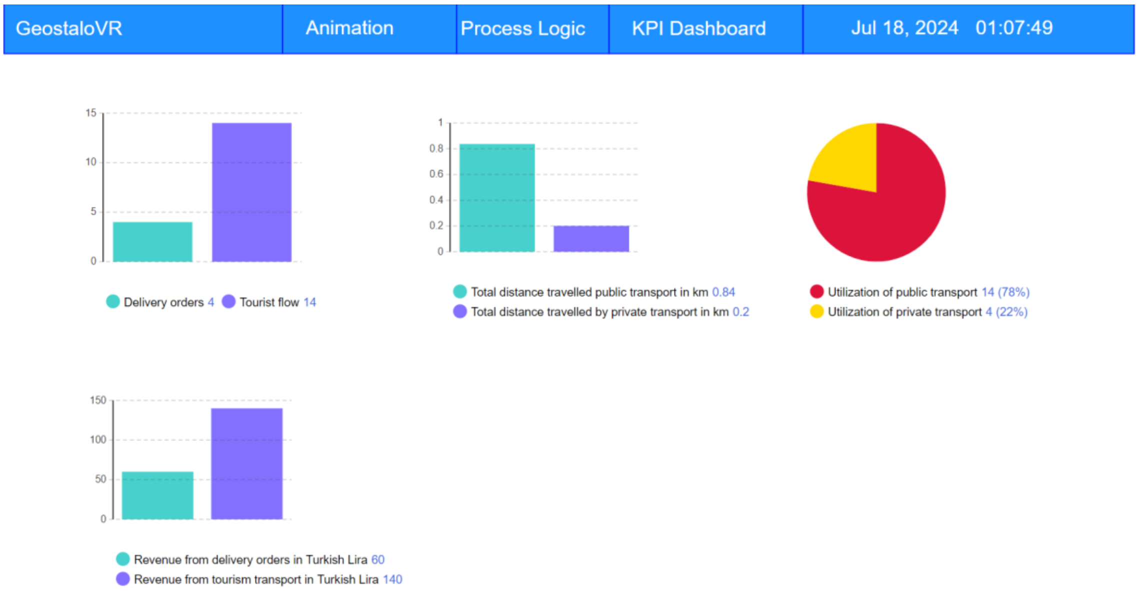

Figure 7. Example KPI dashboard view

The main KPIs collected and displayed include: the number of tourists in the system (domestic, international), tourist flow, accommodation occupancy, revenue generated from public transportation, the number of delivery orders, revenue generated from tourism and delivery orders, utilization of modes of transport (public and private), the average duration of each mode of transport, and cost analysis of infrastructure and mobility upgrades. These KPIs assist planners and policymakers in optimizing tourism and mobility flows according to tourist activity.

5. Conclusion

In conclusion, the scope of urban tourism development mainly depends on policymakers, urban planners, and governments. With the help of dynamic simulation models, it is possible to integrate new infrastructure, plan mobility flows in advance, and evaluate outcomes and cost analyses. This paper discussed the elements of tourism value creation based on tourism value chain analysis and urban planning processes. Furthermore, we presented a dynamic agent-based simulation testbed based on the conceptual model derived from the value chain analysis. This simulation testbed will be utilized in the GeostaloVR project to conduct experiments in tourism and urban planning scenarios in Şanlıurfa, Turkey. Moreover, the simulation testbed is modular and dynamic in nature, allowing it to be adapted to any city with the help of a custom input data interface.

Acknowledgements

The GeostaloVR project is funded by the Central Innovation Programme for Small and Medium-Sized Enterprises (ZIM) under the Federal Ministry for Economic Affairs and Climate Action, Germany. We also extend our gratitude to all partners participating in the GeostaloVR project for their invaluable assistance and collaboration.

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